Strength assessment and strength training in pulmonary rehabilitation

Kate Pittaccio

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School of Sport, Rehabilitation & Exercise Sciences

University of Essex

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Impact of Covid-19

The Covid-19 pandemic impacted this thesis extensively, leading to major changes, setbacks, and delays. A basic timeline of this PhD is outlined in Appendix A. This PhD commenced in October 2019, six months prior to the first national lockdown, which was enforced on 23rd March 2020. In response to the pandemic, face-to-face research was suspended, labs were closed, and 'standard' in person pulmonary rehabilitation (PR) programmes ceased. Restrictions were even more extensive for individuals with COPD, as they were a high risk and vulnerable group due to their respiratory condition and being of an older demographic.

A large proportion of the PhD research project had already been planned and designed by this point, specifically two qualitative studies involving PR practitioners (Chapter 3) and PR patients (Chapter 4). For these studies, NHS/HRA ethical approval was granted on 1st April 2020, which included face-to-face participant recruitment and data collection. However, due to government enforced restrictions on person-to-person contact, an amendment had to be submitted. Participant recruitment could no longer take place at PR sites and interviews could not be face-to-face. Instead, participant recruitment for the practitioners took place over email and videocall, and patient recruitment was conducted by a healthcare professional within the participating PR service. This amendment was approved by all necessary organisations by 16th June 2020, allowing both studies to continue.

At this time point there was hope that the disruptions and restrictions would ease soon. Therefore, the original research proposal continued, however modifications were put in place to account for varying levels of restriction. The original thesis proposal was to conduct

interviews with PR stakeholders and these findings would then inform a feasibility study, which would test and evaluate appropriate strength assessments for use within a standard face-to-face PR programme. This was going to be comprised of two parts: part 1 was to test the validity, reliability, and feasibility of strength assessments in the controlled environment of the university's research lab facilities, and part 2 was then going to pilot these assessments within the clinical setting of a PR programme. Following this, the ambition was to implement an intervention into a PR service, with the most feasible strength assessments randomised across three PR sites. The planning of the feasibility study continued, with a hierarchy of proposed plans that accounted for varying levels of restriction (i.e., for person-to-person contact and use of facilities). Unfortunately, further lockdowns came into effect, with the second national lockdown enforced on 5th November 2020 and the third national lockdown enforced on 4th January 2021. This meant further suspension and closure of face-to-face research, laboratories/facilities, and 'standard' in person PR. Consequently, the original plans had to change.

No one could foresee how long the pandemic would last, however as time went on it became clear that the initially proposed thesis plan, even with the modifications, would not be possible. Therefore, in February/March 2021, the decision was made to re-plan and re-focus the thesis, as no more time could be lost waiting for the restrictions to ease or lift. This led to the development and conduction of the national online PR survey (Chapter 5), deemed to be the most appropriate option for the continuation of this PhD as it did not involve face-to-face interaction and would still be possible if restrictions remained. This built on the qualitative studies already conducted, and leant further into the investigation of use, impact, barriers, and influential factors of strength assessment and strength training in PR. Although this thesis did not fulfil the initially proposed plan, the research conducted is original and significant. It

provides a foundation of information and understanding that has not been reported before, which will help inform PR clinical practice and the development of future research.

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Abstract

Chronic obstructive pulmonary disease (COPD) is a major disease with high prevalence, mortality, and morbidity. A commonly associated impairment is muscle weakness, which is considered an important systemic marker of the condition and is argued to be an essential variable for assessment and treatment. One successful treatment for COPD is pulmonary rehabilitation (PR), which is a comprehensive programme of exercise and education. Strength training (ST) is recommended in PR to target muscle weakness, along with the assessment of patient muscle strength. However, the use and impact of strength assessment (SA) and ST in PR clinical practice is unclear.

First, this thesis conducted a narrative literature review to summarise and synthesise the most relevant literature surrounding SA and ST in COPD and PR. Next, two qualitative studies were carried out, exploring the perspectives and experiences of practitioners (*n*=11) and patients (*n*=12) in relation to SA and ST. Lastly, a survey of practitioners (*n*=219) investigated SA and ST use in PR services across England, as well as practitioner training, attitudes, and perceived barriers. Descriptive data was collected, and further statistical analyses performed that explored predictive factors of use/non-use.

The findings show markedly limited guidance for the use of SA and ST in PR. Services report fulfilling basic recommendations, but methods in clinical practice vary. Feasibility is an essential consideration and another explanation for variance, specifically the impact of service-related barriers and differing resources. Staff training is an area of improvement, as many practitioners do not have relevant training despite SA and ST being included in PR programmes. Lastly, findings highlight the importance of patients having the necessary

understanding, with education and support identified as a means of facilitation. Overall, successful implementation and use of SA and ST in PR clinical practice is multifactorial - influenced by services, practitioners, and patients.

Abbreviations

1minS2S	One minute sit to stand
1-RM	One repetition maximum
30secS2S	30-second site to stand
5repS2S	Five-repetition sit to stand
6MWT	6-minute walking test
AACVPR	Association of Cardiovascular and Pulmonary Rehabilitation
ACCP	American College of Chest Physicians
ACSM	American College of Sports Medicine
ADL	Activities of daily living
AECOPD	Acute exacerbation of Chronic Obstructive Pulmonary Disease
AT	Aerobic Training
ATS	American Thoracic Society
BTS	British Thoracic Society
COPD	Chronic Obstructive Pulmonary Disease
CT	Combined Training
EFA	Exploratory Factor Analysis
EPV	Events per variable
ERS	European Respiratory Society
FEV1	Forced expiratory volume in 1-second
FVC	Forced vital capacity
GOLD	Global Initiative for Chronic Obstructive Lung Disease
HCP	Healthcare professional
HGS	Handgrip strength

HHD	Handheld Dynamometer
HRQoL	Health-related quality of life
ICC	Intraclass correlation coefficient
ISWT	Incremental shuttle walk test
KMO	Kaiser-Meyer-Olkin
MCID	Minimal clinically important difference
MRC	Medical Research Council
m-RM	Multiple-repetition maximum
MVC	Maximal voluntary contraction
NACAP	National Asthma and Chronic Obstructive Pulmonary Disease Audit Programme
NICE	National Institute for Health and Care Excellence
PR	Pulmonary Rehabilitation
RCP	Royal College of Physicians
RPE	Rating of perceived exertion
S2S	Sit to stand
SA	Strength Assessment
ST	Strength Training
WHO	World Health Organisation

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Chapter 1. Introduction

1.1 Chapter Overview

This chapter will introduce the foundational topics of this thesis, providing an overview of Chronic Obstructive Pulmonary Disease (COPD) and pulmonary rehabilitation (PR). It will describe COPD, outlining the cause, prevalence, symptoms, and associated impairments. Particular focus will be placed on the importance of muscle strength within this patient population. Furthermore, it will describe PR for the treatment of COPD, outlining its structure of education and exercise, along with a brief discussion surrounding its effectiveness. This chapter sets the scene for subsequent chapters, which will specifically focus on strength assessment (SA) and strength training (ST) in COPD and PR.

1.2 What is COPD?

1.2.1 Definition

COPD is a long-term, progressive, and irreversible condition, with the slow and gradual onset of symptoms and associated impairments. It is defined as "*a heterogeneous lung condition characterised by chronic respiratory symptoms (dyspnoea, cough, sputum production) due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) that causes persistent, often progression, airflow obstruction*" (1) (pg. 1321). There is no known cure, however, there are treatments available that can slow its progression, and with appropriate management can minimise the burden imposed (2).

1.2.2 Cause and Risk Factors

The leading cause and primary risk factor of COPD is cigarette/tobacco smoking, contributing to nearly half of all global cases and over 70% in high income countries (3). Additional causes and risk factors include occupational exposures, such as inhalation of harmful gases in the workplace and air pollutants (2). There is also a rare genetic risk factor, called a1-antitrypsin deficiency (4, 5), which in combination with environmental risk factors can influence and increase the susceptibility of COPD (6). Other reported risk factors include asthma, impaired lung growth, low socioeconomic status, and lung infections (e.g. tuberculosis) (2, 3).

1.2.3 Prevalence

COPD is a major disease with high prevalence, mortality, and morbidity. In 2020, the World Health Organisation (WHO), reported it as the 3rd leading cause of death worldwide (7), with around 3.2 million people dying from COPD globally each year (8, 9). In the UK, COPD is the 2nd greatest cause of death from lung disease, after lung cancer (10), and was reported as the 6th biggest killer in 2019 overall (11). COPD prevalence and mortality increases with age due to its slow and progressive nature, with occurrences higher in age groups over 50 years, specifically affecting 9% of all people over the age of 70 (10, 12). Additionally, multi-morbidity frequently occurs in individuals with COPD, with co-morbidities including cardiovascular disease, diabetes, hypertension, anxiety, depression, osteoporosis, and skeletal muscle dysfunction (2, 13-15). One review reported approximately 86-98% of individuals with COPD had at least one comorbid condition, with the number of comorbidities per individual being 1.2 to 4 (16).

1.2.4 Diagnosis and Symptoms

The diagnosis of COPD is carried out using a spirometry test to measure lung function, specifically forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), and the ratio of the two (FEV1/FVC). The Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines state confirmation of a COPD diagnosis is based on the criterion for airflow obstruction – outlined as a post-bronchodilation ratio of FEV1/FVC < 0.7 (2). In the presence of this parameter, the assessment of airflow limitation severity is based on the value of FEV1 (% reference). It is estimated that FEV1 declines by 47-79ml per year in COPD patients, compared to 30ml per year in healthy comparisons (17). The GOLD grades of COPD severity were established to aid classification (**Table 1**).

Table 1. *GOLD classification of COPD severity (2)*

GOLD Grades and Severity of Airflow Obstruction in COPD (based on post-bronchodilator FEV1)		
In COPD patients (FEV1/FVC < 0.7):		
GOLD 1 (I):	Mild	FEV1 ≥ 80% predicted
GOLD 2 (II):	Moderate	50% ≤ FEV1 < 80% predicted
GOLD 3 (III):	Severe	30% ≤ FEV1 < 50% predicted
GOLD 4 (IV):	Very Severe	FEV1 < 30% predicted

Although this is the primary criteria for confirming a diagnosis, it is also important to consider the presentation of other symptoms, such as dyspnoea (breathlessness), chronic cough, sputum production, and exposure to disease-related risk factors. It is often these symptoms, or an exacerbation (worsening of symptoms), which leads patients to seek initial medical help (18, 19). Not all symptoms may be present in every individual and they can vary day-to-day, as well as imposing substantial burden to health-related quality of life (HRQoL), physical activity, and daily activities (20, 21). Therefore, it is important to consider patient-reported

symptoms when assessing the extent of the disease and guiding appropriate treatment (2). Dyspnoea is most common, shown to significantly increase as COPD severity worsens (22). The American Thoracic Society (ATS) (23) defines it as '*a subjective experience of breathing discomfort consisting of qualitatively distinct sensations that vary in intensity*' (p.322). Patients describe it as a sense of increased effort to breathe, a heavy chest, or air hunger (24). It is commonly assessed using the Medical Research Council (MRC) dyspnoea scale, which measures the degree of functional disability as a result of habitual dyspnoea (25, 26) (see **Figure 1**), or as a domain in HRQoL questionnaires, which evaluate dyspnoea within a larger framework of how a disease hinders and interferes with a patient's normal daily life (23, 27). Other methods of assessment include ratings of perceived exertion (RPE) during exercise which include the original Borg RPE scale that ranges from 6 (no exertion at all) to 20 (maximal exertion) (see **Figure 2**), or more commonly, the modified Borg RPE scale that ranges from 0 (nothing at all) to 10 (very, very severe) (see **Figure 3**) (28-31) .

Grade	Degree of breathlessness related to activities
1	Not troubled by breathlessness except on strenuous exercise
2	Short of breath when hurrying or walking up a slight hill
3	Walks slower than contemporaries on level ground because of breathlessness, or has to stop for breath when walking at own pace
4	Stops for breath after walking about 100 metres or after a few minutes on level ground
5	Too breathless to leave the house, or breathless when dressing or undressing

Figure 1. Medical Research Council (MRC) Dyspnoea Scale (32).

1.2.5 Exacerbations

Acute exacerbation of COPD (AECOPD) is the worsening of symptoms beyond normal day-to-day variations (25, 33). Even if a diagnosis is made early, and proactive care and

management of the condition is successfully put in place, for many it is inevitable (34). For some, the effects of a severe exacerbation can persist, with a small proportion of patients failing to recover (35). Exacerbations are associated with a decline in HRQoL (36-38), reduced physical ability (39-41) and increased healthcare use (33, 42). They are the most common reason for hospitalisation among individuals with COPD, increasing the risk of mortality (41, 43-46). One review reports mortality rates of around 35% during the year following a period of hospitalisation (47).

Score	Level of exertion
6	No exertion at all
7	
7.5	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Figure 2. Original Borg RPE Scale 6-20 (48)

Score	Level of exertion
0	No exertion at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight
3	Moderate
4	Somewhat severe
5	Severe
6	
7	Very severe
8	
9	Very, very severe (almost maximal)
10	Maximal

Figure 3. Modified Borg RPE Scale 0-10 (48)

1.2.6 Associated Impairments

As outlined above, the primary symptoms of COPD are localised to the lungs, however substantial morbidity is also caused by other associated impairments that develop over time. Consequently, COPD is now understood as a systemic disease, impacting the body as a whole – not just the lungs. COPD is associated with a decline in many factors, including muscle strength, exercise tolerance and capacity, physical activity, performance of daily activities, psychological wellbeing, and HRQoL. The primary impairment focused on in this thesis is muscle dysfunction, specifically muscle weakness. The other impairments will be briefly discussed to demonstrate the complexity of COPD and the interconnectedness of these impairments, particularly the relationships with muscle strength (49).

1.2.6.1 Exercise Tolerance and Capacity

Exercise tolerance declines with COPD, especially when compared to age-matched controls (50-52). It is quantified by measuring exercise capacity using either maximal tests (e.g. treadmill/cycle ergometers), or submaximal/functional tests, such as the 6-minute walk

test (6MWT) or the incremental shuttle walk test (ISWT). Walking tests are commonly used in clinical practice because they are low cost and require minimal equipment, as well as considered to be more reflective of daily living (53, 54). The cause of exercise limitation is complex and multifactorial, with contributions from respiratory impairment, cardiovascular comorbidities, and musculoskeletal dysfunction (55). Evidence shows reduced exercise capacity is a strong predictor of mortality (56-58) and is associated with muscle weakness (51, 59-62).

1.2.6.2 Physical Activity

Physical activity is significantly lower in patients with stable COPD compared with healthy age-matched comparisons (63, 64), with activity declining over time and with increasing disease severity (65, 66). Physical inactivity has been associated with a higher risk of exacerbation, hospitalisation, and mortality (40, 67-69), and is related to other outcomes, such as exercise capacity, dyspnoea, and HRQoL (69). A main contributor to physical inactivity are COPD symptoms, particularly dyspnoea, with the majority of patients perceiving symptoms to be a substantial burden and challenge to exercise and activities of daily living (ADL) (70-72). Dyspnoea is unpleasant for most and many become fearful of causing exacerbation, resulting in the avoidance of physical activity and exercise, even in the early stages of disease progression (66, 73, 74). However, inactivity leads to further physiological and functional impairments, such as muscle dysfunction and reduced exercise capacity (73, 75, 76).

1.2.6.3 Psychological Wellbeing

The presence of anxiety and depression are common with COPD (77, 78), increasing over time and with disease severity (22, 79). One meta-analysis (80) found the prevalence of

depression among COPD patients was twice (24.6%) as high compared to those without the disease (11.7%). Additionally, the prevalence of anxiety among COPD patients is also high, estimated at up to 55% (81) - typically manifesting as fear or avoidance (77). The causes of depression and anxiety are multifactorial and include behavioural, social, and biological factors such as dyspnoea, physical impairments, low HRQoL, and living alone (79, 82, 83).

1.2.6.4 Health-Related Quality of Life (HRQoL)

HRQoL, also referred to as health status, is a patient's perception and judgement of how a health condition affects their life. In this instance, it reflects how COPD impacts their ability to perform and enjoy ADL (84). Evidence demonstrates that HRQoL is markedly diminished in COPD, significantly deteriorating over time (22, 85), and across all stages of disease severity (86). Many factors are associated with a decline in HRQoL, including dyspnoea, depression, anxiety, reduced exercise capacity, and muscle weakness (87-90). High frequencies of COPD exacerbations also negatively impact HRQoL (37, 91), with reductions persisting beyond the exacerbation period (92).

1.2.6.5 Muscle Dysfunction and Muscle Weakness

Skeletal muscle dysfunction is recognised as an important systematic consequence of COPD and is attributed by reduced muscle strength, mass, endurance, and increased susceptibility of fatigue (93-96). Due to these deficits in muscle strength and functional status it increases the risk of individuals with COPD developing frailty, which is associated with increased mortality and morbidity (97-99). In comparison to healthy controls, people with moderate-to-severe COPD show marked deficits in muscle strength, mass, endurance, and mobility (100-105). Regarding muscle strength specifically, it is widely shown that it is reduced in patients with COPD, with one review reporting up to a 20-30% deficit when compared to

healthy subjects (93). Prevalence of muscle weakness is also shown to increase with disease severity, although a significant proportion of patients with mild disease (≈27%) also display weakness (106). One study reported the annual decline in quadriceps strength was faster in COPD patients compared to a healthy aging sample, reducing by an average of 4.3% and 1-2% per year, respectively (107). Acute exacerbations also contribute to muscle dysfunction, particularly muscle weakness (33, 36, 39, 40), with hospitalisation found to significantly reduce muscle strength even further when compared to those with stable disease (39).

Regarding the distribution of muscle weakness, both upper and lower body strength are reduced, although evidence demonstrates it is more prominent in the lower limbs, particularly the quadriceps (100-102, 104, 108). Some studies report a relative preservation of upper-limb muscle strength (59, 104), whereas others found a similar degree of muscle weakness for lower and upper limbs (101). Although differences were found between proximal and distal arm muscle groups, with handgrip and elbow flexion significantly less affected than shoulder abduction (108). The relative preservation of upper limb strength could be due to the maintenance of daily activities involving the arms (e.g. washing and dressing) and use as accessory muscles for breathing (109-111). Consequently, quadriceps muscle strength is considered an important systemic marker for COPD (33). It is readily available and a primary muscle of locomotion and deconditioning in this patient population - it is the muscle that is most commonly studied and assessed in COPD research (96).

Reduced muscle strength is associated with a number of other relevant COPD outcomes (93), including increased mortality (112-114), disease severity (106) and healthcare use (115, 116), as well as reduced physical activity (117), exercise and functional capacity (51, 59, 118, 119), performance of ADL (120) and HRQoL (87, 88, 90). Muscle weakness is an important

variable as it has better prognostic indicators than lung function or age (112), and is linked with many other COPD outcomes. Therefore, assessing and treating muscle weakness, is of paramount importance in the comprehensive management of this disease.

The cause of muscle dysfunction, specifically muscle weakness, is often multifactorial including structural muscle changes and wider physiological influences. At a structural level many changes occur to muscle physiology, including muscle atrophy. This is known as the wasting of muscle tissue, resulting in decreased fat-free mass (i.e. muscle) and bodyweight as a whole (121). Muscle atrophy is common among individuals with COPD (122, 123), reported to be lower when compared to healthy age-matched individuals (124-126). Furthermore, it is found to be greater in the lower limbs (104) and prevalent across all disease severities (76). Other structural changes contributing to muscle dysfunction in COPD include: a shift in muscle fibre types, from type I to type II, resulting in predominate anaerobic metabolism; mitochondrial dysfunction, due to reduced production of energy from oxidative metabolism; and oxidative damage, resulting in poor oxidative capacity in the muscle (78, 93, 127). Aside from these structural alterations, several wider physiological mechanisms are hypothesised to also contribute to these muscle limitations, such as systemic inflammation, oxidative stress, hypoxemia, nutrition depletion and energy imbalance, vitamin D deficiency, and use of corticosteroids and other pharmacological treatments (93).

One key contributor to muscle dysfunction and deconditioning is disuse and inactivity (76, 128), typically the result of avoiding exertional symptoms and discomfort (e.g. dyspnoea) (110). Unfortunately, as the amount of activity decreases, muscle strength decreases also, leading to further increases in dyspnoea and exercise limitation – resulting in a vicious cycle of deterioration (129, 130). Therefore, strategies targeting physical inactivity and muscle

weakness is of paramount importance for the management and treatment of COPD, for example interventions that aim to strengthen the skeletal muscles, such as ST.

1.2.7 Cost and Healthcare Utilisation

As a consequence of COPD being highly prevalent and chronic, it is a very resource consuming disease, demanding exhaustive use of healthcare provisions (131). Therefore, it is not surprising that COPD is associated with significant clinical and economic burden. Estimates of the annual economic burden of all respiratory diseases have been reported, with COPD accounting for 50.2% and 29% of the total direct and indirect costs in Europe (132) and the UK (133), respectively. Direct costs include primary and hospital healthcare (e.g. NHS) and indirect costs include loss of productivity. A significant contribution to such costs are exacerbations, resulting in emergency hospital admission (134). It has been approximated that about a third of COPD patients in the UK and Europe experience further hospital admission within 90 days of being discharged (135, 136). Additionally, it is shown that costs vary considerably with the severity of the exacerbation and the severity of disease (42). Higher costs are associated with increasingly severe COPD, a history of more frequent or severe exacerbations, and an exacerbation history of hospitalisation and primary care visits (137). It is evident that COPD is a substantial economic burden to healthcare systems, like the NHS. Therefore, the use and availability of cost-effective treatments is vital.

1.2.8 Treatment and Management

A number of pharmacological and non-pharmacological treatments and management interventions are available for COPD, outlined by leading health and respiratory organisations including GOLD and the National Institute for Health and Care Excellence (NICE) (2, 25, 138, 139). Pharmacological treatments aim to reduce symptoms and the risk and severity of

exacerbations, as well as improve exercise tolerance and HRQoL (2). Medications used to treat COPD, include bronchodilators, antimuscarinic drugs, methylxanthines, and corticosteroids. Most drugs prescribed are administered using inhaler devices, meaning inhaler technique is crucial to optimise benefit and adherence (140). Non-pharmacological treatments are complementary to the pharmacological, and form part of the comprehensive management strategy for COPD. These include vaccinations, smoking cessation, oxygen therapy, and PR (2). This thesis will be focusing on PR specifically.

1.3 What is Pulmonary Rehabilitation?

PR is a proactive programme of care for patients with chronic respiratory conditions, particularly COPD. It aims to improve the physical, psychological, and social impairments of the disease, so patients can live a more comfortable and fulfilling life. There have been numerous definitions for PR over the years, however in 2013 the ATS and European Respiratory Society (ERS) published a comprehensive statement which described PR as a "*comprehensive intervention based on a thorough patient assessment followed by patient tailored therapies that include, but are not limited to, exercise training, education, and behaviour change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviours*" (53) (p. e14). The immediate aims of PR are to reduce symptoms and improve physical function and HRQoL. In the long-term it aims to maintain these benefits and reduce healthcare utilisation and costs by preventing hospital admissions, reducing length of hospitalisations, improving self-management, and limiting dependence on medical care.

Evidence-based guidelines and position statements, published by leading respiratory societies and organisations, recommend PR for the treatment and management of COPD. These

include the British Thoracic Society (BTS) (33, 36, 141), ATS (53, 142-144), American College of Chest Physicians (ACCP) (145), American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) (31, 145, 146), ERS (53, 143, 144), Canadian Thoracic Society (147, 148), Thoracic Society of Australia and New Zealand (149), and GOLD (2). Specifically in England and the UK, PR is a key management strategy for people with chronic respiratory disease. In 2011, the Department of Health highlighted the role of PR in their 'outcomes strategy for COPD and asthma in England' (150). There are a number of documents outlining recommendations and quality standards for PR, as well as guidance for respiratory healthcare services, published by the BTS (33, 36, 141), NHS (34, 151, 152), and Royal College of Physicians (RCP) (153, 154).

In 2018, the RCP created a programme to improve the quality of PR services throughout the UK, called the Pulmonary Rehabilitation Services Accreditation Scheme (PRSAS) (153, 154). It aims to support PR services to measure and improve quality, and outcomes of care provided to patients. Accreditation is voluntary, with an annual subscription fee of up to £1500 (plus VAT) (155). It is a self-assessment process, with the overall aim being to achieve PR accreditation, which recognises that a service demonstrates high levels of quality. Presently, the RCP reports that 153 services in England are participating in the accreditation scheme, with varying statuses (155). A detailed overview of the PRSAS can be found on the RCP website: https://www.prsas.org/about-accreditation. The PRSAS standards of practice (153, 154) are influenced and based on the BTS quality standards (33), and cover all aspects of PR. They are organised into seven domains:

1. Leadership, strategy, and management
2. Systems to support service delivery (e.g., staff support and training, and facilities, equipment, and clinical space)

3. Person centred treatment and/or care (e.g., individualised care plans)
4. Risk and Safety
5. Clinical Effectiveness (e.g., effectiveness of clinical interventions and measurement and management of clinical outcomes)
6. Staffing a clinical service (e.g., adequate staffing levels, training and CPD, and appraisals and competency)
7. Improvement, innovation, and transformation

A detailed presentation of the PRSAS standards, and other guidelines and standards (e.g., BTS), relevant to SA and ST are presented in the subsequent chapter (see page 81).

1.3.1 Referral

Patients with a confirmed diagnosis of COPD are referred to PR if they: have a chronic respiratory disease with persisting symptoms; an MRC dyspnoea score of grade 3 or above (**Figure 1**); limited ability to perform ADL and exercise; and are unable to adjust to their illness even when optimal medical management is given (33, 143, 156). However, PR is not only for those with COPD, but it is also common for patients with other chronic respiratory diseases, such as interstitial lung disease, pulmonary fibrosis, and bronchiectasis, to be referred to PR as well (53, 151, 157). These other conditions present with similar symptoms and impairments, and as such PR is recommended as a non-pharmacological intervention (149, 158, 159), with research showing promising results (160-162). However, PR is not suitable for all, particularly those with an unstable cardiac disease, locomotor or neurological difficulties preventing exercise (e.g. severe arthritis or peripheral vascular disease) (33, 156).

1.3.2 Structure and Content

The BTS guidelines on PR in adults (33) recommend that programmes are structured with a minimum frequency of two supervised sessions twice-weekly, as well as a third unsupervised exercise session advised, if possible. PR programmes of 6-12 weeks in duration are recommended, with cohort or rolling programmes both deemed acceptable forms of delivery. Evidence shows optimal benefits are achieved from programmes with a duration of 6-8 weeks, with no additional benefits gained from extending programmes to 12 weeks (2). The RCP leads the National Asthma and Chronic Obstructive Pulmonary Disease Audit Programme (NACAP), which conducted an audit in 2019 on the provision of PR in services across England, Scotland, and Wales (163-165). It reported that programmes are predominately rolling programmes (66.5%), with a duration of six weeks (65.2%) and offering twice-weekly supervised sessions (90.2%). In the UK, PR programmes are traditionally centre-based, taking place in either hospital (outpatient) or community settings, such as church halls, community centres, leisure centres, gyms, and hospitals (33, 166). This allows for supervised face-to-face sessions with healthcare professionals (HCPs) and ensures increased accessibility for patients in varying locations.

Over the last few years, the frequency and prevalence of home-based and tele PR programmes have increased, primarily in response to the Covid-19 pandemic, which necessitated remote delivery of treatment (167, 168). A meta-analysis concluded home-based PR to be an effective alternative to centre-based PR, improving exercise capacity and HRQoL (169), and is an option that enables people whose lifestyle and geographical circumstances make attending centre-based PR difficult. However, it does not provide the benefit of social support and the presence of a HCP or exercise instructor (170). Home-based and tele PR are separate variations of rehabilitation, faced with their own benefits, challenges, and

implications. Consequently, it is beyond the scope of this thesis. Hereafter, focus is placed on traditional/standard PR programmes with face-to-face supervision.

PR programmes are comprised of two main components: 1) education, providing disease and symptom related information and support, and 2) exercise, including aerobic training (AT) and ST (33).

1.3.2.1 Education

Patient education is a core component of comprehensive PR and has evolved beyond simply providing didactic information. It involves a combination of teaching and counselling approaches, with the intention to support and promote lifestyle and behavioural changes, self-management skills, and self-efficacy (i.e. confidence in ability) (171). The content covers a wide range of topics but importantly promotes adaptive behaviour change, such as stopping smoking, adherence to pharmacologic and exercise therapy, and early recognition and treatment of exacerbations (33). Additional areas include chest clearing techniques, anxiety management and relaxation, nutritional and physical activity advice, and managing travel (172). It has been shown by equipping COPD patients with the knowledge and skills of self-managing their condition it reduces the use of healthcare services and costs (173, 174).

1.3.2.2 Exercise

Exercise training is widely regarded as the cornerstone of PR, combining AT and ST (53). Aerobic, or endurance, training commonly involves lower limb focused exercise, such as walking or cycling. Strength, or resistance, training refers to the generation of force by specific muscle groups with the aim of improving muscle strength (175). Upper and lower limb exercises are typically included using a variety of equipment, such as multi-gym apparatus,

free weights, resistance bands, or bodyweight. Emphasis is placed on ST being progressive and individualised to the patient (33). Initially, standard training delivered in PR was based around aerobic exercise, however since the recognition of muscle strength as an important factor in COPD, research has evidenced that ST in combination with AT is ideal for ensuring patients receive all associated benefits (176).

Exercising for the benefit of strength is now recognised and recommended for all adults (177). In 2019, The UK government published updated Chief Medical Officers' Physical Activity Guidelines (178), which emphasise the importance of regular strength activity. For adults and older adults (≥65 years), it recommends in addition to moderate-to-vigorous aerobic activity that "*muscle strengthening activities should be done on at least two days a week*" (pg.10). Similar public health guidelines have been published in the US (179). PR guidelines also support and recommend the combination of AT and ST in PR programmes (33, 180). ST is safe and well tolerated by COPD patients, with no adverse events (33, 181-183), and when combined with AT it is the best strategy to improve overall impairments, including muscle strength, exercise capacity, dyspnoea, and HRQoL (33). A detailed discussion of ST and the assessment of muscle strength in COPD and PR is outlined in Chapter 2 (page 48).

1.3.3 Effectiveness of Pulmonary Rehabilitation

There is extensive research and literature supporting PR as an effective intervention and management strategy, particularly for COPD. PR has considerable benefits, leading to improvements in dyspnoea, exercise and functional capacity, muscle strength, ADL, HRQoL, psychological wellbeing, mortality rates, and healthcare utilisation (2, 33, 184). Consequently, there was a call from The Cochrane Airways editorial board to cease controlled trials comparing PR to usual care, and instead focus on how to improve outcomes and usage of PR

going forward (185). PR is ranked as one of the most cost-effective treatment strategies for COPD (2, 186). Literature reports many economic benefits, including reduced mortality, hospital admissions, inpatient hospital days, hospital readmission, and number of home visits (47, 187-189). The NHS acknowledges the effectiveness of PR and as part of their long term plan aims to expand services over the next 10 years, increasing access for patients (190).

A highly cited Cochrane review, conducted by McCarthy et al. (184), compared the effects of PR versus usual care in people with COPD (65 RCTs). Usual care was defined as conventional care in which the control group was not given education or any form of additional intervention. Outcomes of interest were confined to HRQoL, and functional and maximal exercise capacity. The results strongly support PR as a treatment for COPD, with clinically and statistically significant improvements demonstrated in HRQoL, dyspnoea and fatigue (self-reported HRQoL domains), and exercise capacity. Comparable results have been reported in subsequent meta-analyses, supporting the effectiveness of PR on HRQoL and exercise capacity following an exacerbation of COPD (47, 189). PR is shown to be effective at all stages of COPD severity (191), although evidence particularly supports its use with moderate-to-severe disease (2).

Regarding dyspnoea, this positive impact is not necessarily attributed solely to the exercise component of PR programmes. It has been suggested that these significant reductions could be somewhat credited to other, less defined mechanisms at work, such as desensitisation, which is a decrease in patient perception of dyspnoea due to the alleviation of fear and anxiety by repetitive exposure to exercise in a safe and supervised environment (192). Factors hypothesised to contribute to this include the antidepressant effect of exercise, psychosocial support, social interaction, self-management education, and distraction from the sensations

often caused by dyspnoea during exercise (193). PR has shown to alter patient's perceptions of breathlessness, positively impacting on physical and social activities. Qualitative evidence demonstrates that PR decreases fear of activity, physical limitations, and social isolation, and promotes confidence in managing breathlessness, physical activity, and social engagement (194, 195). Overall, PR improves control over breathlessness and tolerance of high levels of dyspnoea.

PR is also shown to improve the performance of ADL. One study (196) found a comprehensive PR programme improved the physiologic response and performance of ADL in patients with COPD, indicated by lower metabolic load, less symptoms, and a shorter time to perform assigned tasks. Other studies have also shown PR to have a positive impact on patient-reported measures of ADL (197-199). Factors associated with improvements in performance of ADL include functional exercise capacity, quadriceps muscle strength, and reduced dyspnoea (196, 200, 201). It is likely that such physiological improvements gained from PR, specifically from the exercise training, contribute and translate into improved ADL. Improvements in performance of ADL may result in lower levels of care dependency and in turn may improve HRQoL and prognosis (198, 202). Evidence also shows PR is an ideal intervention to reduce anxiety and depression in people with COPD. Gordon et al. (203) conducted a meta-analysis (11 RCTs) to evaluate the effectiveness of PR versus usual care on the symptoms of anxiety and depression in COPD. Results showed PR led to statistically and clinically significant improvements in both anxiety and depression. These findings are mirrored in previous investigatory reviews (204, 205). This positive impact is likely a result of PR's multi-component design - combining exercise, education, and support. It encourages behavioural change and adaptive thoughts, helps to diminish negative emotions, and provides

a socially supportive environment (143). COPD patients who receive positive social support suffer less with anxiety and depression compared to those who do not (206).

Overall, PR offers many benefits to individuals with COPD, both physically and psychologically. However, a main challenge faced is the gradual decline in the benefits gained, with maintenance of improvements shown to decrease over time following completion of a programme (2). Studies have shown after an average of 6-12 months the gains obtained start to diminish, particularly functional exercise capacity and HRQoL (207-209). Reasons for this include disease progression, exacerbations, comorbidities, and failure to continue and adhere to exercise and physical activity after PR (207, 210). Strategies to address these include structured and supervised maintenance programmes following PR and additional rehabilitation (2, 211). Follow-up maintenance exercise is a promising method, helping to prolong clinical benefits but only in the short term (212-214). Qualitative findings explain that many patients find exercise after PR challenging, with barriers reported to include lack of support, poor physical health, insecurity, family commitments, transport difficulties, and the weather (195, 215-221). This is particularly true for people referred to subsequent exercise programmes in mainstream gyms, who do not continue due to personal cost and a lack of confidence to join with non-COPD groups (36). Another strategy is offering repeat PR if physical, functional, and HRQoL deteriorates a year or more after the initial programme. These can be beneficial even after a long interval between interventions (210), and can increase physical performance and slow disease progression (222). However, the extent of improvements observed in repeat PR programmes are not as high compared to the initial (223). They have shown to offer similar short term gains but do not result in additional long-term physiologic benefits (224). This emphasises even more the importance of enabling self-management and behaviour change

strategies during PR to aid continued exercise and physical activity after programme completion.

As discussed above (page 34), reduced muscle strength is recognised as an important systemic impairment and marker of COPD (33), supporting it as a vital variable for assessment and treatment when managing this disease. Consequently, evidence-based guidelines recommend the inclusion of ST and SA within PR (53, 141, 147, 225). Many research studies have demonstrated the effectiveness of ST in PR and exercise programmes on COPD muscle strength (181, 226, 227). However, on inspection, it is unclear how ST and SA fit into PR clinical practice, due to guidelines and recommendations lacking clarity and sufficient detail. A detailed discussion on SA and ST in COPD and PR is presented next in Chapter 2.

1.4 Chapter Conclusion

COPD is a highly prevalent and complex respiratory condition. It is now understood as a systemic disease, with a multitude of associated impairments impacting the body as a whole - not just the lungs. One prevalent impairment is muscle weakness, which is associated with many other relevant COPD outcomes. Therefore, assessing and treating muscle weakness is of paramount importance in the comprehensive management of COPD. An effective intervention is PR, which is recommended to include ST as a strategy to combat deficits in muscle strength in this patient population. This chapter has outlined the foundational topics of this thesis, providing an overview of COPD and PR, and sets the scene for more specific topics of interest: SA and ST. The next chapter provides a narrative literature review, summarising and discussing the literature surrounding SA and ST in COPD and PR.

Chapter 2. A narrative literature review of strength assessment and strength training in COPD and pulmonary rehabilitation

2.1 Chapter Overview

A narrative literature review was conducted to summarise and synthesise the body of literature surrounding SA and ST in COPD and PR. Due to the copious amount of literature in these areas a comprehensive review will be outlined, with the most relevant literature presented and discussed. To aid navigation, this review has been organised into three key parts. Firstly, research investigating SA and ST in PR and COPD will be presented, providing context and information about the different SA methods and the effectiveness of ST. Secondly, PR guidelines will be compared and evaluated, outlining guidance and recommendations for SA and ST in PR clinical practice. Lastly, the use of SA and ST in real world PR programmes will be presented, by discussing published surveys which collected data on PR service provision.

2.2 Search Strategy

A systematic search of electronic databases was conducted to identify relevant literature for this narrative review. The following databases were searched: EBSCO (CINAHL Ultimate, MEDLINE Ultimate, APA PsychArticles, APA PsychInfo, E-Journals, SPORTDiscus with full text), SCOPUS, Web of Science, Cochrane Library, PubMed, and PEDro. Grey literature was also searched, such as government documents/reports, audits, and conference papers. Searches included a combination of keywords and terms related to the main thesis topics: COPD, PR, ST, and SA. Search terms were used in various combinations and with truncation where needed. Appendix A

Timeline of PhD and Covid-19 Pandemic Restrictions

Date	Action/Information
21st Oct 2019	PhD started

28th Oct 2019 to 15th Nov 2019	Introductions and observations of PR and PROVIDE CIC. PROVIDE had three PR sites (Maldon, Braintree, and Chelmsford). I visited and observed each of these. I also attended a few home visits and COPD clinics that the service carried out. These provided an introduction and basic understanding of PR and how it was organised and delivered within this service. PhD planning occurred throughout this time and afterwards.
13th Feb 2020	NHS/HRA ethics was submitted for the face-to-face practitioner interviews and patient interviews
23rd March 2020	1st UK national lockdown University of Essex closed and entered 'advanced protection'. Advanced protection = where essential services only are delivered on campus, and research is predominantly delivered and engaged with remotely.
1st April 2020	NHS/HRA ethical approval obtained, however an amendment had to be submitted altering the recruitment and data collection methods to comply with government restrictions.
14th May 2020	NHS/HRA amendment submitted (with Covid-19 changes)
28th May 2020	NHS/HRA amendment approved (with Covid-19 changes)
4th June 2020	University of Essex ethics subcommittee approval obtained
16th June 2020	PROVIDE R&D clinical excellence group approval obtained
23rd June 2020 to 10th August 2020	Practitioner interview and patient interview recruitment and data collection carried out
August – Feb 2020	• Interview transcription • Practitioner interview data analysis • Preparing for PhD confirmation board • Literature search and review • Planning and modifying PhD project plan
5th Nov 2020	2nd UK national lockdown
4th Jan 2021	3rd UK national lockdown
Feb/March 2021	The decision to change the PhD project was made, as the University of Essex research labs were still closed, and local PR services were still not running standard programmes. It was not known when the research labs would re-open or when face to face PR would start again, as restrictions were still in place. The original PhD plan (along with modifications) were abandoned, and a new plan was constructed (online survey), which still linked and utilised the two qualitative interview studies already carried out.
April to August 2021	• Planning and designing the survey • Preliminary contact made, and scoping emails, sent to NHS Trusts/non-NHS organisations with PR services (May – July 2021) • Planning of appropriate ethical protocol for this study. It was unclear how ethical approval should be submitted and obtained for this study. Multiple meetings were had with the REO at the University of Essex, and direct correspondence was needed with the HRA, to determine the most suitable course of action.

15th April 2021	University of Essex moved from ‘advanced protection’ to ‘enhanced protection’. Enhanced protection = with many functions delivered remotely, and other, limited services available safely on campus. Research is delivered and engaged with remotely where possible, and only essential lab work on site following approved risk assessments.
19th July 2021	England removed the vast majority of Covid-19 restrictions, including social distancing
27th July 2021	University of Essex moved from ‘enhanced protection’ to ‘sustained protection’ Sustained protection = providing measures that enable more elements of on-campus activity to resume than within Enhanced Protection and envisaged to be required over an extended time period. Research is delivered and engaged with remotely where appropriate, and lab work on site following approved risk assessments.
7th Sept 2021	HRA ethics submitted for national survey study
7th Oct 2021	HRA ethical approval obtained for national survey study
16th Oct 2021	University of Essex ethics subcommittee approval obtained
25th Oct 2021 to 6th May 2022	• Individual research site R&D approval obtained • Subsequent ethical amendments submitted to include more participating research sites (24th Nov 2021, 16th Dec 2021, 21st Jan 2022, 15th Feb 2022, 9th Mar 2022) • Participant recruitment • Data collection
May 2022 to Oct 2022	• Patient interview analysis • Survey data analysis
Oct 2022 – Oct 2023	Studies/chapters and thesis write up

Appendix B shows the search strategy used for the EBSCO database. The search covered the period of 1980-2023 and was last run on 05/05/2023. Results of all database searches were combined, and duplicates removed. Literature was excluded if they were non-English language, unpublished dissertations/theses, and the primary focus was on other chronic respiratory diseases (e.g. asthma and lung cancer), respiratory/inspiratory muscle training, or home-based, tele-rehab, virtual/remote PR. After the search results were screened at the title level 326 articles remained. As this narrative review covered a broad combination of topics;

review papers, systematic reviews, and meta-analyses were prioritised within the discussion to best summarise the body of literature.

2.3 Review of Strength Assessment and Strength Training in COPD and PR Research

2.3.1 Strength Assessment

As discussed in Chapter 1 (page 34), individuals with COPD frequently experience skeletal muscle dysfunction, with reduced muscle strength being a common impairment (228). The ATS and ERS highlighted the importance of muscle dysfunction in COPD through a joint statement initially published in 1999 (229), which was subsequently updated in 2014 (93). Within its conclusion it encouraged the assessment of limb muscles for COPD. In the years following, a number of articles and reviews were also published supporting the assessment of muscle strength for COPD (228, 230-232). They outline that SA is essential for identifying muscle weakness, prescribing individualised exercise training (e.g. ST), and evaluating effectiveness of interventions (233). SA should be included in the routine assessment of COPD, particularly within clinical practice and interventional programmes, such as PR. In the clinical evaluation of COPD it can help identify patients who are at increased risk for exercise limitation and premature mortality (93). Focus is primarily placed on the assessment of the quadriceps muscles, which is considered an important systemic marker for the condition (33). Evaluating a patient's strength allows for the individualised prescription of adequate training intensity and load (i.e. weight), as well as general insight into a patient's physical capabilities. It yields important information about the status of the muscles, providing clinicians with the knowledge and understanding to appropriately treat their patients. Lastly, measuring muscle strength during exercise training, or other interventions, provides a mechanism for monitoring

progress and evaluating effectiveness. Actions should be taken to ensure treatments are evaluated using this criterion alongside other outcomes (e.g. dyspnoea, HRQoL, and exercise capacity). Overall, muscle strength is an important outcome measure for COPD, and assessing it within this patient population and PR programmes has clinical and prognostic value.

The choice of SA should be specific to the clinical question being asked, considering both the advantages and limitations of the methods available. Marklund et al. (230) outlines the key factors that influence the choice of measurement. As shown in **Figure 4**, this includes the aim of the measurement, quality indicators, what muscle(s) will be targeted, and the equipment used. It is also important to consider the setting and environment in which the SA will take place, as this will impact measurement choice. A SA conducted in a research setting, where specialist equipment is available and accessible, may not be feasible in a clinical setting like PR, which can take place in a variety of settings (33, 166). Overall, the measurement chosen should be accurate, reliable, and sensible (234).

The following section of this review will outline the different methods for assessing skeletal muscle strength, extent of use in COPD and PR research, and applicability and feasibility in PR clinical practice.

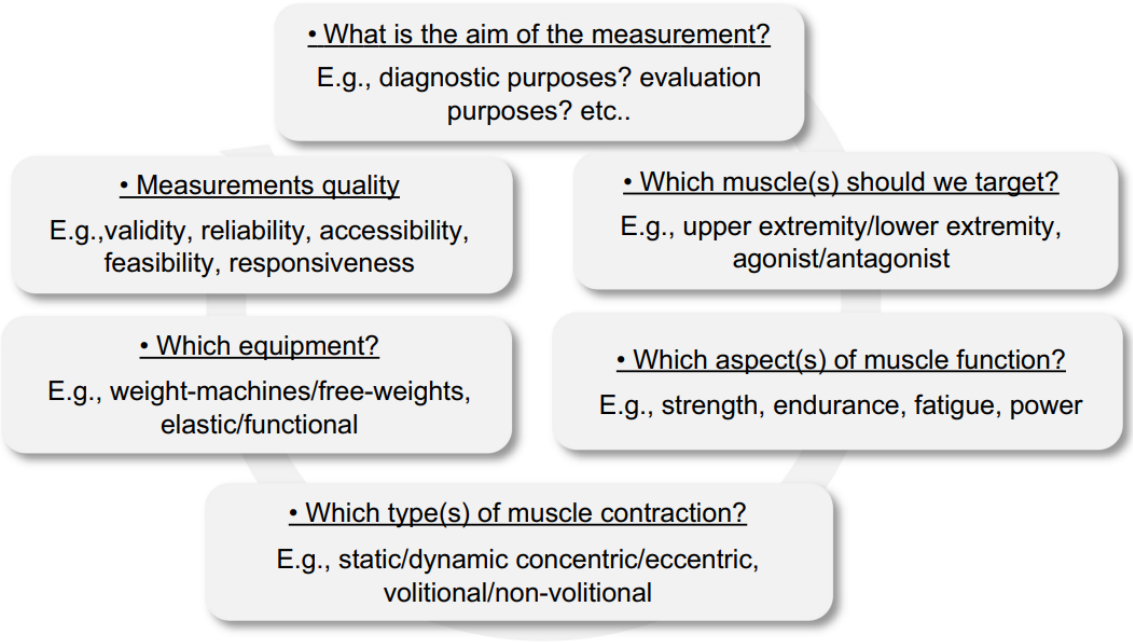

Figure 4. Factors influencing choice of muscle measurement (230)

2.3.1.1 Strength Assessment Methods

Muscle strength refers to the voluntary external force generated by a muscle or muscle group to meet or overcome resistance, commonly expressed in newtons, kilograms, or pounds (235). The goal of a SA is to determine the force or torque generated from a maximum volitional contraction (MVC) (234). Muscle movement can be separated into two distinct categories: static or dynamic (235) (see **Table 2**). Static muscle movements involve no movement at any given joint(s) and are typically comprised of isometric contractions, where the muscle stays the same length, often acting against an immovable resistance (236). Whereas, dynamic muscle movements involve movement of a body part or external load where the muscle changes length (235) - often performed using isotonic or isokinetic contractions. Isotonic contractions are where the muscle is kept under constant tension through a range of motion with fixed external loading. Isokinetic contractions are where the muscle is held at maximal tension throughout a range of motion at a fixed speed. There are methods of assessing

muscle strength using involuntary tests, such as electrical or magnetic stimulation of the muscle or nerve, however such approaches will not be discussed here as they are predominately limited to research settings (236).

Table 2. Types of muscle movements and contractions

Muscle Movement	**Dynamic**		**Static**
Muscle Contraction	**Isotonic**	**Isokinetic**	**Isometric**
Description	Muscle is kept under constant tension through a range of motion, with fixed external loading.	Muscle is held at a maximal tension throughout a range of motion at a fixed speed.	No movement of the muscle, it remains the same length.
SA Example(s)	One-repetition Maximum (1-RM), multiple-repetition Maximum (m-RM)	Computerised dynamometer	Hand-held dynamometer (HHD), computerised dynamometer, strain gauge

Descriptions of different SA methods are outlined below, along with brief discussions of advantages and disadvantages in clinical practice and PR. Further details of each SA are also presented in **Table 3**, which outlines reliability, validity, availability of normative values, and minimal clinically important difference (MCID) for COPD.

2.3.1.1.1 One-Repetition Maximum (1-RM)

1-RM is defined as the maximum amount of weight/load lifted for one full repetition of an exercise, through the full range of motion with correct form (235). It is primarily used to prescribe training load for an exercise programme, but can also be used to measure strength

change (i.e. pre-post treatment). Once 1-RM is determined it can be used to calculate the training load for a desired number of sets and repetitions of an exercise. This is done by calculating percentages of the 1-RM, for example, if an individual's 1-RM back squat is 100kg, a prescription of 60-80% 1RM (approx. 60-80kg) may be prescribed for between 8-12 reps. As shown in **Table 3**, 1-RM is reliable in adult populations and for a variety of upper and lower exercises (237), however reliability within COPD populations is yet to be determined. High validity is demonstrated with COPD patients (238) and older adults (239), with strong significant correlations reported between 1-RM leg extension and leg press, and isometric and isokinetic knee extension measured on a computerised dynamometer.

1-RM is considered the gold standard of field strength tests, which can be used with a variety of exercises and equipment (e.g. free weights and weight machines). It is shown to be safe in older adults and COPD populations, with no adverse events (240), however it is very time consuming, due to familiarisation, multiple trials, and repeat testing. Therefore, in a clinical setting like PR it may not be feasible due to time constraints. Another limitation is the dependency on equipment that is heavy enough to reach a maximum exercise repetition. For PR programmes which are based in settings with limited equipment, a 1-RM may not be possible due to a lack of available resources. It can also be a daunting test as it requires maximal effort, so may not be appropriate for all people, particularly novice strength trainers. Lastly, there is a lack of standardisation in the protocols used and described within COPD research studies (234), as well as the absence of a COPD-specific 1-RM protocol. The ACSM provides a brief protocol description but this is not COPD-specific (235).

2.3.1.1.2 Multiple-Repetition Maximum (m-RM)

M-RM is an alternative to direct 1-RM testing. It is defined as the greatest amount of weight/load lifted for a specified number of repetitions, for example if a maximum of 8 repetitions of an exercise can be performed with a certain load, then it is denoted as 8-RM. There are two methods for m-RM testing: choosing a pre-determined number of repetitions (e.g. 8RM) and increasing the load until this number is reached; or choosing a pre-determined load and lifting it for as many repetitions as possible. Similar to 1-RM, it can assess muscle strength as an outcome measure, and prescribe training weight/load. Prescription of load can be carried out in two ways. Firstly, taking the initial m-RM result and increasing it by 2-10% when 1-2 repetitions can be performed over the desired number. Secondly, using the initial m-RM result and calculating a predicted 1-RM. This uses prediction equations, such as Bryzicki's (241) or Epley's (242). From this predicted 1-RM, prescribed 1-RM percentages (%1-RM) for weight/load can be determined. As shown in **Table 3**, m-RM testing and prediction of 1-RM are both reliable and valid methods in adult populations (243-246). However, predicted 1-RM methods show some degree of error and variability depending on the equation used (1-10kg), emphasising the importance of determining the most appropriate equation for the chosen population and exercise (247). Unfortunately, validity and reliability are not yet determined in COPD populations.

M-RM is less time consuming compared to direct 1-RM, and can be conducted using lighter weight equipment - making it more feasible within PR settings with limited equipment. Furthermore, as it does not require the individual to lift maximum weight, it may be more appropriate for untrained individuals or those with health conditions, such as COPD. There is not a COPD-specific m-RM testing protocol, but the ACSM proposes the same genetic 1-RM testing protocol be used with slight alterations (235). The aim is to achieve as many repetitions

as possible with a certain load until failure. However, if the number of repetitions exceeds 10 then the load is increased until repetitions are ≤10. Utilisation of 1-RM prediction equations are more reliable and accurate if m-RM is ≤10 repetitions (235, 248).

2.3.1.1.3 Computerised Dynamometer

Computerised dynamometers can be used to assess isometric and isokinetic muscle contractions. There are a variety of commercially available devices, such as Cybex, Biodex, and Kin-Com. Isometric MVC are static movements where the joint angle and muscle length do not change. Whereas isokinetic contractions are dynamic measures of strength where the entire range of motion is pre-set to a certain velocity – meaning the speed stays constant. As shown in **Table 3**, both are reliable when measuring quadriceps and biceps for COPD (249-252). These devices are considered the gold standard of strength testing in a research and laboratory setting, and are used as the validated comparison for which other methods are evaluated against for accuracy (230). This specialised equipment is expensive and requires adequate space and a suitable setting. Substantial time is required to set up and conduct the test, and technical expertise is required. Consequently, the use of computerised dynamometers are not practical or feasible in a clinical setting.

2.3.1.1.4 Hand-Held Dynamometer (HHD)

HHD is a portable device used to objectively measure muscle strength in units of force (i.e., newtons, kilograms or pounds). The device is held against the body/limb to quantity the force applied against it. There are a variety of devices commercially available, such as MicroFet™ and Lafayette. As shown in **Table 3**, HHD is valid when compared to computerised dynamometry (253, 254), and has good-excellent reliability in adults and COPD patients (255-258). However, limits of agreement are wide as a HHD is dependent on the strength of the

tester and the individual being tested, which can negatively impact reliability. The tester must have a mechanical/strength advantage over the subject, which is particularly important for large muscle groups (e.g. quadriceps), as this can lead to underestimation. Nevertheless, HHD are portable and versatile with different targeted muscles. Compared to computerised dynamometers they are less expensive and easier to use, requiring less technical skill.

To overcome this limitation and eliminate the need for the tester's direct involvement, the HHD can be fixed in place with belt-stabilisation (e.g. to a chair or table). As shown in **Table 3**, a fixed HHD is reported to have excellent test-retest, intra-tester, and inter-tester reliability for COPD (259, 260). It is a valid measure when compared to a computerised dynamometer (259), but results from a fixed HHD are usually lower in comparison, which could be due to differences in patient stabilisation during testing (261, 262). Despite its advantages over a non-fixed method, its feasibility in a clinical setting is still questionable as 'how it is fixed' and 'what it is fixed to' may limit its practically in PR. A standardised approach to using a fixed HHD has not been documented within the literature and set-up is variable throughout research studies.

2.3.1.1.5 Hand-Held Dynamometer (Handgrip Strength)

A HHD is also used to assess handgrip strength (HGS), which measures the amount of force that the hand can squeeze around a dynamometer. As shown in **Table 3**, excellent validity of handgrip dynamometry is reported (263), and good-excellent test-retest, inter-tester, and intra-tester reliability is shown in COPD and older adult samples (255, 264-268). A handgrip dynamometer shares similar advantages to the other HHD methods - it is portable, inexpensive, and easy to use. HGS is frequently used in research and clinical settings, such as to identify

sarcopenia, frailty, and malnutrition, and evaluate impact and recovery of health events (e.g., stroke and surgery).

Research has shown moderate correlations between HGS and other SA methods, such as 1-RM strength (leg press, leg extension, and bicep curl) in older adults (269, 270), and isokinetic and isometric quadriceps strength in COPD patients (238, 271, 272). Despite these moderate associations, it is recommended that HGS should only be used to evaluate hand and forearm strength rather than an indicator of overall body or upper body strength (228, 231). Regarding the preservation of HGS in COPD, distal upper body strength (e.g. HDS) is reported to be better preserved than proximal upper body strength and lower body strength (96). Additionally, varying results have been reported, with some studies reporting no significant differences in HGS when compared to age-matched controls (273, 274), and others reporting significantly lower HGS in COPD patients (275). These discrepancies could argue HGS is not the most suitable muscle for assessment in COPD or PR. HGS is shown to lack responsiveness and sensitivity to short term strength changes, making it unsuitable for evaluating interventions, such as PR which typically last 7-8 weeks (269). Instead it is better used in clinical consultations for indicating muscle weakness, such as a marker for sarcopenia and frailty (276), evaluating disease prognosis, and directing treatment strategies (277).

2.3.1.1.6 Strain Gauge

A strain gauge system is similar to a fixed HHD regarding set up and testing protocol. It measures isometric MVC, typically of the quadriceps, with the device fixed to a chair or purpose-built apparatus. Research has shown excellent test-retest reliability in a COPD sample (251, 278) and high validity when evaluated against a computerised dynamometer in COPD patients (251) (see **Table 3**). Strain gauges have been used extensively in COPD research

studies, but are described as complex laboratory-based equipment that requires long time commitments and specific technical expertise (234). Clinical utility is questionable as it requires custom built apparatus (not commercially available), careful calibration before testing, and additional computer software to acquire and record the signal. Some reviews indicate feasibility in a clinical setting (93, 232), but these recommendations are unsupported with no clear clinical justification (279).

2.3.1.1.7 Sit to Stand (S2S) Tests

S2S tests assess a person's ability to repeatedly change from a sitting position to a standing position. There are a number of variations: the five-repetition sit to stand (5repS2S), which assesses how long it takes to complete five repetitions; and the 30-second sit to stand (30secS2S) and the 1-minute sit to stand (1minS2S), which both assess how many repetitions can be completed in the allocated time. All three variations are shown to have good-excellent test-retest reliability in older adults and individuals with COPD (272, 280-284).

However, validity as a SA is unclear, which questions if a S2S test is actually a measure of muscle strength. As shown in **Table 3**, S2S tests have moderate correlations with measures of quadriceps strength, such as 1-RM, HHD, strain gauge, and computerised dynamometers. Whereas other studies report no significant associations (259, 285-287). A literature review conducted by Vaidya et al. (288) concluded that S2S tests appear to be more appropriate for assessing functional status in COPD and evaluating lower limb activity, as well as considered to be an alternative to other frequently used functional tests (e.g. 6MWT). Studies have shown significant correlation between S2S tests and 6MWT (281, 286, 289-291), which further supports its relevance as an evaluative tool for functional status. Consequently, a S2S test may not be a direct measure of strength, but instead an indirect or surrogate measurement that

provides insight into strength, along with other performance factors, such as balance, motor coordination, and gait speed (228).

S2S tests are feasible in clinical settings, like PR, as they are easy to conduct and require minimal space and equipment. It is a motion which mimics a movement essential for daily living (288), which could be considered meaningful to COPD patients in terms of the testing protocol and benefit of improvement. However, a reported limitation is the presence of a floor effect, with 6-15% of COPD patients unable to complete the test or rise from the chair (292). Moreover, the use of S2S tests to track muscle weakness and prescribe exercise training programmes is unclear (230), as well as limited research investigating its use in COPD populations (288).

Table 3. Details of each strength assessment method

	Muscle Contraction	**Description**	**Reliability**	**Validity**	**Normative/ Reference Values**	**MCID in COPD**
One-Repetition Maximum (1-RM)	Isotonic	The maximum amount of weight/load lifted for one full repetition of an exercise with correct form.	**Reliability not yet determined in COPD.** Excellent test-retest reliability (median ICC=0.97) in general populations (older adults and untrained) (237). Excellent test-retest reliability in Parkinson's disease (ICC=0.91-0.97) (293) and chronic heart failure (ICC=0.97) (294). Moderate to excellent inter-rater (ICC=0.85-0.98) and intra-rater (ICC=0.64-0.99) reliability (237).	Strong correlations between 1-RM leg extension and isometric and isokinetic knee extension measured on a computerised dynamometer (Cybex II) in a sample aged 19-84 (*r*=0.72–0.88) and elderly adults over 60 (*r*=0.76–0.93) (239). Strong correlation between 1-RM knee extension and isokinetic quadriceps strength on a computerised dynamometer (Cybex 6000) (*r*=0.77) in COPD patients (238).	Normative values are available for general populations (age and gender) for 1-RM bench press and leg press (235).	5kg in leg extension and 6kg in chest press (295). 5.7kg in leg extension (279). 2.5-3kg leg extension (296).
Multiple-Repetition Maximum (m-RM)	Isotonic	The greatest amount of weight/load lifted with correct form for a certain number of repetitions. Predicted 1-RM: an m-RM result can be used to predict 1-RM using prediction equations (e.g. Bryzicki's (241) or Epley's (242).	**Reliability not yet determined in COPD.** 5-RM and 8-RM has excellent test-retest reliability (ICC>0.9) in upper and lower body exercises and in a variety of populations (men, women, young and older adults) (243-245). Predicted 1-RM: Excellent test-retest reliability (Bryzicki's formula; ICC=0.90–0.99) in middle aged diabetics for bench press, leg press, lateral pull, leg extension and bicep curl (297).	**Validity not yet determined in COPD.** Strong correlations (r=0.71-0.85) between 8-RM and isokinetic computerised dynamometer (Biodex) in young adults for chest press, row, pull down, and overhead press (243). Predicted 1-RM: Moderate to strong correlations between direct 1-RM and predicted 1-RM for upper and lower body exercises (upper: r=0.77–0.90; lower: r=0.60–0.80). But, direct 1-RM values consistently greater than predicted, within a range of 1-10kg (247).	None.	0.324kg for biceps curl and 2.47kg for leg extension (298).
Computerised Dynamometer (e.g. Biodex, Cybex, Kin-com)	Isometric	Isometric MVC are static movements where the joint angle and muscle length do not change. Typically a	Good to excellent test-retest reliability (ICC =0.82–0.99) for quadriceps and biceps in individuals with COPD (249-251). Good to excellent intra-rater (ICC=0.85–0.94) and inter-rater (ICC=0.89–0.97)	No. It is the 'gold standard' of lab testing. Other assessments and devices are measured against this.	Normative values of isometric muscle strength in both upper and lower limbs are provided, with consideration for	None.

		measurement of force or torque, reported in newton meter (Nm).	reliability reported for isokinetic knee flexion and extension in a healthy older adults (252).		age and gender (299, 300).	
Computerised Dynamometer (e.g. Biodex, Cybex, Kin-com)	Isokinetic	Isokinetic movements are dynamic measures of strength where the entire range of motion is pre-set to a certain velocity, meaning the speed stays constant. Typically measured as peak torque, reported in newton meter (Nm).	Good to excellent test-retest reliability (ICC=0.82–0.99) for quadriceps and biceps at two angular velocities (30 and 90 degree/s) in a COPD sample, both within and between trials (249). Good to excellent intra-rater (ICC=0.85–0.94) and inter-rater (ICC=0.89–0.97) reliability for knee flexion and extension at two angular velocities (60 and 120 degree/s) in a healthy older adults (252).	No. It is the 'gold standard' of lab testing. Most assessments are measured against this.	Normative values of isometric muscle strength in both upper and lower limbs are provided, with consideration for age and gender (299, 300).	None.
Hand-held dynamometer (non-fixed; e.g. MicroFet and Lafayette)	Isometric	A portable device used to objectively measure muscle strength in units of force. The device is held against the body/limb of the patient to quantify the force applied against it.	Good to excellent test-retest reliability (ICC=0.79-0.89) for quadriceps, pectorals, shoulder flexors, and hip abductors in COPD patients (258). Good inter-rater reliability for quadriceps strength in COPD patients (ICC=0.76-0.83), however limits of agreement are wide indicating results are dependent on testers strength (255-257).	**Validity not yet determined in COPD.** A systematic review concluded HHD to be a valid instrument for SA in clinical settings when compared to isokinetic dynamometry (253). Moderate to excellent relationships (ICC=>0.7) between HHD and computerised dynamometer (Kin-Com) for 8 lower body assessments of peak force (254).	Normative values are available for upper and lower limbs in healthy age ranges (301, 302).	None.
Hand-held dynamometer (fixed; e.g. Jamar)	Isometric	A HHD device fixed in place, eliminating the need for a tester to hold the device against the patient's body using their own strength.	Good to excellent test-retest reliability (ICC=0.87–0.97) in a COPD sample (259). Excellent intra-tester and inter-tester reliability (ICC=0.95–0.99) in a COPD sample (260).	Strong correlation (r=0.86) between fixed HHD and computerised dynamometer (Biodex) in COPD (259). But results using a fixed HHD are usually lower which could be a result of differences in patient stabilisation during testing (262, 280).	None.	MID estimated at 7.5-7.8 Nm (303).
Hand-held dynamometer	Isometric	HGS can be quantified by measuring the	Good to excellent test-retest reliability (ICC=0.80–0.99) in COPD and older adult samples (264, 265, 267, 268).	**Validity not yet determined in COPD.**	Multiple studies outlining normative values	None for COPD. However, an MCID of 5-6.5kg

(Handgrip Strength; HGS)		amount of force that the hand can squeeze around a dynamometer.	Excellent inter-tester and intra-tester reliability (ICC=0.90-99) in COPD and older adult samples (255, 266, 268).	Strong correlations (r=0.99; r=0.96) between HGS dynamometer with known weights (263).	for age and gender (304-306).	is estimated for adults (307).
Strain Gauge	Isometric	Measures isometric MVC, typically of the quadriceps, with the device fixed to a chair or purpose-built apparatus.	Excellent test-retest reliability (ICC=0.96-0.97) of quadriceps isometric MVC in a COPD sample (251, 278).	Strong correlation (r=0.88) between strain gauge and computerised dynamometer (Biodex) in COPD patients (251).	Reference values are available for both upper (neck, shoulder, elbow) and lower (knee, hip and ankles) body (308).	9.4-16Nm for quadriceps MVC (296).
Sit to Stand (5repS2S, 30secS2S, 1minS2S)	N/A (Functional Test)	Sit to stand tests assess the ability to repeatedly change from a sitting to a standing position. There are a variety of variations: 5repS2S (how long it takes to complete 5 reps), and the 30secS2S and 1minS2S (how many reps can be completed in the allocated time).	5repS2S: good to excellent test-retest reliability in healthy older adults (ICC=0.64–0.94), older hospitalised patients (ICC=0.99) and COPD patients (ICC=0.97), as well as excellent inter-rater reliability in COPD and hospitalised patients (ICC=0.99) (272, 280, 283). 30sec-S2S: good to excellent test-retest reliability in older adults aged 70yrs (r=0.89) (282). 1min-S2S: good to excellent test-retest reliability in older adults (ICC=0.80) (284) and COPD patients (ICC=0.99) (281).	Weak to moderate correlations (r=0.33-0.41) between 5repS2S and isometric quadriceps MVC (measured using a strain gauge, HHD and fixed HHD) in COPD patients (283, 291, 309). Whereas other studies report no significant associations (259, 285-287). Moderate to strong correlations (r=0.398–0.80) between 30secS2S and quadriceps strength (measured by 1-RM leg extension, computerised dynamometer and HHD) in a COPD sample (62, 291, 310). Whereas other studies report no significant associations (287). Weak to strong correlations between 1minS2S and quadriceps strength (measured by 1RM leg extension and leg press, strain gauge, and fixed HHD) in older adults (r=0.68) (284) and COPD patients (r=0.36–0.65) (271, 289, 290, 310). Whereas other studies report no significant associations (259, 285-287).	5repS2S values aged 60-90 years old (311). 30secS2S values in 60-90 years old (282). 1minS2S values aged 20-80 years old (312).	5repSTS MCID estimated at 1.7secs (283). 30secS2S MCID estimated as 2 or more reps (313). 1minS2S MID estimated at 3 reps (290).
Note. ICC = intraclass correlation coefficient, MCID = maximal clinically important difference, MVC = maximal volitional contractions, HHD = handheld dynamometer, HGS = handgrip strength, 5repS2S = five-repetition sit to stand, 30secS2S = 30-second sit to stand, 1minS2S = one-minute sit to stand, N/A = not applicable						

2.3.1.2 Strength Assessment Use in COPD and PR Research

During the literature search, three systematic reviews were identified which reported on SA use in COPD and PR research studies (234, 314, 315).

In 2011, Robles et al. (234) reviewed literature on measurements of muscle strength used in COPD studies. It reviewed 66 English language articles, searched between 1999-2009. Results showed 55 studies used a static (isometric) measure, and 25 used a dynamic (isotonic or isokinetic) measure. Note, some studies reported more than one type of measurement. The most common measurements used were handgrip dynamometer (*n*=30), strain gauge (*n*=18), and isokinetic (*n*=16) or isometric (*n*=13) computerised dynamometer. The least used were 1-RM (*n*=9), HHD (*n*=6), and functional tests (*n*=3). In terms of methodology and protocols, there was a lack of standardisation and consistency, with study descriptions failing to provide key information e.g., number of trials, rest periods, familiarisation, and use of encouragement. The review highlights key methodological issues that need considering when assessing strength in clinical and research settings. Standardisation of test procedures is essential to obtain valid and reliable results, therefore it is important that all variables are addressed when developing a SA protocol. In the absence of such information it makes replication and comparison challenging. The review is useful as it provides an overview of the SAs used in COPD research, however it is not specific to use in PR settings.

Additionally, in 2022, Souto-Miranda et al. (314) identified outcomes and measures used in PR clinical trials with COPD patients. It reviewed 267 studies, searched between 2000-2020. Studies were included if it was a stable COPD sample and a PR intervention, with at least exercise training and education. It reported on a broad range of outcomes and measures, with the most frequently reported being exercise capacity (*n*=218), HRQoL (*n*=204), and

COPD symptoms (*n*=158). Regarding SA, only 37 studies included it as an outcome, with measures including HHD (*n*=19), number of arm lifts (*n*=8), and isokinetic (*n*=4). Assessment of functional performance was also reviewed (*n*=22), of which six studies used 5repS2S. The review showed widespread measures were used to assess the same outcome. The existence of such dispersed measurements is important as it can hinder comparisons across studies and the summary of evidence (316). It shows that SA within PR research is minimal, but if it is included the most used method is HHD. Unfortunately, further description and discussion about SA use is not provided in the review. Furthermore, it reveals studies do not reflect PR recommendations, with 55% based in outpatient settings, 46% with a duration between 8-12 weeks, 56% with a frequency 2-3 times per week, and 75% combining AT and ST. Therefore, if basic PR recommendations are not being met in research studies, it is not surprising that SA is not widely used as an outcome measure – despite recommendations. A caveat emphasised is careful interpretation of the results as the outcomes and measures being reported does not necessarily imply their adequacy in PR. The authors conclude that due to the heterogeneity found, there is a need for a core outcome set, as defining 'what to measure' and 'how to measure' will improve consistency in research studies, reduce the risk of outcome reporting bias, and provide recommendations for clinical practice - which would be particularly beneficial for SA in PR.

Investigation of PR outcome measures is not solely confined to stable COPD. In 2018, a systematic review by Oliveira et al. (315), reviewed the measurement properties of patient-reported and clinical outcome measures in PR for AECOPD, with a particular focus on application in community-based practice. Studies were included if they assessed PR and assessed patients with AECOPD within 3 weeks of the onset. Studies were excluded if they reported on measurement properties of outcome measures not feasible for use in community-

based PR programmes. The search was conducted up to 2016, and 37 studies were included. From these studies, 23 patient-reported outcome measures (e.g., dyspnoea and HRQoL) and 18 clinical outcome measures were found. The most common clinical outcomes were functional exercise capacity (e.g., walking tests) and lung function (e.g., FEV1). Muscle strength was identified as a clinical outcome, with 10 studies using isometric MVC measurements, however, specific details on the SAs used were not reported in the review.

Overall, SA in PR clinical trials for AECOPD is minimal, even more so than the results reported in Souto-Miranda's (314) review in stable COPD. Oliveira et al (315) specifically mentions the review had a focus on application in community-based practice, however the inclusion criteria did not specify how this was fulfilled, nor did it discuss or evaluate feasibility in community settings in the results. All the studies that used an isometric MVC measurement were located in hospital departments (inpatient and outpatient), not community settings. As individuals had AECOPD, it is understandable that many will be referred to hospital-based PR programmes, which further questions why the emphasis was on community-based practice. These results are not reflective of the variety of settings used for PR. Regardless of whether it is stable COPD or AECOPD, SA is important. It is known that the inflammatory effects of AECOPD are not confined to the lungs but also impair skeletal muscle strength and exercise capacity, which are shown to be independent predictors of hospitalisation and mortality (93). Hence, there is a need to establish measurement properties of clinical outcomes for AECOPD to assess patient dysfunctions, plan interventions, and verify their effectiveness (315). As PR programmes, and the management of COPD, often takes place in community and primary care settings, it is important to consider how SA fits into this context. Future research needs to focus on SA in clinical settings and real-world PR, with consideration for all factors involved (e.g. validity, reliability, feasibility, responsiveness, interpretability (MCID), and acceptability)).

It is evident from these systematic reviews there is heterogeneity in the SA methods used in COPD research (234), as well as minimal use in PR clinical trials (314, 315). As discussed above (page 53), each SA has its own advantages and disadvantages, particularly regarding setting and context. It is possible to conduct many assessments within research settings due to funding, available resources, and strict protocols. However, the measures utilised within the parameters of research may not be practical or feasible in PR clinical settings. To implement these into clinical practice some key aspects need to be considered, such as standardisation, feasibility, and relevance to the target population. Validity and reliability are important factors when choosing an appropriate assessment, therefore standardisation of testing protocols is vital, which includes preparation of guidelines, measurement instructions, equipment, warm-up, familiarisation, positioning, rest periods, velocity, and encouragement. Standardised conditions to account for these factors help minimise measurement error and increase measurement quality (249), which is particularly important when tracking change over time, e.g. before/after PR or hospitalisation. However, standardisation of measurement strategies are often left out of COPD studies (234). It is evident that standardisation and reporting of testing protocols need to be improved in research studies to reduce heterogeneity in future trial results. SA is encouraged and recommended, but if explanations and descriptions are lacking, then it will make adaption and implementation into real world practice challenging. Therefore, it is important to consider feasibility and how it will be integrated into the intended clinical context (i.e., PR). There are many influential factors which need considering including time, resources, cost, equipment, ease of use, technical skill, acceptability, and patient understanding. However, research studies do not typically account for these feasibility factors.

Another important aspect is the relevance to the target population. In COPD, SA should, at a minimum, include the quadriceps due to its clinical, prognostic, and functional value (51,

59, 112). Depending on the purpose and scope of evaluation, other muscles can be tested to help in designing and individualising training programmes or to evaluate effects of interventions (231). Additionally, because muscle strength can vary, assessment techniques need to be compatible with a large range of force development (93). Limiting factors to consider in COPD include the impact of cardiorespiratory function and dyspnoea on test performance, and avoidance of overtasking the subject. Most people with COPD will be unfamiliar with strength testing, therefore familiarisation with procedures, use of verbal encouragement during testing, and an adequate number of trials and rest periods will be required to obtain a maximal effort (234).

Published recommendations for SA in PR clinical practice are sparse and inconsistent, with suggestions lacking evidential support. According to the ATS/ERS statement on muscle dysfunction in COPD (93), a strain gauge to assess quadriceps muscle strength is recommended, however justification and discussion surrounding this choice is absent – which has also been observed by other authors (279). This recommendation referenced use in an exercise laboratory setting, which is not typical practice for PR programmes. An exercise laboratory likely has access to specialised equipment to carry out a SA like this, whereas other settings may not (e.g., community and primary care settings). Following the publication of the ATS/ERS statement, other reviews have referenced this recommendation without true consideration for clinical feasibility (228, 231, 232). They state a strain gauge should be favoured due to its simplicity, availability, and quality of information provided, as well as its applicability in clinical and laboratory settings. However, the discussion and recommendations outlined by Robles et al. (234) are vastly different. Robles et al. (234) state strain gauges are more suited to research settings, similar to a computerised dynamometer, as they require a longer time commitment to complete the testing and specific technical expertise. The clinical

utility is questionable as it requires custom built apparatus, careful calibration before testing, and additional computer software to acquire and record the signal. A strain gauge to assess muscle strength has been utilised in COPD research (234), but utility in PR clinical trials is limited and restricted to hospital-based settings (314, 315). Instead, Robles et al. recommend the use of a HHD in a clinical setting, to compensate for limited time and resources. A HHD has been effectively used with COPD, is less expensive, and requires less technical skill compared with other laboratory-based SA equipment. However, the authors do acknowledge its tester dependency and the negative impact on reliability. Therefore, a further recommendation of 1-RM is offered, as it does not require manual resistance from the tester. 1-RM is shown to be safe with COPD (240) and may be preferable for exercise prescription, especially exercise training using weight-lifting equipment. Despite these SA recommendations for clinical practice, the overall consensus is that it depends on the SA purpose and goal, availability of equipment, and skill of the tester.

Irrespective of all factors to consider when deciding how to assess muscle strength in clinical practice, the take-home message is that the muscle strength should be evaluated. Despite the prognostic and clinical relevance to COPD, and even though assessment of limb muscles is recommended in international guidelines (93), it is still not an integrated part of the routine evaluation and management of COPD (236). Less is known about the assessment of limb muscle function in community and primary care settings (93), and the assessment of muscle strength is yet to become a clinical reality (230). Further research is needed to evaluate SA in PR clinical practice and the varying settings programmes take place in. Particular attention should be placed on the feasibility and implementation of SA in clinical practice, specifically PR.

2.3.2 Strength Training

2.3.2.1 Effectiveness of Strength Training

The inclusion of strengthening exercise within PR programmes is supported by research which has extensively studied the effects of ST either alone or in combination with AT in COPD populations (181, 227, 317-320). A recent meta-analysis, published by Li et al. in 2021 (320), compared the effect of ST, AT, and combined training (CT; i.e. ST and AT) on muscle strength in stable COPD (30 RCTs). Studies were considered relevant if ST and/or AT were an included intervention with a comparable control group, and muscle strength was an assessed outcome. Thirteen studies assessed muscle strength, with all pooled exercise intervention data demonstrating a significant improvement. Despite this positive effect, high heterogeneity in the methods used to assess muscle strength were observed. On closer inspection, each exercise modality (ST, AT, and CT) had different effects on muscle strength. Subgroup analysis was performed for each modality, reporting significant increases in muscle strength after ST, but non-significant results after AT and CT. Previous systematic reviews and meta-analyses report similar results and conclusions about ST and AT (181, 227, 317-319). However, the non-significant result in response to CT is inconsistent with previous reviews, which report CT produces similar or even greater effects than ST or AT alone (317, 318).

It is likely that ST alone elicited significant improvements as exercises were designed for specific muscle groups, and the programmes were prescribed with the purpose of improving muscle function and strength. Despite CT including a ST component, Li et al. (320) speculated that CT did not elicit significant results because of diversity and variation in the exercise programmes prescribed. Many included studies did not provide sufficient information on the proportion of ST and AT in the combined programmes, and failed to report clear details about the prescription parameters of exercise intensity for ST. Of those which did, prescribed

intensity may have only resulted in maintenance of muscle strength not improvement. Overall, this review concluded that exercise training for COPD patients, specifically ST, has meaningful and beneficial effects on muscle strength. Future research should aim to explore the best prescription protocol for CT, especially as it is a common exercise modality in PR.

It is evident that exercise interventions, specifically ST, can improve muscle strength for COPD patients. However, exercise programmes and outcome measures are heterogeneous, making it difficult to determine the degree of benefit (182). To aid comparison and discussion, the literature has been grouped according to the type of muscle strength assessed: isotonic, isometric, and isokinetic. Primary focus will be placed on the quadriceps muscle. Muscle weakness is more prominent in the lower limbs (100-102, 104, 108), with the quadriceps considered an important systemic marker for COPD (33). It is readily available and a primary muscle of locomotion and daily activity, as well as being the muscle most commonly studied and assessed in COPD research (96). Quadriceps muscle strength can also be described as knee/leg extension or leg press strength.

2.3.2.1.1 Isotonic Muscle Strength

Isotonic quadriceps strength, commonly assessed using 1-RM, is shown to improve in COPD patients after a ST programme. Simpson et al. (52) investigated the impact of a ST programme on COPD patients, measuring muscle strength using 1-RM leg extension and press. Patients were randomised to either an 8-week ST programme or a control group. The ST programme consisted of three sessions per week, and exercise load progressively increased from 50-85%1-RM, with 1-RM re-assessed every 6^{th} session. Results showed the ST group had significant increases in strength for both 1-RM leg extension and press, rising by 44% and 16%, respectively. No changes were observed in the control group. Similar improvements have been

reported in subsequent research (102, 124, 321-324). Improvements have also been demonstrated after a CT programme. Daabis et al. (183) investigated whether ST was a useful addition to AT in a PR programme for COPD. Patients were randomly allocated to one of three groups: AT, CT, or usual medical care. The CT programme consisted of 30-minutes of treadmill training and 30-minutes of ST, which was prescribed at an intensity of 50-80%1-RM, with 1-RM reassessed every 2 weeks. Results revealed 1-RM leg extension strength significantly increased by 32% in the CT group, whereas no significant changes were observed in the aerobic group or controls. Similar magnitudes of improvement have been reported in other studies after CT, specifically leg extension (310, 323, 325-327) and leg press (324, 328).

Contrary to this, one study reported no significant increases in quadriceps strength after CT (329). This 8-week ST programme comprised of twice weekly sessions with five exercises prescribed for 1 set of 12 repetitions at an intensity of 50%1-RM. Minimal effect could be the result of low training volume, intensity, and load, and limited progression. However, other studies with similar programme structures have reported improvements, with two studies even demonstrating noticeable gains in muscle strength after single set resistance exercises (328, 330). Overall, it has been demonstrated that CT is an effective approach, with aerobic only training showing little to no change in muscle strength (183, 325, 326, 328, 329). This is not to say that AT cannot elicit improvements, as significant increases have been reported (323, 327), however the magnitude of change is inferior when compared to CT. Interestingly, two studies have compared all three training modalities. Ortega et al. (323) reported significant increases in quadriceps strength after AT, ST, and CT by 20.5%, 52.8%, and 52.8%, respectively. Similarly, Vonbank et al. (324) reported significant increases of 20.4%, 39.3%, and 43.3%, respectively. Overall, evidence shows comparable improvements to isotonic lower limb strength in both ST and CT modalities.

2.3.1.1.2 Isometric Muscle Strength

Isometric MVC quadriceps strength is shown to increase in COPD patients after ST. Commonly used equipment includes HHD, strain gauge, and computerised dynamometer. Kongsgaard et al. (124) randomised COPD patients to either a 12-week ST programme or a control group, with knee extensor strength measured using a computerised dynamometer. The ST programme was comprised of twice weekly sessions with load prescribed at 80%1-RM, with load adjusted each week to ensure constant relative load. Results revealed a significant increase in quadriceps strength of 14.7%, compared to a decline in the control group. These improvements are in accordance with other reported findings of increases between 13.2%-25.4% (52, 331-335). Improvements have also been demonstrated in CT programmes, with significant increases reported in isometric quadriceps strength of 7-32% (182, 201, 331, 336-339).

Although research is limited, some studies have shown an increase in isometric quadriceps strength after AT only (340-342). Spruit et al. (343) randomised COPD patients to either a 12-week exercise programme of AT or ST, with strength measured as knee extension peak torque and maximal force using a HHD. Results showed both groups had a significant increase in knee extension peak torque, with the AT increasing by 42% and the ST by 20%. In contrast, results of maximal knee extension force demonstrated a different result, with ST showing a significant increase of 35%, and AT showing a non-significant increase of 25%. At first glance this may seem surprising, but on closer inspection this is an example of how the way in which strength is assessed can impact the outcome. Past research has found strength gains were significantly better at the joint angle at which ST was undertaken, in comparison to other angles (344). In this instance, knee extension exercises in the ST programme was performed over a range of 0–90 degree knee flexion, while cycling in the AT was performed

over a range of 10–60 degree knee flexion. This could explain the differences in the strength gains between both groups, as knee extension peak torque was measured at 60-degree flexion, while maximal force was measured at 90-degree flexion, indicating a dependence on angle specificity. Overall, ST is a very effective strategy to increase isometric quadriceps strength in COPD, however, emphasise is placed on the methodologies used for SA (343).

2.3.1.1.3 Isokinetic Muscle Strength

Isokinetic quadriceps strength also significantly increases after ST programmes, measured using a computerised dynamometer. The study conducted by Kongsgaard et al. (124), as described above, also measured isokinetic knee extension peak torque using a computerised dynamometer. Findings revealed a significant improvement of 18% in the training group, with no significant changes in controls. Similar magnitudes are reported by other studies (333, 345), however non-significant results have also been demonstrated, but this is likely due to a lack of programme intensity (102, 346). Aside from ST alone, significant increases in isokinetic quadriceps strength have also been evidenced after CT programmes (101, 125, 347-349). AT has also shown to produce significant improvements (350), however, research is limited, with only one study demonstrating significant improvements in a small sample of men after 12-weeks of only cycle ergometer training. Overall, evidence demonstrates that isokinetic quadriceps strength significantly improves after completion of an exercise programme that includes ST.

In summary, isotonic, isometric, and isokinetic SA methods have all been used within this body of literature, with improvements in quadriceps strength ranging from 9-52.8%, 7-35%, 8-30%, respectively (182). This literature demonstrates ST, either alone or in combination with AT, is an effective intervention for improving lower limb muscle strength in individuals

with COPD - justifying the recommendations for inclusion in PR (25, 33, 36, 53, 143, 156, 211, 317). ST is safe and well tolerated by COPD patients, with no adverse events (33, 181-183), making its inclusion even more attractive and feasible for this patient population, especially within a clinical setting (53, 182). However, emphasis is placed on ST being appropriately prescribed to elicit significant improvements in muscle strength.

2.3.1.1.4 Upper Body Muscle Strength

Although COPD research primarily focuses on the lower extremities, upper body strength also requires some attention. Evidence demonstrates an exercise programme incorporating ST can significantly increase upper body strength, specifically the arms (52, 343), shoulders (323, 343), back (102, 323, 325), and chest (183, 323, 325, 326). However, non-significant results have also been reported (102, 329, 345, 346). A meta-analysis conducted by O'Shea et al. (181) found ST to have a significant positive effect on upper extremity strength, but not of the same magnitude as the lower limbs. This could be due to upper body strength being better preserved among those with COPD (59, 104, 143).

2.3.2.2 Impact of Strength Training on Other COPD Outcomes

From this narrative literature review it is evident that ST, either alone or in combination with AT, significantly improves muscle strength in individuals with COPD, making it an important exercise component in PR. However, its effectiveness and impact on other relevant outcomes is mixed. ST offers benefits to functional exercise capacity and ADL, but its impact on HRQoL and maximal exercise capacity is inconsistent, with conclusions stating an absence of positive effect.

A number of systematic reviews and meta-analysis have investigated the impact of ST on functional exercise capacity (i.e. 6MWT) (319, 320, 351-353). The consensus is that ST can lead to significant improvements in walking distance, but AT or CT produce more positive effects (227, 318). However, this is not the case for maximal exercise capacity, with no significant differences observed when ST is compared to control groups (320, 352). Instead, evidence supports the effectiveness of CT and AT (227, 317, 318). From this it can be concluded that ST is associated with walking distance (354), but offers limited improvements in overall exercise capacity. Instead, an exercise modality which incorporates AT is more beneficial. This may be attributed to AT bringing about more aerobic metabolism changes and greater improvements in ventilation capacity compared to ST.

Another important COPD outcome is HRQoL, measured using patient-reported questionnaires. Earlier research showed small but significant differences in HRQoL when ST was compared to AT (355) and a management intervention (354). However, two recent meta-analyses reported no significant differences when ST was compared to non-exercise controls (227, 353). Instead, significant improvements were found in response to AT and CT (227, 317, 318). Nevertheless, ST is shown to elicit positive effects on dyspnoea (356), with one meta-analysis reporting significant improvements in the dyspnoea domain of a HRQoL questionnaire after a ST intervention, when compared to controls (227). Overall, evidence suggests ST does not provide additional benefits to HRQoL beyond those provided by AT.

Research shows that ST can improve ADL and functional performance for COPD (317-319, 329, 357, 358), however evidence is limited, with large variation in measurements used - making comparisons challenging. One systematic review and meta-analysis (319) examined the effects of progressive ST on movements reflecting daily tasks (e.g. stair-climbing, sitting-

to-standing, and upper-limb lifting activities). However, this review included a variety of exercise modalities in the analysis (ST vs controls, ST vs AT, and CT vs AT), making it difficult to decipher the independent impact of ST. Results revealed a large effect favouring ST for timed stair-climbing and sitting-to-standing, but not the lifting tasks. These findings suggest that improvements in muscle strength may translate into improved task performance, but results should be interpreted with caution. Only a small number of trials were included in the analysis, as well as inconsistency in the outcomes used. A more recent review compared ST to AT, reporting improvements but no differences between modalities (317, 318). A major problem reported was the use of different ADL tests which likely caused large variability in results. Further research is needed to investigate the impact of ST on ADL, and the use of consistent measurements.

In summary, ST or AT alone cannot lead to improvements in all relevant COPD outcomes. Therefore, combining exercise modalities is an optimal strategy, reaping more benefits than the individual components. This approach is strongly recommended within PR, with emphasis on the inclusion of ST for its significant impact on muscle strength (33), as well as functional exercise capacity and ADL. ST is an essential component of PR, further emphasising the need for appropriate prescription and assessment.

2.3.2.3 Considerations for Strength Training in Clinical Practice

As discussed throughout this section, multiple reviews have evaluated the effectiveness of ST for COPD patients (181, 226, 227), concluding that it significantly increases muscle strength, which supports its inclusion in PR. However, replication in clinical practice is questionable due to inconsistencies and limited prescription details reported. The ACSM outlines key training variables for the prescription of ST, which includes frequency,

intensity/load, volume, rest periods, muscle actions, velocity, exercise selection, and exercise order (235). Descriptions of ST interventions in published research are argued as being inconsistent and incomplete, with many failing to report even the basic of ST prescription variables. Westra et al. (359) conducted a systematic review to investigate the reporting of ST interventions for COPD. In total, 78 studies were included, of which 86% reported ST frequency, 65% intensity, 51% exercise selection, 49% volume, 17% rest periods between sets, 12% muscle actions, 9% velocity of muscle action, 5% exercise order, and 0% rest periods between exercise. The reporting of ST prescription variables is limited and lacking in COPD research for both RCTs and observational studies. This means practitioners and healthcare services cannot reliably replicate and implement effective interventions into clinical practice when this essential information is missing. Not to mention, sufficient reporting is a necessity for subsequent research to build on these previous findings. Future COPD studies should ensure high quality descriptions of ST interventions are reported, published, or easily available upon request. Furthermore, the optimal prescription of ST for COPD is yet to be determined, mainly due to the wide variation in its prescription and delivery (53, 180, 360). Of the reviews which investigated ST in COPD populations, all report large inconsistencies in the prescription parameters set (181, 227, 317-320), for example programme duration ranges from 6-12 weeks, exercise volume ranges from 1-4 sets of 5-15 repetitions, and exercise intensity ranges from 50-85% 1-RM. This too makes replication in clinical practice challenging, as prescription protocols across research studies vary drastically.

Another issue is the variation in ST equipment used. Although research shows significant positive effects of ST programmes for COPD, many trials utilise weighted machines (52, 102, 124, 321, 322, 336, 361). However, this does not reflect the reality of most PR settings. While some PR settings (e.g. leisure centres and gyms) may have access to heavy

weights, weight machines, or multigym apparatus, many programmes take place in community and primary care settings, which do not have such equipment readily available (166). In the UK specifically, only a small portion (22%) of PR services in England report access to weighted machines (164). In recent years there has been an increase in research investigating PR in low resource settings. Emerging evidence suggests PR programmes using minimal equipment elicit clinically significant improvements in functional exercise capacity, HRQoL, and strength - comparable with exercise equipment based programmes (362, 363). Studies have demonstrated a positive impact using more accessible equipment such as resistance bands, which are portable, easy to use, and relatively low cost (335, 345, 364-370). For COPD, ST using resistance bands is shown to be a potential alternative to conventional ST using weight machines, demonstrating similar effects on muscle strength, functional exercise capacity, HRQoL, and dyspnoea (360). Although there has been an increase in investigation, the number and overall quality of studies is low, with further robust research needed (371).

Evidence demonstrates ST is beneficial for people with COPD by improving muscle strength, and thus is strongly recommended as an exercise intervention, particularly in PR. However, the lack of adequate reporting of prescription protocols makes replication and implementation into clinical practice challenging. Therefore, in the absence of an optimal prescription strategy for COPD, and questionable reflections of clinical practice in research studies, it begs the questions of what advice and recommendations do guidelines provide for its inclusion in PR specifically.

2.4 Review of Strength Assessment and Strength Training in PR Guidelines

Guidelines, statements, and standards have been published to help with the implementation and delivery of PR programmes. Such documents have been published by leading respiratory and healthcare organisations within the UK, and internationally. A previous review of selected guidelines was published by Garvey et al. (180) summarising three COPD guidelines for exercise prescription of endurance, strength/resistance, and flexibility training in PR settings. The guidelines reviewed were published by the ATS/ERS (53), ACCP/AACVPR (372) and ACSM (235). It found inconsistencies and differences across these guidelines, and in the absence of an optimal exercise prescription strategy for COPD it recommended that HCP should be familiar with all major evidence-based guidelines. This article is beneficial as it highlights the diversity of guidance for exercise prescription in PR, however it only reviewed guidelines published by American-based organisations, which are not typically referenced in relation to PR programmes and practices in the UK. Instead documents published, accredited, or influenced by the BTS are utilised, which include: 1) the BTS guideline on PR in adults (33); 2) BTS IMPRESS guide to PR (36); 3) BTS quality standards for PR in adults (141); 4) RCP PRSAS standards for PR in the UK (154); and 5) NHS service guidance for PR (34, 151).

Consequently, the current review will primarily focus on the prescription of ST and the assessment of muscle strength in UK PR. The five UK-based PR guidance documents listed above (e.g., BTS, RCP PRSAS, and NHS) will be reviewed, summarised, and discussed (33, 36, 141, 151, 154). Detailed descriptions of other PR content and components are beyond the scope of this review. To the researcher's knowledge, a review summarising published guidance for SA and ST in UK PR has not been conducted previously. Although this review (and thesis) is primarily concerned and localised to PR in England and the UK, it is also important for

comparison purposes to look further afield at guidance produced and published in similar countries. A number of international PR guidelines, statements, and standards are available from other western countries, including America, Canada, Australia and New Zealand, and Ireland (373). Published by leading respiratory organisations and societies, including ATS/ERS (53), ACCP/AACVPR (225, 374), ACSM (235, 375), Canadian Thoracic Society (147, 148), and Thoracic Society of Australia and New Zealand (149). These international PR guidelines will be briefly reviewed and discussed with regards to their guidance and recommendations for SA and ST in PR.

2.4.1 Strength Assessment in PR Guidelines

The five UK-based PR guidelines (33, 36, 141, 151, 154) and the nine international PR guidelines (53, 146-149, 235, 373-375) were reviewed, and the following SA information was searched for and extracted:

- Inclusion of a SA in PR
- Purpose of SA (e.g., outcome measure and/or exercise prescription)
- Type of SA (e.g., are specific SA methods named?)
- SA instructions and/or signposts (e.g., are descriptions in text provided or other resources/literature referenced?)
- Target body area/muscle(s) for SA

As shown in **Table 4**, all five UK guidance documents mention SA in PR, but to varying extents. The three most recent guidelines explicitly state and recommend muscle strength as an outcome measure in PR (141, 151, 154), for example the RCP PRSAS (154) standard 5.1 states services should show "*evidence of a validated measurement of strength used at the start and end of a PR programme*" (pg. 13). However, the remaining two guidelines only mention

muscle strength in passing (33, 36), for example the BTS guidelines (33) state muscle strength is an important systemic marker for COPD and recommends the development of validated outcome tools to incorporate extra-pulmonary manifestations which have prognostic significant to COPD, such as skeletal muscle dysfunction. But this is the extent of "guidance". All five PR guidelines do not mention, in any capacity, SA for prescribing exercise intensity/load. Furthermore, although SA in PR is stated, no further details (i.e. instructions, signposts, or references) are provided by any guideline documents regarding the suitability of different tests and how it fits into a PR programme.

Compared to the UK, international PR guidelines provide slightly more detail, but guidance is still insufficient. All extracted information is available in Appendix C. Of the nine international PR guidelines, six mention SA (53, 146, 147, 235, 373, 375) and three do not (148, 149, 374). Of those which do, the primary purpose described is for the prescription of ST intensity/load, recommending a direct 1-RM or indirect 1-RM (i.e., m-RM) strength test to determine %1-RM. The most recent PR guidelines (146, 147, 373) also acknowledge SA as a PR outcome measure to track pre-post changes, however, it is unclear if a 1-RM test should be used for outcome purposes. Instructions for conducting a 1-RM test (direct or indirect) is not provided within guideline text, but signposts to other literature are provided. They typically reference the ACSM guidelines (235, 375), which describe the basic steps – but these directions are not specific to COPD or a PR setting. Two guidelines (146, 375) list the addition of physical function tests to assess muscular strength and endurance in individuals with chronic lung diseases, for example the 30secS2S or hand grip dynamometer. However, these function test suggestions are not recommended for COPD specifically, but rather chronic lung diseases as a whole.

Overall, PR guidelines for SA are limited, vague, and inconsistent. In the UK specifically, there is markedly limited guidance, and although international guidelines provide slightly more direction, these too lack sufficient detail specific to COPD and PR. Consequently, the absence of appropriate guidelines and recommendations may cause challenges for services trying to meet these guidelines (e.g., PRSAS), for example choosing, implementing, and conducting a SA in PR clinical practice.

Table 4. UK guidelines and standards for strength assessment in PR

	BTS Guideline on PR in Adults (2013) (33)	BTS IMPRESS Guide to PR (2011) (36)	BTS Quality Standards for PR in Adults (2014) (141)	NHS PR Service Guidance (2020) (151)	RCP PRSAS Accreditation Standards (2020) (154)
Inclusion of SA in PR	Limited details: Not directly stated, but acknowledges muscle strength as a systematic marker for COPD. Research Recommendation: "To develop validated easy-to-use, sensitive outcome tools that extend the range to incorporate assessment of PR on extra-pulmonary manifestations, such as skeletal muscle dysfunction, which are of prognostic significance in COPD"	Limited detail: "PR must include an element of sports science assessment so a patient's skeletal muscles are trained including both lower limb strength (resistance) and endurance exercise."	Yes. QS8: People attending PR have the outcome of treatment assessed using as a minimum, measures of exercise capacity, dyspnoea, and health status. Other measures of PR outcome (such as muscle strength) may be of benefit in assessing individual benefit.	Yes. "The Provider shall undertake an individual comprehensive assessment based on all the information provided and the face-to-face assessment, including: assessment of peripheral muscle strength, as stated in the BTS Quality Standard"	Yes. "Standard 5.1: The service measures and manages clinical outcomes. Evidence of validated measurement of strength used at the start and end of a PR programme."
SA as outcome measure	No.	No.	Yes. Initial and discharge assessments (baseline status).	Yes. "The Provider shall retain the results of the baseline assessment, and use the results to benchmark the patient's progress, by repeating these again at the end of the programme." and "The Provider shall ensure that the same tools for assessment are used throughout the programme and appropriate assessment measures should be used to record final outcomes (as per guidelines)."	Yes. "Standard 5.1: The service measures and manages clinical outcomes. Evidence of validated measurement of strength used at the start and end of a PR programme."
SA for exercise prescription	No.	No.	No.	No.	No.
Type of SA	No.	No.	No.	No.	No.
SA instructions or signpost	No.	No.	No.	No.	No.
Target muscle/body area	Limited detail: Guidelines narrowed to quadriceps muscle.	No.	No.	No.	No.

Note. Colour code: green = provides sufficient information, yellow = limited detail provided, red = not mentioned/addressed
Note. SA = Strength Assessment, BTS = British Thoracic Society, RCP = Royal College of Physicians, PRSAS = Pulmonary Rehabilitation Services Accreditation Scheme

2.4.2 Strength Training in PR Guidelines

The five UK-based PR guidelines (33, 36, 141, 151, 154) and the nine international PR guidelines (53, 146-149, 235, 373-375) were reviewed, and details about ST prescription were extracted. Specifically, the recommendation of ST in exercise programmes, and the FITT-VP principle of exercise prescription (Frequency, Intensity, Type, Time, Volume, Progression) (235). Note, the domain of 'time' was not included as this is predominantly used for AT/CT. Additional information extracted included exercise rest periods. The information exacted was as follows:

- Inclusion of ST in PR exercise programme
- Frequency of ST (e.g., how often)
- Intensity/Load (e.g., how hard to exercise or how heavy are the weights/resistance used)
- Type (e.g., what kind or mode, such as exercises, body area/muscles targeted, equipment)
- Volume (e.g., the amount of exercise done)
- Rest Periods (e.g., amount of time between exercise sets to recover)
- Progression (e.g., advancement in an exercise once it is easily completed)

As shown in **Table 5**, all five UK-based PR guidelines recommend the inclusion of ST in exercise programmes, however details for prescription are limited. Fulfilment of each prescription variable is briefly discussed below.

Inclusion of ST in PR: All five guidelines recommend the inclusion of strength/resistance exercise alongside aerobic/endurance exercise, for example the RCP PRSAS (154) standard 3.8 states services should "*evidence that all patients undertaking PR receive a resistance training exercise programme, which is individually prescribed and progressive*" (pg. 10).

Frequency: ST frequency is not stated specifically, instead it is indicated in accordance with the frequency of PR sessions per week. Four guidelines state twice weekly supervised PR sessions, with either a third unsupervised session or additional home training (33, 36, 141, 151). The inclusion of strengthening exercises in these additional sessions is assumed based on the recommendation of its inclusion and prescription alongside aerobic exercise, but this is not specified. The RCP PRSAS standards do not specify a frequency for PR sessions or exercise (154).

Intensity/Load: All five guidelines state exercise intensity and/or load should be individually prescribed. However, they only provide vague wording, failing to describe how such prescriptions should be conducted and determined. No descriptions are provided, nor is the reader signposted to instructions or additional resources with relevant information. The NHS service guidance for PR (151), states exercise training should be prescribed "*at the highest tolerated intensity (above 60% peak performance/VO^2)"* (pg. 21), however such parameters are typically used for AT not ST (235).

Type/Mode: Three guidelines (33, 36, 151) provide additional, but limited, details regarding types of strengthening exercises, body area/muscle(s), and equipment. Guidance for which body area should be targeted is mentioned, such as "*major muscle groups, particularly the quadriceps*" (33) (pg. ii12), lower and upper limbs (36, 151), and core (151). However, detail beyond these broad categorises is not provided (e.g., specific muscle groups or types of exercises). Regarding equipment recommendations, only two guidance documents address this. The BTS guideline on PR in adults (33) mentions the use of weights and heavy loads, and the NHS service guidance for PR (151) emphasises the necessity to provide weights and resistance equipment in a PR programme, stating such equipment is an essential requirement. However,

further information regarding different types of equipment and how it can be used for ST in PR and for COPD patients is absent. The BTS quality standards (33) and the RCP PRSAS standards (154) do not address this prescription variable.

Volume: Only the BTS guideline on PR for adults (33) provides information on how ST should be prescribed in terms of volume, stating "*two to four sets should be completed, with each set comprising 10-15 repetitions*" (pg. ii12). The other four guidelines do not provide a prescription for ST volume.

Rest Periods: None of the guidance documents mention or address the prescription of rest periods/intervals between exercises and/or exercises sets.

Progression: All five guidelines mention PR exercise programmes overall should be progressive. However, guidance on how this is achieved or prescribed is vague, for example "*weights chosen should be individualised and progressed once all sets can be completed with the selected weight*" (33) (pg. ii12) and "*training should progressively increase so that the relative intensity remains constant*" (36) (pg. 9). Firstly, there is no indication how 'chosen weights' or 'relative intensity' should be prescribed. Secondly, no descriptions are provided for ST progression, nor is the reader signposted to instructions or additional resources with relevant information.

Overall, guidelines and standards for PR in the UK lack considerable and sufficient detail regarding the inclusion of ST. Consequently, this lack of guidance may cause challenges when programming, prescribing, and delivering ST in clinical practice. Many services may struggle to comply and achieve the standards outlined (e.g., PRSAS). An adequate level of

detail should be provided in guidelines to ensure PR services and practitioners have the guidance and information needed to appropriately prescribe ST to patients within their programmes.

Table 5. UK guidelines and standards for prescription of strength training in PR

	BTS Guideline on PR in Adults (2013) (33)	BTS IMPRESS Guide to PR (2011) (36)	BTS Quality Standards for PR in Adults (2014) (141)	NHS PR Service Guidance (2020) (151)	RCP PRSAS Accreditation Standards (2020) (154)
Inclusion of ST	Yes. "To ensure strength and endurance benefits in patients with COPD, a combination of progressive muscle resistance and aerobic training should be delivered during a PR programme."	Yes. "PR must include an element of sports science assessment so a patient's skeletal muscles are trained including both lower limb strength (resistance) and endurance exercise."	Yes. "QS5: PR programmes include supervised, individually tailored and prescribed, progressive exercise training including both aerobic and resistance training"	Yes. "A PR course includes an individually prescribed exercise and education programme including aerobic exercise and resistance training and lifestyle support"	Yes. "Standard 3.8: Evidence that all patients undertaking PR receive a resistance training exercise programme, which is individually prescribed and progressive"
Frequency (e.g. how often to exercise)	Yes. In accordance with PR frequency of a minimum of 2 supervised sessions per week, and 1 unsupervised session. "A minimum of 48hrs between each session is advised."	Yes. In accordance with PR frequency of twice weekly sessions, augmented by daily home based sessions.	Yes. In accordance with PR frequency of minimum twice weekly sessions, and a third unsupervised prescribed session.	Yes. In accordance with PR frequency at least twice a week, with encouragement to undertake additional home training.	No.
Intensity/Load (e.g. how hard to exercise or how heavy are the weights/resistance used)	Limited detail: "The weights chosen should be individualised and progressed once all sets can be completed with the selected weight."	Limited detail: "The exercise component is individually prescribed for each patient so that the correct intensity is achieved to obtain the desired effect."	Limited detail: "individually tailored and prescribed " "proportion of PR programmes that provide assessment of physical performance and prescription of exercise intensity at enrolment."	Limited detail: "The Provider shall ensure that every individual has a written prescription of endurance and strength exercise training at the highest tolerated intensity (above 60% peak performance/VO2) with evidence of increments and progress."	Limited detail: "Standard 3.8: Evidence that all patients undertaking PR receive a resistance training exercise programme, which is individually prescribed and progressive"
Type/Mode (e.g. exercises, body area/muscles targeted, equipment)	Limited detail: Major muscle groups, particularly the quadriceps. Mentions the use of weights and heavy loads.	Limited detail: Mentions lower and upper limb exercise. No mention of equipment.	No.	Limited detail: "Strength training of both upper and lower limbs. Core exercises can be included." "The following essential equipment is required: weights and resistance equipment"	No
Volume (e.g. the amount)	Yes. 2-4 sets of 10-15 repetitions	No.	No.	No.	No.
Rest Periods (e.g. the recovery time between sets and exercises)	No.	No.	No.	No.	No.
Progression (e.g. advancement in an exercise once it is easily completed)	Limited detail: "The weights chosen should be individualised and progressed once all sets can be completed with the selected weight."	Limited detail: "The intensity or duration of training should progressively increase so that the relative intensity remains constant."	Limited detail: "individually tailored and prescribed, progressive exercise training" "Proportion of PR programmes that ensure progression of exercise goals at intervals during programme according to individual progress and needs."	Limited detail: "The Provider shall ensure that every individual has a written prescription of endurance and strength exercise training at the highest tolerated intensity (above 60% peak performance/VO2) with evidence of increments and progress."	Limited detail: "Standard 3.8: Evidence that all patients undertaking PR receive a resistance training exercise programme, which is individually prescribed and progressive"

Note. Colour code: green = provides sufficient information, yellow = limited detail provided, red = not mentioned/addressed
Note. ST = Strength Training, BTS = British Thoracic Society, RCP = Royal College of Physicians, PRSAS = Pulmonary Rehabilitation Services Accreditation Scheme

Compared to the UK, international PR guidelines provide slightly more detail, but it is not specific to COPD or PR. All extracted information is available in Appendix D. Of the nine international PR guidelines, eight recommend the inclusion of ST in PR (53, 146-148, 235, 373-375) and one does not (149). It is widely acknowledged that an optimal exercise prescription strategy for ST is not yet determined for COPD, meaning available guidance is limited to recommendations for general adult populations. Most recent PR guidance documents (53, 146, 147) reference the ACSM guidelines for exercise testing and prescription (235, 375, 376). Although the ACSM guidelines briefly discuss exercise prescription in relation to different health conditions, including COPD, recommendations for ST are limited to those for healthy adults or older adults. It is important to note that these guidelines are not specific to PR either and do not account for PR settings, resources, and variations. It is general guidance published from a strength and conditioning perspective, with limited consideration for PR programmes and clinical practice. According to the ACSM (235), older adults are defined as "*individuals ≥65 yrs or individuals 50–64 yrs with clinically significant conditions or physical limitations that affect movement, physical fitness, or physical activity*" (pg. 204). Individuals with COPD would fall into this older adult category as they are commonly of older age and have a chronic respiratory disease which impacts their physical fitness and function. It further states exercise prescriptions for older adults is initially recommended, with graduation to guidelines for younger adults (i.e. higher intensity) after a period of adaption to ST and improved conditioning. Despite this, most PR guidelines do not acknowledge this distinction, recommending exercise prescription parameters for healthy adults.

As shown in **Table 6**, the main differences between the ACSM ST prescriptions for healthy adults and older adults are exercise intensity/load and volume. However, it is unclear when each of these prescription strategies should be applied. A moderate intensity is likely

more appropriate for COPD, especially those who are novice strength trainers. Therefore, following an initial conservative prescription strategy for older adults would be more appropriate. These ACSM guidelines are the most detailed recommendations currently available, and give better guidance than anything provided in UK-based PR guidelines. However, it is vital to stress that these ST prescription guidelines are only general guidance. They are not specific to COPD, and do not account for use and application in a PR practical setting.

Overall, PR guidelines for the inclusion and prescription of ST are insufficient. UK-based guidelines lack considerable detail for clinical practice and international guidelines are inconsistent. This conclusion is consistent with that of Garvey et al (180). Consequently, this lack of guidance may cause challenges when programming, prescribing, and delivering ST in PR. An adequate level of detail should be provided in guidelines to ensure PR services and practitioners have the guidance and information needed to appropriately prescribe ST to patients within their programmes.

Table 6. ACSM strength training prescriptions for healthy 'adults' and 'older adults' (235)

	Adults	**Older Adults**
Frequency	2-3 days per week	2 or more days per week
Intensity	a moderate to vigorous intensity of 60-70% of 1-RM for novice to intermediate, and a vigorous to very vigorous intensity ≥80% 1-RM for experienced strength trainers	a light intensity of 40-50% of 1-RM for beginners, progressing to a moderate intensity of 60-70% of 1-RM. If 1-RM is not measured, intensity can be prescribed between a moderate (5-6) and vigorous (7-8) score on the modified Borg RPE scale ranging from 0-10
Type	major muscle groups and multi joint resistance exercises are recommended, using a variety of exercise equipment (e.g., weight machines, free weight, or body weight exercises)	can include equipment such as free weights, weighted machines, resistance bands, and/or weight bearing/bodyweight exercises
Volume	2-4 sets of 8-12 repetitions	8-10 exercises per session involving major muscle groups, with 1 or more sets of 10-15 repetitions per exercise
Progression	gradual increase in load/resistance, repetitions, sets, and/or frequency	gradual increase in load/resistance, repetitions, sets, and/or frequency

To conclude, PR guidelines by respiratory and healthcare organisations state SA and ST should be included. However, there is a significant lack of guidance for practical application, with very limited PR specific resources providing enough guidance, advice, and recommendations on how it should be implemented, used, and delivered within PR programmes and to COPD patients. If guidelines and standards are lacking in such detail, then it could be challenging for services to determine exactly how they are supposed to achieve and comply with them. One example is the RCP PRSAS (153-155), which aims to demonstrate

quality within PR, however their standards of practice related to SA and ST are limited. This puts into question how quality is being determined, as it is not clear what constitutes high quality SA and ST within PR.

Overall, UK guidelines are limited and vague; and international guidelines are diverse and inconsistent, lacking sufficient detail to support the prescription of ST and the assessment of strength in COPD specific populations and PR settings. Future research needs to focus on isolating optimal ST prescription strategies. However, acknowledgement of real world factors is needed, for example consideration for patient needs, varying abilities and experience, and service variation (e.g. setting and equipment). The development of more detailed and practical guidelines would be beneficial, along with accessible and easy to use resources to aid individualised prescriptions. If published PR guidance is insufficient, then it begs the question of how services are prescribing ST and assessing muscle strength in their programmes.

2.5 Review of Strength Assessment and Strength Training Provision in PR Services (UK and International)

As discussed above there are many published guidelines which provide evidence, recommendations, and standards for PR programmes. All guidelines recommend the inclusion of ST, and most acknowledge the significance of muscle strength and its assessment within PR. However, guidance is limited, vague, and inconsistent. Therefore, it is reasonable to question the extent of compliance and fulfilment by PR services and providers.

A systematic review conducted by Desveaux et al. (377) investigated the international provision of PR, comparing structure and delivery across a variety of countries. The review took place in 2013 and identified surveys from seven English-speaking countries, including the

UK (378), Ireland (379), Sweden (380), America (381), Canada (382), Australia (383), and New Zealand (384). It focused on characterising a broad range of PR components e.g., staffing, structure and delivery, programme components, referral sources, outcome measures, and programme follow-ups. It found that the components provided in PR were similar, irrespective of country, but outcome measures demonstrated variation. These results provide a useful snapshot of PR implementation internationally and overall it concluded that surveys were consistently well-designed, with a low risk of questionnaire and sample bias. However, the authors note that not all included surveys provided data relating to each category of investigation, making overall comparisons impossible. One limitation of the review included brief and limited descriptions of the exercise components. It reported exercise was a principal component of PR programmes across six surveys/countries, but the specific type of exercise varied. Two surveys reported ST as the primary component, two reported AT, and two did not describe the nature of the exercise intervention. Investigation and extraction of additional detail regarding ST delivery and prescription was not included. Desveaux et al. (377) did discuss outcome measures used in PR programmes, but did not comment on SA. Investigation was limited to functional walking tests, and measures of HRQoL and psychological wellbeing. Due to the review's broad focus on multiple PR components, a comprehensive overview of SA and ST in PR was likely beyond its scope.

In response to this, a review will be presented in this thesis summarising, discussing, and comparing surveys of PR provision, specific to the prescription of ST and assessment of muscle strength. A clearer picture is needed regarding these PR components, as well as how much information is collected and reported in published surveys. Since Desveaux et al's (377) systematic review, new and updated surveys have been published. To the researcher's knowledge, a review focusing on SA and ST in PR has not been conducted before. Within the

wider literature review of this thesis, 17 PR surveys were identified. This included all seven surveys from Desveaux et al's review (377), and 10 new articles, of which seven were more recent publications (164, 166, 385-389), and three were from new countries, specifically Scotland (390), Norway (391), and one spanning Europe and North America (361). There were no strict inclusion and exclusion criteria for this review. Surveys were included if they reported data on the provision of PR programmes within English-speaking countries. No surveys were excluded, as the omission of information about the use of SA and ST is still valuable to know. Of the 17 included surveys, 15 investigated the characteristics and content of PR programmes as a whole, and two specifically investigated PR exercise prescription practices. The two main areas of focus were:

- Is muscle strength assessed in PR? If so, how is it assessed?
- Is ST included in PR programmes? If so, how is it prescribed?

As this thesis is concerned and localised to PR in England and the UK, the seven surveys conducted in these locations will be presented and discussed separately (164, 166, 378, 379, 385, 389, 390). This is because the findings are more relevant and applicable to the research conducted in this thesis. However, it is also important to acknowledge and represent the provision of PR in similar countries for comparison purposes. The 10 international PR surveys will be discussed and compared to those from the UK. Countries include Sweden (380), Norway (391), America (381, 386), Canada (382, 387), Australia (383), and New Zealand (384, 388), and one survey spanning Europe and North America (361).

2.5.1 Provision in UK PR Services

In total, seven surveys have been conducted within the UK (England, Wales, Scotland, and Northern Ireland), either in separate countries or combinations. **Table 7** presents the details

extracted from each UK survey. Earlier surveys (378, 379, 389) did not address SA or ST in PR programmes, however over time more information has been collected. The collection of such data appears in the first and second NACAP PR audits (166, 385). They both address SA as an outcome measure, and report prevalence of ST in PR programmes, along with a basic overview of prescription methods. However, the level of detail collected and reported overall is limited and mainly restricted to dichotomous (yes/no) data of each component's prevalence. This is the same for the Scottish PR action group survey (390). In the most recent NACAP PR audit published in 2020 (163), more questions were added, allowing for further information about SA and ST to be collected and reported. NACAP PR audits are led by the RCP and are mapped against the BTS quality standards of PR in adults (141), allowing practices to be evaluated against recommendations and quality indicators. The addition of these questions is likely in response to evolving research, guidelines, and recommendations in these areas.

The most recent NACAP PR audit (163) collected data from 144 PR services in England (*n*=132), Wales (*n*=4), and Scotland (*n*=8). Subsequent discussion of results will be related to PR services located in England only (*n*=132). Regarding SA, use has increased over the last eight years. The NACAP PR audits published in 2015 (385), 2018 (166), and 2020 (163), reported 22%, 31%, and 41.7% of PR services recorded muscle strength at assessment, respectively. These increases are likely attributed to increasing evidence supporting its utility, particularly PR guidelines and recommendations by the BTS for its role in exercise prescription and outcome measurement (33, 141). In the most recent NACAP PR audit (163), 55 out of 132 (41.7%) PR services in England reported measuring muscle strength, with multiple methods of assessment reported. The most used SA was the 5repS2S (49.1%, n=27), followed by 1-RM (40%, n=22), 10-RM (21.8%, n=12), dynamometer (18.2%, n=10), and strain gauge (1.8%, n=1). These results provide insight into SA use in PR, but also demonstrate no clear or

consistent method of assessment across services. This could be a consequence of the limited and insufficient guidance for use and application in clinical practice, as previously discussed above. Further details regarding the implementation and use of SA would provide a clearer picture, such as the body area and muscle(s) targeted for assessment, timepoint of conduction within a PR programme, and clear stipulation of purpose (i.e., outcome and/or prescription). However, this level of detail was likely outside the scope of the audit.

Regarding ST, information reported included the number of services which included ST, the type of equipment provided, and how ST intensity was individually prescribed. Results revealed, 100% (*n*=132) of PR services in England offered ST in PR programmes and 94.7% (*n*=125) individually prescribed it. Of those which prescribed ST, methods varied, with 79.2% reporting use of Borg breathlessness or perceived exertion scores, 28.8% a measurement of 1-RM or strength, and 11.2% 'other'. Unfortunately, it does not elaborate on what 'measurement of 1-RM or strength' is, which 'Borg breathlessness or perceived exertion scores' were used, or what the 'other' methods of prescription were. It also reports the equipment provided for ST, with the most used being free weights (97.7%), followed by resistance bands (47.7%), and then weighted machines (22%). These results of the 2020 NACAP PR audit provide useful information about ST prescription, but details on other acute training variables are missing, such as exercise volume, rest periods, exercise progression, type of ST exercises, and body area/muscle(s) targeted. This level of detail is likely outside the scope of this audit as it focuses on PR provision as a whole, which provides an explanation for these shortcomings. As shown in **Table 7**, when the 2020 NACAP PR audit (163) is compared to those which preceded it (166, 385), the inclusion of ST in PR exercise has remained constant, with 99-100% of participating services reporting inclusion. Whereas the use of a 1-RM for ST prescription

purposes has increased marginally from 17% in 2015 (385) to 28.8% in 2020 (163), but still remains low.

Instead, the primary method of ST prescription still remains a Borg breathlessness or perceived exertion score, but it is not clear exactly how this method effectively prescribes ST intensity, as it is not a prescription strategy used in COPD research (181, 227, 317-320) or one recommended in UK PR guidelines (33, 36, 141, 151, 154). The ACSM guidelines for ST prescription in older adults do state that if %1-RM is not possible, then a moderate intensity of 5-6 Borg RPE on a scale of 0-10 can be used (235). However, they do caution the universal application of such scales as there can be large variability when used with healthy individuals and patient populations (392). Borg breathlessness/RPE scales are subjective ratings of an individual's feelings during exercise, and therefore can be influenced by psychological factors and environmental conditions (235). Intensity is a key determinant of outcomes for ST programmes, as training below a minimum threshold intensity will unlikely result in sufficient challenge to the muscles to allow for physiological adaptions to fitness and strength (393). Therefore, relying solely on patient-reported symptoms to prescribe ST is unlikely to elicit effective exercise prescription. Overall, future research is needed to investigate and gain a clearer picture of ST prescription and SA use in PR in England.

Table 7. Strength assessment and strength training provision in UK PR (surveys)

	Country and Time frame	Survey Aim/Focus	Sample/Population	Is ST included in PR programme?	ST Prescription Details	Is peripheral muscle strength assessed in PR programme?	SA Details.
Yohannes (2004) PR programmes in the UK: a national representative survey (378)	UK 2001	Surveyed UK hospitals to assess provision of PR programmes and their content size, duration, and staffing.	190 physiotherapy departments within acute hospitals. 171 (90%) responses were received, of which 68 centres (40%) ran a PR programme.	Not mentioned.	N/A	Not mentioned.	N/A
O'Neill (2008) PR and follow-on services: a Northern Ireland survey (379)	Northern Ireland 2007	The aim of this survey was to determine the characteristics of the different components of the patient pathway, that is, PR programs, ongoing exercise facilities, and support networks in Northern Ireland.	23 PR programs, which are based within four health boards.	Not mentioned.	N/A	Outcome measures used in the PR programmes: Grip dynamometry = 9% (n=2/23)	No additional information provided.
Yohannes (2011) PR in the UK (389)	UK Mar-May 2008	Audited the UK provision of PR for COPD and the quality of the programmes provided against national standards.	Data were received from 239 acute units, a trust participation rate of 98%.	Not mentioned.	N/A	Not mentioned.	N/A
Steiner (2015) PR: Time to breath – NACAP organisation audit report (385)	England and Wales Jan-July 2015	To disseminate the results of the national audit of the resources and organisation of PR services in England and Wales 2015.	Audit data were received from 224/230 programmes (154/158 providers).	What modes of exercise training are offered (n=224)? ST using free weights = 99.6% ST using multi-gym equipment = 30%	How is ST prescribed (n=224)? Not done = 6% Best guess = 31% Borg perceived exertion scores = 70% 1RM = 17%	How is muscle strength measured (outcome) (n=224)? Not done = 78% Isometric = 5% 1RM = 14% Other = 7% 22% overall (multiple responses possible)	No additional information provided.

Scottish PR Action Group (2017) PR Survey (390)	Scotland 2015/16	This survey was driven by the lack of knowledge surrounding current delivery of PR services.	14 regional health boards, but only 11 provided a response/data.	Resistance exercises included in exercise (n=14): Yes = 71.4% (n=10) Unknown = 21.5% (n=3) N/A = 7.1% (n=1)	No additional information provided.	Muscle strength included as an outcome measure (n=14): Yes = 14.3% (n=2) Mixed = 14.3% (n=2) No = 42.9% (n=6) Unknown = 21.4% (n=3) N/A = 1 (7.1%)	No additional information provided.
Steiner (2018) PR: an exercise in improvement NACAP organisation audit data analysis and results (166)	England and Wales Jan-April 2017	To disseminate the results of the national clinical and organisational audits of PR services in England and Wales 2017.	Audit data was received from 187 services (out of the 195 identified) and 592 sites, in England and Wales.	What mode of exercise training is offered during rehab (n=187)? Resistance training = 99% (n=185)	Is resistance training individually prescribed (n=185)? No = 10% Measure of 1RM or strength = 19% Borg or perceived exertion scores = 71%	Is muscle strength measured at assessment (n=187)? Yes = 31% No = 69%	No additional information provided.
Singh (2020) NACAP organisational audit 2019 (164)	England, Wales, and Scotland July-Sept 2019	Aims to provide an increasingly comprehensive picture of PR care and service provision provided across the country.	228 services were identified, of which 144 (63.2%) participated and fully completed the audit. A total of 132/196 (67.3%) in England, 4/18 (22.2%) in Scotland and 8/11 (72.7%) in Wales Only England data presented here.	Is resistance training offered during the PR programme (n=132)? Yes = 100%	What resistance training equipment is provided (n=132)? Free weights = 97.7% Bands = 47.7% Weight machines = 22% Other = 7.6% Is resistance training individually prescribed (n=132)? Yes = 94.7% (n=125) If yes, how is it prescribed (n=125)? Borg breathlessness or perceived exertion score = 79.2% Measurement of 1RM/strength = 28.8% Other = 11.2%	Is muscle strength measured at assessment (n=132)? Yes = 41.7% (n=55) No = 58.3%	If yes, how is muscle strength assessed (n=55)? Dynamometer = 18.2% Strain Gauge = 1.8% 1-RM = 40% 10-RM = 21.8% 5repS2S = 49.1%

Note. Colour Code: green = provides information, yellow = limited detail provided, red = not mentioned/addressed or not applicable (N/A)
Note. PR = pulmonary rehabilitation, ST = strength training, SA = strength assessment, BTS = British Thoracic Society, ATS = American Thoracic Society, 1-RM = one repetition maximum, 10-RM = 10 repetition maximum, 5repS2S = 5 repetition sit to stand,

2.5.2 Provision in International PR Services

Regarding the inclusion and prescription of ST, the majority of international PR surveys either did not address it (381, 384, 388, 391) or the amount of data collected was minimal, for example some only reported the inclusion of upper and lower extremity training (380, 382) or basic equipment used (361, 383). All details extracted from each international survey are available in Appendix E. Two surveys have been published that focus specifically on PR exercise prescription practices: one in America/US (386) and the other in Canada (387). Garvey et al. (386) conducted a survey in America/US, which included 371 PR providers (30.2% response rate). Of these, 325 providers gave data on ST, stating 93.5% (*n*=303) prescribed ST, of which 75.9% included weight lifting, 69% elastic bands, 57.1% weighted machines, and 41.6% bodyweight resistance exercises. In addition, the survey asked about general exercise intensity prescription and progression. Among the pre-determined answer options were 'Borg dyspnoea 10-point scale' and 1-RM. The most utilised method for exercise intensity prescription and progression was the Borg 10-point scale (over 80% of PR providers). Use of 1-RM was very low, with 4.6% and 5.3% of PR providers using it to prescribe intensity and progression, respectively.

The second survey was conducted by Dechman et al. (387), which examined the use of exercise testing and prescription practices in Canadian PR programmes. The survey sample included 112 PR programmes (83% response rate). It reported 93% (*n*=104) of these PR programmes included ST, of which 97% included ST for lower extremities, 100% for upper extremities, and 68.3% for core. Additional questions included if a training protocol was used (i.e., number of sets and reps), if exercise testing was used to establish a ST prescription, and if so, what exercise test was used. Of the PR programmes which included ST (n=104), 60% (*n*=62) used a training protocol and 30.8% (*n*=32) used an exercise test. The type of exercise

test to prescribe ST varied. About half (*n*=14) selected 'patients ability to life weight 10 times', and about half (*n*=12) selected 'other'. Elaboration of 'other' was not provided in results. Use of a 1-RM measurement was also reported, however frequency was very low and protocol varied widely, for example 3-RM (*n*=6), 10-RM (*n*=5), and 1-RM (*n*=3). Note, answers were not exclusive to one option.

When the results of these two surveys are compared to the 2020 NACAP PR audit (164), ST inclusion is comparable, with 100% of PR services in England including ST verses 93% in America and Canada. Results are also similar for prescription of exercise intensity, with the majority of PR services in England and America using a Borg breathlessness scale measurement. Use of this method is not known for Canada, as it was not included as a pre-determined answer option. The use of SA for prescribing ST was reported by all, with a similar number of PR services in England (*n*=36/125, 28.8%) and Canada (*n*=32/104, 30.8%) using a measurement of 1-RM or strength, followed behind by America (*n*=15/326, 4.6%). Lastly, regarding equipment, free weights are used the most in England and America, followed by resistance bands and then machine weights. However, the proportion of PR providers which use weighted machines in America (*n*=173/303, 57.1%) is much higher compared to England (*n*=29/133, 22%). Equipment provision was not addressed within the Canadian PR survey.

Regarding SA, only three international surveys addressed use in PR. All SA details extracted from each international survey are available in Appendix E. As discussed above Garvey et al. (386) and Dechman et al. (387) both report SA use in terms of ST prescription. However, as both surveys are only concerned with exercise prescription, data was not collected on PR outcome measures. The only other survey which reported SA as an outcome measure in PR was Wadell et al. (380). This survey investigated the availability and content of hospital-

based PR programmes in Sweden, with 46 out of 70 hospitals offering this intervention. Of these 46 hospitals, 43% (*n*=20) measured lower limb muscle strength and 17% (*n*=8) upper limb muscle strength. In regard to percentage, this is similar to England, which reported 41.7% (*n*=55/132) assessed muscle strength, however this result does not indicate which extremities are measured (164). One limitation of this Swedish survey is the inclusion of only hospital-based PR programmes, lacking possible representation of other centre-based programmes. This means results can only be generalised to hospital-based PR as it is not known if or how muscle strength is assessed in other settings.

Overall, data available from these international surveys is lacking and limited. Most report the inclusion of ST in PR, but additional details regarding its prescription is missing. Moreover, the majority of surveys do not address SA in PR, particularly as an outcome measure. This lack of attention could be due to the diverse and limited guidance available for PR. Most international surveys reference American respiratory organisations, such as the ATS and ACCP/AACVPR. However, as presented above, the associated PR guidelines are guilty of inconsistencies and limited information. This could explain the lack of data collected about SA and ST in PR programmes. Future research should focus on these specific components of PR, particularly investigation of provision and application across these international countries.

To conclude, although surveys carried out in the UK provide more insight compared to international surveys, a clearer picture of SA and ST use in UK-based PR is needed. Further research building on these previous surveys is warranted to address these gaps, for example conduction of a survey which focuses on the delivery and prescription of ST, and the use of SA methods in PR clinical practice. A clearer picture of use and application will show the methods

utilised and how they are being used by PR services, as well as help highlight areas which can be targeted for improvement and further investigation.

2.6 Thesis Rationale

Reduced skeletal muscle strength is a commonly reported impairment of COPD, and as such has important clinical and prognostic value within this patient population. Consequently, the assessment of muscle strength is encouraged and recommended due to its numerous benefits, including identification of muscle weakness, prescription of individualised training, and evaluation of intervention effectiveness. The inclusion of SA in clinical evaluations has received increasing support within the literature and use within PR has slowly risen in recent years. However, the majority of PR services in England do not assess muscle strength in any capacity, and of the services which do, detail and understanding regarding its use is lacking. Additionally, ST is an effective strategy and intervention to combat muscle weakness in COPD and is strongly and widely recommended within PR programmes. However, guidance for its inclusion and application is lacking, with limited information provided on delivery and prescription within a PR setting. Published PR guidelines are vague and inconsistent, and research investigating PR provision lacks sufficient detail. Presently, there is no clear picture of how ST is included in PR. Overall, this begs the question of how PR services are prescribing ST and assessing muscle strength.

As shown throughout this literature review, SA and ST are encouraged and recommended components within PR. However, research and recommendations for clinical practice are limited and inconsistent, which could make adaption and implementation into real world practice challenging. Research typically does not consider the feasibility of its methodology and results, and how it will be integrated and applied into the clinical context -

as what is conducted and concluded within a research study setting does not necessarily reflect the practical reality and variance of PR practice. Considering this, it is not surprising that guidelines for SA and ST in PR are vague and unclear. If such guidelines are based on the best evidence currently available, then it could be argued that the evidence is not sufficient. This puts into question how useful the research findings and recommendations are if they cannot be successfully applied within real-world PR. Evidence and research typically informs practice to ensure safe and effective care for patients, however, there must also be some understanding of the context and world in which it is being applied. Therefore, it would be beneficial to conduct research which explores SA and ST within the specific context of clinical practice and gain insight from the stakeholders involved (i.e., practitioners and patients). There is a need for research to consider the feasibility and clinical application of SA and ST within PR. Therefore, by exploring the perspectives and the reality of clinical practice and gaining a better understanding of this it could help inform future research and lead to more feasible recommendations.

If future research wants to increase and improve SA use and ST prescription in PR, it is essential to first investigate what PR services are actually doing, how they are doing it, and what factors influence this in real world practice. Once a better understanding is gained, recommendations and considerations can be outlined with the aim of improving future provision and implementation. This thesis aims to provide a clearer picture of SA and ST in PR in England, as well as gain an understanding of influential factors and barriers faced by services that determine and impact use and non-use.

Thesis aims:

- To explore and understand the use of SA and ST in PR clinical practice

- To explore and identify barriers and influential factors impacting the use of SA and ST in PR clinical practice
- To provide recommendations and considerations for improvements in PR clinical practice and future research

Chapter 3. A qualitative exploration of practitioner perspectives and experiences of strength assessment and strength training in pulmonary rehabilitation

3.1 Chapter Overview

This chapter explored practitioner perspectives and experiences of SA and ST in a PR programme, with a particular focus on use, impact, and influential factors. A qualitative study design was taken using semi-structured interviews, and analysed using reflexive thematic analysis. Eleven practitioners took part who had a role working in a PR service. Five themes were constructed: 1) Strength training is important, 2) Is assessing patient muscle strength important? 3) Challenges for pulmonary rehabilitation and strength assessment, 4) Considerations and support for patients, and 5) Practitioners need for further training. These findings show that practitioners have positive views and opinions of SA and ST in PR, and recognise the benefits they offer services and patients. However, a number of barriers were identified, including uncertainty of SA in current practices, the need for staff training, physical and psychological limitations of patients, and service-related challenges (e.g., limited time and equipment). These findings emphasise the need for these factors to be considered in PR clinical practice when implementing and using a SA, and prescribing and delivering ST.

3.2 Introduction

Muscle weakness is a common consequence of COPD (93, 228), and as such exercising with the purpose of building and maintaining muscle strength is an effective and supported intervention for this patient group (181, 317-320). Therefore, ST is strongly recommended

within PR programmes, with UK (36, 141, 151, 154, 394) and international (53, 147, 148, 225, 235, 373, 375) guidelines advising inclusion. In the UK, a key detail of this recommendation is the prescription of individualised and progressive ST. Unfortunately, guidance regarding how to achieve this is vague and limited. One useful and relevant tool is SA, with methods allowing for exercise intensity and load to be tailored to each individual (228, 230). Additional benefits of SA include identification of muscle weakness, which provides insight into the progression and prognosis of COPD, and evaluation of intervention effectiveness, such as PR (228, 230). A number of resources support the assessment of muscle strength for COPD (228, 230-232), along with PR guidelines recommending the inclusion in programmes – both within the UK (141, 151, 154) and internationally (53, 147, 225, 235, 373, 375).

As outline in Chapter 2 (page 94), literature has investigated the provision of SA and ST in PR services across the UK (164) and other western countries (380, 383, 386, 387). Data was collected using survey methods, providing vital information about prevalence and frequency. Within the UK, the NACAP audit programme has published and reported valuable data on PR provision within England (164, 166, 385). Over the last eight years the use of a SA has gradually increased in clinical practice, however the majority of services (58.3%) are still not assessing patient muscle strength as an outcome measure, with even more services (71.2%) not utilising it for exercise prescription purposes (164). Despite this, ST is a core component of PR programmes with all participating services reporting inclusion (164).

These surveys deliver an overview of utility, providing information on prevalence, guideline adherence, and changes in patterns of use. However, there is a lack of insight and context into why services use or do not use SA. As outlined in Chapter 2 (page 51), there is extensive literature evaluating the efficacy, validity, and reliability of different SA methods for

COPD and in response to exercise interventions (e.g., ST). However, there is a noticeable lack of research investigating and evaluating implementation, use, and feasibility in PR. Multiple reviews have discussed the advantages and limitations of SA methods, commenting on the suitability in clinical settings and aspects which need consideration, such as time, cost, equipment, and technical skill (228, 230-232). However, there is limited evidence explicitly aiming to explore and investigate factors which impact and influence the use of SA and ST in PR clinical settings. Barlow et al. (298) conducted a study in England, which assessed the impact of a 7-week PR programme on COPD patient outcomes, with a tertiary purpose to assess the feasibility of incorporating individually prescribed 1-RM training loads into the existing ST programme. The findings evidenced an effective PR service, with statistically significant increases reported in 1-RM strength. The authors concluded that basic strength exercise programming and assessment are feasible in PR services and should be implemented to maximise patient outcomes. However, beyond the measure of muscle strength, no further evaluative criteria was reported assessing feasibility in this PR setting. Additional information outlining how it was feasible would aid future application in other PR services, such as how it fits into the existing PR infrastructure, how it impacted stakeholders involved, what challenges were faced, and what factors influenced its execution. To date, research has been limited to quantitative methods focusing on SA and ST efficacy and prevalence. However, this only provides an overview of use.

To the researcher's knowledge, a qualitative study exploring SA and ST use in UK PR clinical practice has not been conducted. Research in similar areas and contexts of COPD and PR have been published, which provide some understanding and insight into exercise and the delivery of training programmes (215, 216, 219, 395-397), and the implementation of treatment devices and assessments (398-401). One qualitative study of 11 HCPs explored the use of

behaviour change interventions in UK cardiac rehabilitation and PR, reporting it to be an underdeveloped component (402). HCPs did not perceive themselves to have the competence or skills to deliver effective behaviour change interventions in routine practice, and did not have access to training programmes to remediate this knowledge gap and optimise delivery. The authors emphasised that training needs to include practical utility to facilitate translation into practice. Another qualitative study, conducted in Norway, examined factors which influenced clinicians (*n*=8) use of written action plans in COPD self-management support (403). Findings revealed a number of influential factors, including knowledge and skill, motivations, social influences, and environmental context and resources. The authors state that the identification and understanding of these factors can be used to guide future initiatives to promote targeted self-management support and tackle the gap between what is advocated in clinical guidelines and what is available in routine settings. Both these studies provide value insight into the application of COPD-related interventions, emphasising the need for application strategies to have practical utility in PR clinical practice.

Relevant research has also been conducted in other healthcare areas, such as the delivery of an exercise programme for low back pain prevention in adults (404), provision of cardiac rehabilitation (405), and the clinical implementation of a patient needs assessment tool for interstitial lung disease (406). In particular, Dennet et al. (407) conducted a mixed methods study investigating exercise in oncology rehabilitation programmes in Australia. The study consisted of two phases: 1) a quantitative survey describing provision and 2) follow-up interviews with senior clinicians (*n*=15). Despite evidence supporting oncology rehabilitation, there were only a few programmes available. Challenges to implementation were identified including limited awareness of exercise benefits and broader community and organisational barriers (e.g. funding, staffing, programme promotion, and location). The mixed methods

approach added richness and depth to the survey data and helped provide perspectives on how oncology rehabilitation was run.

Over the years the acceptance of qualitative research within healthcare has increased, with support shown for its usefulness and contribution (408-410). These methods are recognised as playing a crucial role in improving the management, planning, and provision of healthcare and services. They are widely used to inform and design healthcare interventions, and shape decisions made by practitioners, managers, policy-makers, and healthcare organisations (411). Qualitative evidence is now used within the development of clinical practice guidelines by identifying clinical questions, supporting recommendations, and considering barriers and facilitators of implementation (410, 412). Such evidence can provide rich detail and understanding within healthcare and can be used to assess a multitude of facets. Specifically, the values and preferences of relevant stakeholders, the acceptability of an intervention, and its feasibility (412). Therefore, a qualitative approach will be used to further explore the use and impact of SA and ST in PR, providing additional understanding and insight. This study was conducted to examine practitioner perspectives and experiences of SA and ST in PR.

3.2.1 Research Aims

This study aims to explore:

- The use of strength assessment and strength training in a pulmonary rehabilitation programme
- The impact of strength assessment and strength training on practitioners and their patients

- Factors which help and hinder the use of strength assessment and strength training in pulmonary rehabilitation

3.3 Methodology

3.3.1 Study Design

A qualitative study design was chosen and data was collected using semi-structured interviews, which is the format typically used (408, 413) when investigating healthcare and service provision (414). A semi-structured format were deemed appropriate due to its guided yet flexible structure, allowing the delivery and order of questions to follow the natural conversation and input from the participant (415, 416).

One-to-one interviews were chosen over other data collection methods, such as focus groups, because they allow for in-depth exploration and discussion, as well as limiting the influence of other participants (417, 418). This is particularly important within a healthcare service where there is a hierarchy of staff, both in terms of role and experience. In focus groups, there is a risk that some participants may feel uncomfortable voicing their experiences and opinions in the presence of others, particularly those deemed in a position of power or authority (e.g., staff in higher positions or with more experience). Their responses may be altered or they may feel unable to truly express their views, especially those that may shed a negative light on the organisation, service, or other colleagues. Furthermore, a key aspect of focus groups is their use for examining interpersonal communication, group interactions, and cultural and social dynamics (419) - which was not a focus of the current study. One key pragmatic influence was the feasibility and practically of getting the PR team together at one time point. Most practitioners had varying work schedules and duties, with PR sessions and clinics operating at

differing times. Therefore, organising individual interviews allowed for adaption around participant availability.

3.3.1.1 Initial Familiarisation Activities for Study Design

Prior to the conduction of the qualitative studies, informal observations were carried out to introduce the researcher to the structure and organisation of PR, particularly within the participating PR service. These familiarisation activities did not form part of the formal research process, however initial observations and casual conversations with practitioners and patients provided the researcher with a better understanding and a starting point for the planning of this PhD project and the qualitative studies. Specifically, the researcher attended and observed a PR session at each site offered by the participating service, where preliminary thoughts and observations were noted. Such notes outlined observations related to the PR setting, environment, practitioners, and patients. Examples included differences between PR sites, use of SA and ST, structure and delivery of the exercise programmes, practical challenges, and practitioner-patient interactions. Importantly, through these familiarisation activities, it became apparent that the stakeholders involved had a lot to contribute and say about this subject matter. This emphasised that further exploration and understanding was required about SA and ST in PR from the perspectives of those involved, and that this was needed before any research took place which included changes and interventions in PR clinical practice. These initial and informal activities led to the decision to conduct qualitative interviews and helped direct the development of the interview questions and guides.

3.3.2 Philosophical and Theoretical Underpinnings

An important initial step when planning and conducting qualitative research is consideration of the theoretical and philosophical positions from which the research will be

undertaken. Such positions influence and inform the research process, such as the study design, data collection method, and analytical approach (408). Consideration is needed for what constitutes the nature of reality (i.e., the ontological position) and the nature of knowledge (i.e., the epistemological position).

3.3.2.1 Ontological Positions

Ontology refers to theories about the nature of reality (i.e., what it is that we think we can know). A key ontological debate concerns whether reality exists independent of human thinking, understanding, and practices, or whether reality cannot be separated from such things, meaning any knowledge gained is always going to reflect human perspectives (408, 413). There are various ontological positions, often described as ranging along a 'continuum' (413). The three main positions are realism, relativism, and critical realism.

Realism, commonly described as naïve realism, is often associated with traditional science, underpinning quantitative methods (420, 421). It views reality as singular, external, and entirely independent of human practices and the individual who is attempting to understand it (422). It assumes there is a knowable world, and reality can be observed directly, accurately, and objectively – it is waiting to be uncovered and discovered (421, 423). At the opposing end of the continuum is relativism. This position argues that reality is the product of human practice and understanding, and does not support the idea of a singular, external, and objective reality (423). Instead it argues the existence of multiple realities; that reality is bound within the confines of these different constructions, with the world only knowable through the human mind (413, 424). Lastly, critical realism can be understood as a combination of realism and relativism. It retains the idea of a true and knowable world, but this world sits behind the subjective and socially influenced knowledge that a researcher can access (420, 421). It does

not support the idea of multiple realities, but it does conceptualise different perspectives, interpretations, and representations of this singular reality or truth (423).

3.3.2.2 Epistemological Positions

This branch of philosophy is concerned with theories about the nature of knowledge and knowledge production (408). A basic distinction between epistemological positions is whether reality is *discovered* through the process of research, or whether it is *created* (413). Three epistemological positions are discussed: (post)positivism, constructionism, and contextualism.

Postpositivism evolved from the previously dominant scientific approach, positivism. Positivism assumed reality to be objective, and that objective knowledge could be generated through rigorous scientific methods (423). Postpositivism represents a refinement of this former position. It still supports the idea of objective and unbiased knowledge, but that reality is approximated and never fully known or determined (420). Constructionism, on the other hand, argues that knowledge of the world, and the ways in which we know it, are tied to the social world we live in (413). It does not support the idea that knowledge is an objective reflection of reality, with research practices *discovering* or *revealing* evidence, but instead that evidence is *produced* or *created* through the research process (413, 423). This position emphasises the importance of understanding people's interpretations and experiences of the world, and that research should attempt to comprehend meaning and significance from the perspectives of the people who live within it (408, 424). Lastly, contextualism is described as the middle ground between postpositivism and constructionism (423). This epistemological position views all knowledge as local, provisional, and situation dependent, contending that results will vary according to the context in which data is collected and analysed (421). Similar

to constructionism, it rejects the idea of being able to obtain knowledge without bias, and instead recognises influences and subjectivity do exist (413). However, it retains an interest in understanding truth, and maintains that results can be justified by being grounded in the data (421).

3.3.2.3 Ontological and Epistemological Assumptions of the Current Study

This study adopted a critical realist ontology and contextualist epistemological position. Most qualitative healthcare research operates within these intermediate positions as it is typically accepted that an external and independent reality does exist (e.g., biological mechanisms, disease presentation, and health organisations), but that understanding of this reality is dependent on accounts that are constructed using various tools and judgments which are ultimately subjective (408). PR can be argued as being a real and true reality - a healthcare service and programme with a specific and determined format. There are standards which dictate the general structure and content of programmes, meaning one service it is unlikely to drastically change their practices from one day to the next. A level of consistency is important to ensure patients receive the care and support they need throughout the programme duration. This research study is based within the context of PR, investigating SA and ST – which are practical and factual entities. Therefore, information regarding their application is likely to hold truth (e.g., what was done and how it was done). This study is seeking knowledge within one PR service, which is one reality shared by the practitioners working within it. However, the context in which practitioners experience, perceive, and understand this 'true' reality will likely differ depending on their subjective perspectives, experiences, biases, and backgrounds. Context is important in this study, as participants had to be contextually situated in order to have and provide the necessary knowledge. This study focused on people and objects (realism), but also considered perspectives and experiences (relativism), therefore a critical realist

position was appropriate, with emphasis on the contextual nature of how knowledge is created and produced.

3.3.3 Sample

3.3.3.1 Participants

The study sample was comprised of HCPs, specifically practitioners who worked in PR and delivered this service. The sampling technique was purposeful, with all prospective participants recruited through one local PR service.

3.3.3.2 Inclusion and Exclusion Criteria

The inclusion criteria specified all participants must be ≥18 years, willing to participate in a recorded interview, capable of making their own informed decisions, and able to speak and understand English. Participants must have worked in a role managing, running, or assisting in PR programmes, sessions, and clinics. The exclusion criteria specified anyone taking part in a conflicting study.

3.3.3.3 PR Service Context

The PR service ran a 7-week PR programme, with two sessions per week. In accordance with BTS guidelines (394), each session included one hour of group exercise, followed by one hour of education and support. This PR service had three sites, all of which took place in varying hired settings. Details of each PR site is presented in **Table 8.** PR site detailsGroup exercise was a circuit-based exercise class, which included a 10-minute warm up and a short cool down. The programme included 12 individual exercises (Appendix F), with 4 minutes allocated for each. Regarding exercise equipment, Site 1 had a range of dumbbells (1-12kg) and weight plates (0.5-5kg), and Site 2 had a limited range of dumbbells (0.5-3kg), a treadmill,

a stationary bicycle, and some weighted machines (e.g., a leg extension machine). Site 3 had no equipment available at the hired location, so the service supplied resistance bands, specifically TheraBands™ (yellow, blue, and red). Weights and resistance bands were typically used for upper body exercises.

Table 8. *PR site details*

Site	**Venue Type**	**Equipment**	**Exercise/ST Programme**	**Strength Assessment used?**
Site 1	Leisure centre (fitness studio)	Dumbbells: 4 x 2kg, 3kg, 4kg, 5kg, 10kg, 11kg, 12kg 2 x 6kg, 7kg, 8kg, 9kg Plates: 8 x 0.5kg, 1kg, 2kg 6 x 2.5kg, 5kg	See Appendix F and G.	Yes. Epley's 1-RM prediction protocol and equation (up to 10 repetitions maximum) (242).
Site 2	Community/church hall	Dumbbells: 2 x 0.5kg, 1kg, 1.5kg, 2kg, 2.5kg, 3kg	See Appendix F (excl. 'strength testing')	No
Site 3	Community centre hall	Resistance Bands: TheraBands (Yellow, Red, and Blue)	See Appendix F (excl. 'strength testing')	No

SA was not routinely performed within this service. However, following participation in a previous research study (298), Site 1 continued using a SA to prescribe optimal training load for the bicep curl exercise. This prescribed training load was then used in conjunction with a progressive ST programme, with a slow increase in repetitions and load over the 7-week period (Appendix G). The SA used was a predicted 1-RM calculation, using Epley's prediction protocol and equation (242). This involved the patient lifting a pre-selected starting weight (i.e.

about 10% of their bodyweight) as many times as possible. If they could lift the weight more than 10 times, then a heavier weight was lifted until it was within this repetition range (i.e. ≤10 repetitions). The final weight and number of repetitions were entered into Epley's formula, estimating their 1-RM. This was then used to prescribe a starting weight of 50% 1-RM, as per the ACSM guidelines (235). At the time of this current study, Site 1 used this SA for prescription purposes and as an outcome measure. Site 2 and Site 3 did not assess muscle strength. Overall exercise intensity and progression were monitored using the modified Borg RPE scale 0-10 (29) (see Appendix G). This PR service was an ideal recruitment site as it had experience including a SA in clinical practice, as well as PR programmes taking place in a variety of settings and environments.

3.3.3.4 Sample Size

Various approaches were reviewed when determining the sample size for this study. Consideration was given to previously published literature and guidance, such as qualitative research methodology (425) and numerical guidelines for data saturation (426). Braun and Clarke (425) have previously stated a small project has 6-10 interviews and a medium project has 10-20, as well as Guest et al. (426) reporting data saturation between 6-12 interviews (426). Furthermore, the study's own characteristics were considered, such as recruitment potential and study resources. Therefore, an estimate of 12 participant interviews was proposed.

3.3.4 Research Procedure

3.3.4.1 Recruitment and Study Process

Recruitment took place between 23rd June and 10th August 2020. A flow chart of the recruitment process is presented in **Figure 5**, Participants were recruited primarily at the PR service's virtual team meetings, and via an email sent on behalf of the researcher from the team

manager. Potential participants were given further details via the participant information sheet (PIS, Appendix H), and if interested were encouraged to contact the researcher, either by email, phone, or text. Once interest was registered, eligibility was screened using the inclusion and exclusion criteria. This was carried out either by phone or email and took no more than 5 minutes to complete. If eligible, informed consent was then obtained (Appendix I), after which details of the interview (e.g. date, time, and method) were arranged to suit the participant.

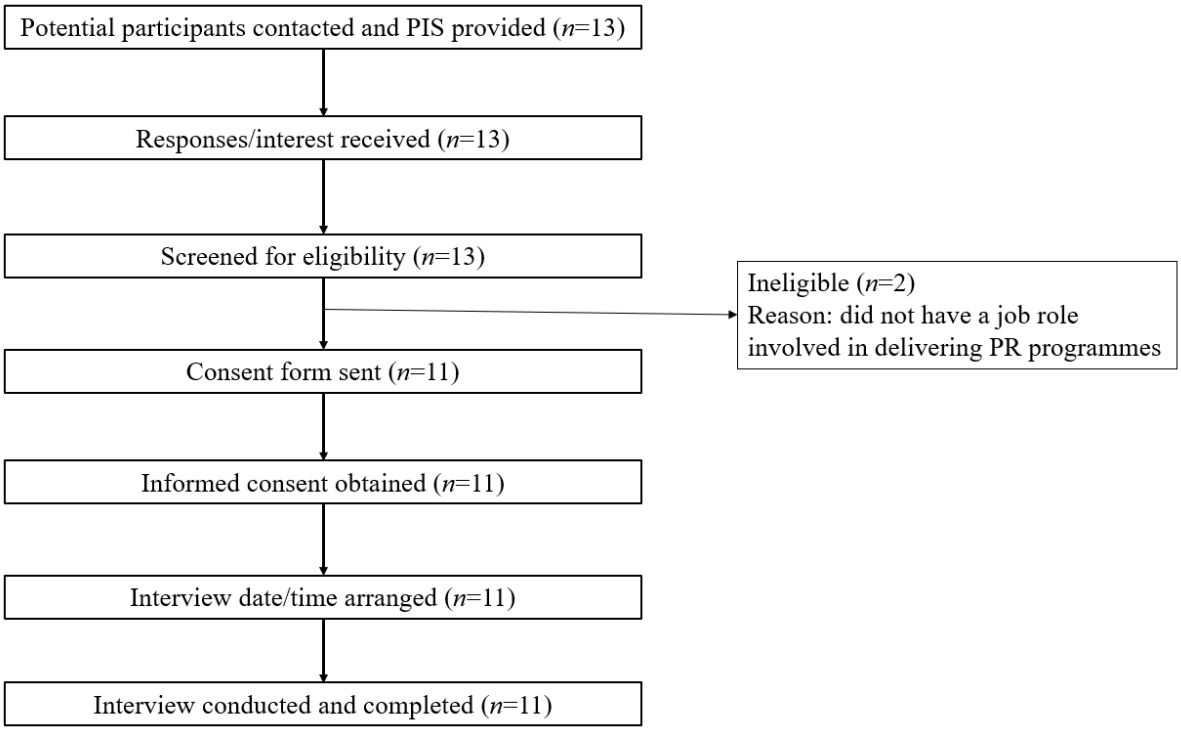

Figure 5. *Practitioner Recruitment Flow Chart*

3.3.4.2 Data collection

Data was collected between 6th July to 18th August 2020. All interviews took place via videocall, using either Zoom (Copyright © 2020 Zoom Video Communications Inc) or Microsoft Teams (Copyright© 2020 Microsoft). The average interview length was 51 minutes, ranging from 34 to 76 minutes, and was audio recorded using a Dictaphone (SONY ICD-PXA70 digital dictation machine). If required, notes were made during the interview.

Following each interview, the audio recording was downloaded from the device and stored in a safe and secure folder on the cloud-based platform 'Box' (Box, Inc), with access restricted exclusively to the researcher. The original recording was then permanently deleted.

3.3.4.3 Ethical Considerations

Ethical approval was granted by the London Bromley REC within the NHS and Health Research Authority (HRA) on 28th May 2020 (REC REF: 20/LO/0339; IRAS ID: 276749) (Appendix N). After which, approval was granted by the University of Essex ethics committee on 4th June 2020 (REF: ETH1920-1511) (Appendix O). Due to unforeseen circumstances, emerging as the Covid-19 pandemic, a non-substantial amendment was submitted to obtain the above approval.

There were no foreseen risks in this study, as the interview subject matter did not cover any sensitive topics deemed to cause psychological discomfort or distress. Potential burdens to participants included asking them to dedicate some of their time to the study in order for the data to be collected. However, by conducting the interviews via videocall it provided a level of convenience and ease for both parties. Furthermore, informed consent was obtained, ensuring each candidate had full awareness and understanding of their contributions. Participants were informed taking part was entirely voluntary, and that they were free to refuse answering any question or stop the interview at any time, no explanation necessary. The privacy of all individuals involved in this study was respected, ensuring participants were not personally identifiable. All information was kept strictly confidential and any documents containing identifiable information were encrypted and stored on a password protected laptop and the cloud-based repository 'Box' (Box, Inc). Participants were assigned a study ID number upon agreeing to take part, and contact details were collected only for the purposes of contacting

them about the study. Reporting of study findings and use of direct data extracts/quotations were all anonymised by assigning pseudonyms. If requested, participants will be given a study summary, and a summary report of the research findings will be submitted to the participating PR service and study funders. Additionally, this study will be considered for publication in relevant academic journals and presented at conferences, as appropriate.

3.3.5 Materials

A bespoke interview guide was created, outlining the content and structure of the topics and questions (Appendix J). This was developed from initial observations of PR programmes and informal discussions with PR staff. Additional inspiration was drawn from behaviour change frameworks and theoretical models, specifically the Theoretical Domains Framework (TDF) (427, 428) and the COM-B Model (429). The TDF is a synthesis of 22 theories of behaviour, clustered into 14 domains including knowledge, skills, social influences, and environmental context/resources (428). It was created to help identify determinants of behaviour in order to assess implementation problems and support intervention design (430). It provides a theoretical lens through which to view the cognitive, affective, social, and environmental influences on behaviour. The COM-B model is an behaviour system consisting of three components: capability (physical and psychological), opportunity (physical and social), and motivation (reflective and automatic) (429). This model was created to help inform intervention development within clinical practice, providing theoretically based guidance to facilitate the interview design process for particular circumstances and situations (431). Studies across healthcare systems have used these as a basis for their research (403, 432, 433), helping to explore and identify barriers and facilitators of behaviours, and understand and change clinical practice (430, 431). These frameworks can aid qualitative data collection and help

development of interview questions and guides to understand a target behaviour in context (430, 431).

To emphasise, the TDF and COM-B model were not used extensively or exclusively to develop the interview questions in this study, but instead provided a starting point to aid formulation of initial question topics and fuel further thinking. As stated by Atkins et al. (2017, pg. 2) "*implementing new practices and/or changing existing practices in organisations, services and systems require changes in individual and collective behaviour. Changing behaviour requires an understanding of the influences on behaviour in the context in which they occur*" (430). Therefore, the TDF and the COM-B model seemed appropriate and relevant to the research aims. This study aimed to explore the use and impact of SA and ST in PR, as well as the relevant barriers and facilitators within this healthcare area. Using a SA is not in itself a 'behaviour', however its implementation and use within clinical practice is likely to be influenced by similar factors outlined in the TDF and COM-B model. Therefore, the domains and components within each were reviewed to ensure all potential factors of influence were considered when developing the interview questions.

Topics within the interview guide revolved primarily around SA and ST in the PR service, specifically current use, implementation, experience, opinions, and perspectives. At the beginning of the interview, background questions were asked to build rapport (e.g., job role, working in PR etc). This allowed some time to ease the participant into the conversation and provided a natural segway into discussing more specific aspects of PR (i.e., SA and ST). In addition to the interview questions, basic demographic information was collected including age, gender, job title/role and length of time working in PR. Throughout interview development, regular consultation was employed with thesis supervisors to ensure key topics

were covered and research aims were addressed. Consultation and confirmation were also provided by the manager of the participating PR service, to ensure the interview questions were relevant and understandable. Once the interview guide was developed a pilot interview was conducted with a respiratory physiotherapist. Following this, minor adjustments were made, such as changing question wording and phrasing to aid comprehension and delivery.

3.2 Analysis

The interview audio recordings were transcribed verbatim, after which the transcripts were checked thoroughly against the recordings for accuracy. The transcripts were anonymised before analysis, such as names, locations, and other recognisable details that could compromise confidentiality. The qualitative data analysis computer software package NVivo (version 1.3) was used to support and organise the analysis process, with data analysed by the PhD researcher.

3.2.1 Selecting an Analytical Approach: Choosing Reflexive Thematic Analysis

The chosen analytic approach was Reflexive Thematic Analysis (TA). However, a number of other options were reviewed including Interpretative Phenomenological Analysis (IPA) and Grounded Theory (GT). TA was developed by Braun and Clark (434) and is widely used in qualitative research for healthcare, sport, and exercise (408, 435). In previous years TA was described as a "*poorly demarcated, rarely acknowledge, yet widely used qualitative analytic method"* (434) (pg. 1). The basis of TA (i.e. thematic coding) is commonly included within other analytical approaches, such as IPA and GT, yet was not recognised as a 'method' in its own right (434). Over time, TA has grown in popularity and is now accepted and widely discussed as its own distinctive analytic approach (413, 435). Many have assumed and

described TA as atheoretical – an approach which needs no theory; however authors Braun and Clarke prefer the term 'theoretically flexible' (423) (pg. 157). This distinguishes TA from the other approaches as it does not rely on pre-existing frameworks. This means it is more accessible and compatible with a wide variety of frameworks, such as critical realist ontology and contextualist epistemology underpinning this study. Through this theoretical freedom, it provides a flexible and useful research method, suitable for a wide range of research questions, data collection methods, and sample sizes (413).

Comparatively, IPA (436, 437) is a theoretically bound and 'ready-made' methodology, with strong roots in phenomenological epistemology – the study of experience (438). It is similar to TA in that it has a thematic orientation, but differs due to its additional idiographic focus, which involves detailed attention to analysis *within* cases before developing themes *across* cases (408, 413, 438). Although TA does acknowledge differences in experience, its primary focus is on patterned meaning *across* the data set, rather than unique features within each individual case. This is more consistent with the aims of the present study which focus on exploring use and impact, and identifying barriers and facilitators – all of which are more suitably identified across the cohort. Similar to IPA, GT is bound to the theoretical constraints of its methodological. The end goal is to generate a useful and plausible theory *from* the data, rather than imposing theory *on* the data (434, 439). It uses an inductive approach, where by the theory is developed from the 'ground up' and data driven, without influence from pre-existing literature, theories, and ideas. GT was not appropriate for this study as it lacks epistemological flexibility. This study did not intend to develop a theory from the data set, but instead identify data patterns and provide description and interpretation of these. GT is also known for its distinct and central features, including theoretical sampling and saturation (408, 413). Theoretical sampling is the collection and analysis of data in a cyclical and iterative process,

where by data analysis feeds into subsequent sampling, further data collection, and testing of emerging theories. This process continues until the point of saturation, where the researcher decides the addition of further interviews would not add any more depth to the emerging theory. This study had no intention of using theoretical sampling due to limited time and resources. It was deemed more appropriate to use TA, as although it is not quick, it is less time and resource intensive.

Due to the flexibility of TA, there are considerations and decisions that need to be made regarding the analysis. Within TA, themes can be identified in two primary ways: inductively or deductively (413, 434). An inductive orientation is described as 'bottom-up' and 'data-driven', whereas a deductive orientation is 'top-down' and 'theory-driven'. This study had an inductive analytic orientation, as it focused on participant accounts, instead of producing findings in reference to existing literature or ideas. It was also appropriate as there is limited research in this specific area. Another consideration is the meaning level at which themes are identified – either semantic or latent (434). Analysis and coding at a semantic level is explicit, staying close to the surface meanings of participant accounts. In comparison, latent level analysis is implicit and interpretative, exploring the underlying ideas and assumptions that shape and govern such semantic content. Semantic level analysis was chosen for this study, firstly because it complimented the theoretical underpinnings of the research, and secondly as it was concerned with practitioner perspectives and experiences of SA and ST while working in PR. This is not a deep psychological or social phenomenon that requires exploration and interpretation beyond the surface meaning provided.

3.2.2 The Six Phases of Thematic Analysis

The structured method of reflexive TA used was the six-phase framework outlined by Braun and Clarke in 2006 (434), along with further guidance from their practical guide published in 2022 (423). The six phases are described below:

3.2.2.1 Phase 1: Familiarisation

At the beginning it is essential to be immersed within the data to grasp the full breadth and depth of its contents. This involved reading and re-reading each transcript to become familiarised and acquainted with the data. It was helpful to initially read each transcript along with the audio recording to get a understand how participants articulated themselves, giving more life and appreciation to the written transcript and data items. At the same time, it was useful to make initial notes of anything interesting that came up during this process. Although the task of transcription can be described as a separate and preceding stage to analysis, it was actually a crucial initial phase of the familiarisation process, providing the first opportunity to come face-to-face with the dataset.

3.2.2.2 Phase 2: Initial coding

A systematic sentence-by-sentence coding strategy was carried out to generate initial codes. This was first done in Microsoft Word using margin comments (e.g., Appendix K). This was conducted throughout the entire dataset with full and equal attention given to each transcript. Following this, codes were manually transferred into NVivo, which provided another opportunity to read the transcripts and review initial codes applied. Preliminary codes were assigned to features of the data in order to describe its content. Collating the data into meaningful coding groups provided a condensed overview of the main points and common

recurring features. All potential themes were coded, as anything could be of interest or importance at a later time.

3.2.2.3 Phase 3: Generating candidate themes

At this point, an array of initial codes had been identified, so the analysis moved away from coding and focused on the broader level of themes. Initial themes were generated by sorting, matching, collapsing, and separating codes into meaningful groups – combining them to form themes and subthemes. Even though some codes were regarded as vague or irrelevant, none were discarded yet. Visual aids, such as mind/thematic maps and coding lists, were created, allowing relationships and overlaps between themes to be illustrated and highlighted. This was particularly helpful as it identified if themes were too similar and needed refinement, or if themes were not strong or relevant enough. Examples of strategies used to aid the generation of candidate themes are displayed in Appendix L and Appendix M, showing electronic methods and annotation tools (e.g., lists and thematic maps).

3.2.2.4 Phase 4: Developing and reviewing themes

Within this phase, two levels of reviewing and refining took place to ensure the themes were relevant and appropriately representative of the data. Level one involved reviewing the themes at the coded extract level, which entailed reading all data extracts for each theme and considering whether they formed a comprehensive pattern. Once satisfied, level two took place. This time the themes were reviewed against the entire dataset, which involved reading back through the original transcripts. This had two purposes: to determine whether the generated themes worked within the original dataset; and to make sure no additional data had been missed or overlooked during the initial coding stage.

3.2.2.5 Phase 5: Refining, defining, and naming themes

Themes were refined, definitions were written, and names created. This means identifying the ‘essence’ of what each theme is about, and illustrating how each theme fits into the broader overall story being told about the data. Clear concise names and definitions were created for each theme and sub-theme. As this phase is concerned with refinement and figuring out the structure and flow of the analysis, it overlapped with phase 6.

3.2.2.6 Phase 6: Writing and producing the report

This was the final opportunity for analytic refinement. For each theme a selection of relevant and appropriate data extracts were selected to illustrate examples of each theme’s content. An analytic narrative was used to describe and interpret the data, representing the story being told, and providing evidence in response to the research questions.

3.2.3 Quality in Qualitative Research

When conducting qualitative research it is important to critically reflect and evaluate its quality and trustworthiness. Unlike quantitative research, which uses measures of validity and reliability, there is not a universally agreed quality criteria that can be applied across all qualitative methods (413, 440, 441). When conducting reflexive TA, Braun and Clarke provide recommendations of published quality criteria (423, 441). This included Yardley’s (442, 443) set of theoretically neutral validity principles, which were used to discuss the quality and associated strategies employed within this study. This criteria is broadly grouped into four key dimensions: sensitivity to context; commitment and rigor; transparency and coherence; and impact and importance.

3.2.3.1 Sensitivity to Context

Yardley (442, 443) states a good qualitative study shows sensitivity to the perspective and socio-cultural context of participants, with consideration for the influential impact of the researcher and research setting. Therefore, it was important to ensure that participants provided their own subjective accounts, not 'socially acceptable' responses (i.e., not speaking negatively about the service). Therefore, it was emphasised wherever possible (e.g., PIS and beginning of the interview) that the research was interested in their personal accounts, that taking part was completely voluntary, that accounts were confidential and anonymously reported, and that this will have no impact on their employment. Open ended questions were used to encourage participants to respond freely, with the researcher conducting the interview in an overtly neutral manner. Additionally, interviews were conducted with consideration for participants working hours and availability, taking place at a date and time which was easy and convenient to them, and using a communication method of their preference. Lastly, during analysis the researcher was actively open to contradicting accounts and alternative interpretations. The aim of the study was to explore the topic and get an overall understanding and insight, with interest in all perspectives – both negative and positive.

3.2.3.2 Commitment and Rigour

Commitment and rigor can be demonstrated through in-depth engagement with the research topic and process, such as displaying competence and skill in the methods used and detailed analysis undertaken (444). The researcher committed fully to the research process, demonstrating this through prolonged engagement with the data and the decision to transcribe all interview recordings. Investigator triangulation was utilised to aid and enrich the analysis. The researcher was the main coder and analyst, however frequent discussions took place throughout with the PhD supervisors. The supervisors independently coded extracts, providing

direct insight and understanding of the data collected, as well as contributing differences in the way data is coded and interpreted. This facilitated data analysis as it helped identify, clarify, and modify analytic insights and ideas, for example identifying a theme which was overlooked or not considered, or interpreting a theme in a different way. Although this process was not looking or aiming for complete consensus, it gave the researcher the opportunity to explain their thinking, be questioned, and discuss alterative ideas. It also provided assurance and validation that the codes and themes identified were useful and representative of the data - not moulder to fit their preconceptions or a particular standpoint. Qualitative analysis can be a very long, monotonous, and isolated process, and when immersed within the data it is somethings challenging to see the 'wood for the trees'. Therefore, discussing it with others helped clarify analytic insights and deepened engagement with the data.

3.2.3.3 Transparency and Coherence

Transparency is important because it shows the processes used and decisions made, rendering them accessible and clear to the reader (444). Various strategies were employed to achieve this. Firstly, in-depth detail is reported within the written thesis, with a clear outline of the methods used. Secondly, an electronic 'paper' or audit trial was kept, outlining how the research was conducted and showing transparency of data analysis (423). The final thematic map and theme definitions are provided within the findings of this chapter (page 134). Evidence of the initial analytic process and theme development is also provided in Appendix K and Appendix M, which present a coded transcript extract and an early thematic map. Lastly, reflexivity is an important part of study transparency, particularly within reflexive TA which embraces and values the researcher's subjectivity. The researcher maintained a reflexive stance throughout and considered their influence on the study and the findings produced. This was facilitated through reflective note taking, which is summarised on page 180. Furthermore,

coherence means the extent in which the research makes sense consistently as a whole, describing the 'fit' between the various elements of a study (442, 443). Coherence is evidenced through detailed discussion and justification of the methods chosen and used, which contribute to overall transparency.

3.2.3.4 Importance and Impact

This refers to the usefulness of the knowledge generated (444). This study hopes to have direct practical implications, which will be useful for PR practitioners, services, and other stakeholders. This project will discuss and provide recommendations for clinical practice within PR, as well as for further research in this area.

3.4 Findings

3.4.1 Participant Characteristics

In total, 11 participants were recruited, all of whom took part in an interview and provided data. Two potential participants expressed an interest, but they did not meet the inclusion criteria, specifically not having a job role involved in delivering PR programmes. All participants were female, with a mean age of 39 years (*SD*=9.1) and had worked specifically within the PR field for an average of five years (*SD*=4.4). Two participants were physiotherapists (18.2%), four were nurses (36.3%), and five were healthcare assistants (45.5%). Participant characteristics are displayed in **Table 9**.

Table 9. Participant/practitioner characteristics (*n*=11)

Pseudonym	**Age (years)**	**Employment (years)**	**Job Category**
Claire	41	11	Physiotherapist
Helen	36	11	Physiotherapist
Elizabeth	36	1	Nurse
Maria	47	1	Nurse
Laura	56	2.5	Nurse
Bridget	51	2	Nurse
Yasmine	28	7	Assistant
Phoebe	30	5	Assistant
Sophia	40	1	Assistant
Emily	31	2	Assistant
Denise	33	12	Assistant
	M = 39 (*SD* = 9.1), Range = 28-56	*M* = 5 (*SD* = 4.4), Range = 1-12	

3.4.2 Themes

Five themes were constructed during the analysis: 1) Strength training is important, 2) Is assessing patient muscle strength important? 3) Challenges for pulmonary rehabilitation and strength assessment, 4) Considerations and support for patients, and 5) Practitioners need for further training. Themes and sub-themes are described in detail alongside selected excerpts from the interviews. A summary of themes is outlined in **Table 10**, and the final thematic map is presented in **Figure 6**.

Table 10. Summary of practitioner interview themes and sub-themes

Theme	Sub-theme	Definition
1. Strength training is important	• Strength training and gender differences	This theme outlines views on the importance of muscle strength and ST for patients, as well as highlighting potential gender differences.
2. Is assessing patient strength important?	• The importance and benefits of strength assessment • Uncertainty of strength assessment usefulness and relevance	This theme discusses whether the assessment of patient muscle strength and the use of SA is important in PR. Participants outline the benefits they think it offers to staff, patients and services. But also their reservations concerning its implementation and use within current clinical practices.
3. Challenges for pulmonary rehabilitation and strength assessment	• Time constraints • High workloads and demands • Limited equipment access and availability	This theme outlines the challenges faced while running PR programmes, and how these same difficulties are mirrored in the implementation and use of SAs in clinical practice.
4. Considerations and support for patients	• Individualised exercise support • Educational and psychological support • Peer support	This theme outlines the support offered within PR, both from staff and peers. Specifically, it explains how participants must consider the physical, educational, and psychological barriers of patients when delivering PR and the exercise sessions, making sure to provide suitable support to address and minimise these.
5. Practitioners need for further training	• Training was ‘learning on the job’ • Perceived differences in professional knowledge and training • Staff support for training	This theme outlines the extent of participant training regarding exercise and ST, highlighting differences between staff delivering PR. Participants acknowledge staff would benefit from further training.

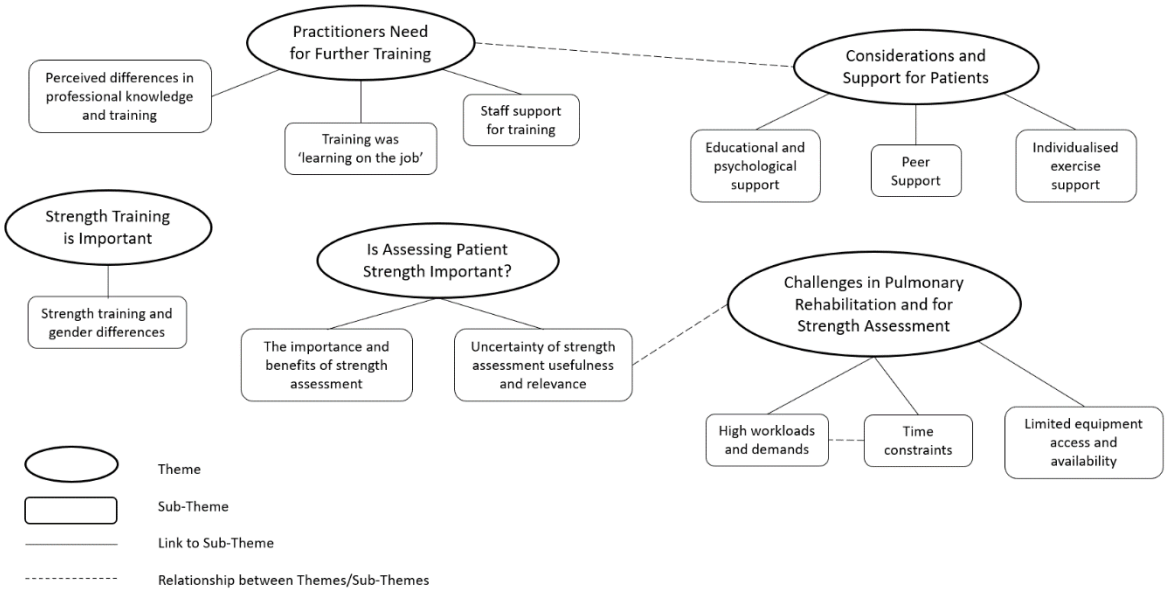

Figure 6. Final thematic map (practitioner interviews)

3.4.3 Theme 1. Strength Training is Important

Overall, participants believe it is important for patients to have physical strength, benefiting them by tackling muscle weakness and improving their day-to-day lives. In addition, participants note strength is regarded more highly by male patients compared to their female counterparts.

Participants explain that PR is designed for individuals with chronic respiratory conditions, aiming to improve overall health and physical fitness through exercise. They state a key focus of the programme is improving lung health and breathlessness, which is understandable considering patients are referred due to their pulmonary disease. Nevertheless, participants also state an intention and benefit of PR is to build and improve physical strength.

> *"So basically it's [PR] for people with lung conditions to hopefully build up their strength… building up their strength and giving them exercises to help with their breathlessness" (Yasmine)*

"Pulmonary rehab is designed for people with long term chronic lung conditions, to help gain the best out of their lung capacity... So the way I explain it, so they get the best out of their lungs, but also to help build up, so muscle mass and any wastage that they might have." (Emily)

Participants explain that strength-based exercises are included in the PR exercise programme. As explained by Elizabeth, the exercises are predominately strength focused.

"a lot of it is around strength, resistance training, a lot of the individual exercises…a lot of them are about sort of developing muscle strength really… So strength is a huge part of it, the strength-based exercises… there's quite a few for strength, I'd say probably more for strength than there are for sort of general cardio." (Elizabeth)

This suggests that ST is important, as participants are acknowledging the inclusion of such exercises in the programme and the improvement of muscle strength as a goal. In fact, the majority either explicitly state or implicitly describe the importance of ST. Patients commonly suffer from muscle weakness and wastage, which is a consequence of their respiratory disease. Therefore, it is vital for patients to exercise with the purpose of maximising and maintaining their muscle strength to combat the decline. Participants explain that incorporating strength-based exercises in PR exercise is important because it can help improve patient strength and their deconditioned state.

"*I think it's [ST] very important because our patients that attend, the majority are deconditioned... I think it's really important" (Laura)*

"There's definitely a place for having ST within that to help, because a lot of patients that we see have got a lot of muscle wastage and are quite frail and weak, and having that extra strength can really make a big difference." (Helen)

Furthermore, participants describe how having more physical strength can positively impact patients' everyday lives. Many day-to-day activities require strength to some

extent, such as standing from a chair, walking up the stairs, or carrying shopping. Therefore, they acknowledge that ST, alongside cardio, is an important part of the exercise programme to help develop and maintain this strength, so patients have the ability and capacity to carry out the tasks required of them on a daily basis. If patients can perform these basic activities, it is likely to lead to better quality of life, minimising day-to-day struggles.

> *"Things in everyday life do involve some form of strength in order to be able to carry them out and fitness in general so by working on not just their cardiovascular side of their fitness but also their muscle strength, it all helps in terms of them being able to achieve daily activities and best quality of life." (Phoebe)*

Lastly, alongside these perceived direct benefits of ST, some participants also describe the positive impact muscle strength can have on overall patient fitness and health. Yasmine further explains why ST is important, stating if patients are strong then they have the strength to fight off infections and cope with exacerbations that are commonly experienced by this patient population. This suggests that ST can go beyond just improving muscle strength and mass, offering systemic benefits that help patients on a larger and broader level.

> *"I think it's [ST] really important because like I said it helps build the muscles up and also with building those muscles up you can make it so it's easier to fight that infection. So you're building up those strength, those muscles to actually fight the infection a little bit quicker and a little bit easier for yourself." (Yasmine)*

Although overall opinions support ST as important, some participants do emphasise the importance of other factors of PR and patient health, for example overall fitness, cardiovascular health, and patient confidence. As stated above, PR is designed and aimed at patients with lung conditions, and thus it can be argued that overall focus should be placed on lung health and cardiovascular fitness. The benefits of patients having strength and doing ST

is acknowledged as important, but it does not mean it is more important than other aspects in the programme.

> *"At the end of the day they're not there to become weight trainers they're there to become lung fit, in my opinion. And I want their cardiovascular system to work really efficiently and for them to actually manage to walk a bit further than they can and do their daily activities… So I think strength-based training definitely has its place and it is important. But I think cardiovascular stuff is just as important, for me." (Claire)*

> *"Probably fairly important, but I wouldn't have said it [ST] was the be all and end all. I think more sort of general fitness and confidence is better for them rather than concentrating on just one thing." (Denise)*

3.4.3.1 Strength Training and Gender Differences

Aside from participant's own views on ST importance, some also briefly note the importance of muscle strength to patients, specifically the gender differences they observe. They explain that the men seem more interested in ST and using weights compared to the women. It is suggested that this could reflect the age and generation of the typical patient group, and the likely "*old-fashioned*" (Phoebe) views patients have of male and female stereotypes, for example lifting weights and wanting to be strong could be described as an activity and quality reserved more for men. This could explain why strength may be perceived as more important to male patients because they want to strength train and lift weights, whereas the women are less inclined.

> *"Like, particularly the men seem to embrace the weights. Some, some of the- I found when I was doing the class, some of the ladies didn't want to increase the weights, I don't know whether that's more of an old-fashioned thing, where it was seen that men had done the strength stuff." (Phoebe)*

> *"it's going to sound really bad and sexist, but if you've got like two little old ladies next to each other and ones got a little weight and ones got a heavier*

weight, the one with the heavier weight looks at the other one and thinks 'I want a little weight as well'." (Denise)

Denise and Phoebe continue to describe how the male patients seem to place greater focus on being strong, showcasing their strength, and progressing in these exercises.

"Male bravado kicks in quite well and they don't like sitting down and looking weak in front of everybody else… especially if you've got some gentlemen who like to show off their muscles and show they can lift heavier weights" (Denise)

"*I think they're quite important [ST exercises]. It sets out goals for your patients and the men in particular seem to like progressing in strength" (Phoebe)*

One reason this may be held to high regard is due to the decline in their health and physical abilities. Laura provides some insight by explaining that many male patients were very practical in their early years, with labour-intensive jobs. However, this changes due to their condition and age. Patients commonly experience muscle weakness and physical limitations as a result of their respiratory disease, which Laura suggests could cause male patients to feel like they've lost their "*manliness*". ST gives them the opportunity to improve their physical strength and function, as well as gain some of their masculine identity back.

"they've lost a lot of their manliness, if you like, the physical abilities and things they used to be able to do and a lot of men, especially the ages we get, are very practical and people with manual labour skills a lot them and for them not to be able to even lift things, the shopping or push a hoover round, things like that is really hard for them." (Laura)

This theme provides useful insight into views and opinions on the importance of ST in PR. Overall, participants believe ST is important within the programme, with strength being an essential aptitude for patients to have. However, some participants place equal or

greater significance on other aspects, particularly lung health and cardiovascular fitness, which is understandable considering PR is an intervention for respiratory diseases. This highlights that one aspect of PR is not necessarily more important than the others. In addition, this theme provides brief insight into perspectives of gender differences, specifically male patients' inclinations towards ST.

3.4.4 Theme 2. Is assessing patient strength important?

The majority of participants acknowledge and recognise the importance of assessing patient muscle strength, and the benefits it can have for patients, staff, and services. However, some do show uncertainty, especially in relation to previous experience, current clinical practices, and outcome measures used. The theme title is framed as a question, illustrating the presence of varying opinions on the topic.

3.4.4.1 The Importance and Benefits of Strength Assessment

Participants explicitly state the assessment of patient muscle strength is important and should be included in PR.

> *"I think there is a place for it, and I think it is important." (Claire)*

> *"I think if you're not going to assess a patient for their muscle strength and then ask them to go into a 7-week program then it's an incomplete program." (Maria)*

As previously discussed in the theme 'Strength Training is Important' (page 136), participants describe one aim of PR is to build and improve patient strength. As such, Laura notes that if PR aims to do this, then it should be assessed, especially as multiple strength-based exercises are included within the exercise programme.

> *"I suppose it depends on the aims of rehab like what the aims are and is the aim to, you know- I suppose if the aim is to promote muscle strength, then you should have a way of assessing that" (Laura)*

Specifically, participants outline three perceived benefits of SA: 1) it provides a safe and individualised guide, 2) it helps track effectiveness of the programme and patient improvement, and 3) it helps patient motivation. Firstly, the majority of participants describe how SA can provide a safe and individualised guide for exercise, benefiting both staff and patients. This is especially helpful for ST exercises when weighted equipment is prescribed and used. Additionally, by assessing strength it means patients can be guided in performing ST exercises safely, but also effectively. This is important because if patients are not exercising efficiently, then the possible benefits they could gain may fall short.

> *"it is important because patients need to know what they're doing, need to be guided, and health and safety, so you don't want to give someone a really heavy weight and their sort of leaning over to lift it or- You need to prescribe the right weight for the right patient to get their effect, so they use it correctly, they don't hurt themselves, but also if it's too light it's not really doing much for them to build the strength. So yeah, I do think strength assessments are very important." (Elizabeth)*

> *"It gives them [patients] a guide and sets them up for the individualised program. So rather than them just following everybody else and just doing a two-kilogram weight that is so easy, they're going to be working with their own body and their own strengths and working to develop that. Otherwise, you're not going to see an improvement." (Laura)*

Secondly, participants describe how assessing muscle strength as a PR outcome could help measure effectiveness of the exercise programme and track patient improvement throughout. It can measure how deconditioned patients are when they first attend, and how successful and beneficial the exercise programme was for patients when they leave.

Alternatively, if a patient's strength has not improved as expected it allows staff the opportunity to reflect on why this may be the case - highlighting potential areas for change and improvement.

> *"The positives are we get a good- anything that helps us get a good guide as before and after it has to be positive really because it tells us whether we've successfully helped the person, or we haven't, and the program is wrong and it needs to be tweaked." (Maria)*

> *"I think with emphysema, they tend to- their muscle wastage is obvious on sight, so it would be really useful I think in measuring deterioration or hopefully improvement." (Sophia)*

Lastly, another perceived benefit is how assessing muscle strength and tracking improvement could help patient motivation. Participants state that it offers patients an objective measure of their improvements, giving them a comparison of where they started and where they finished. It provides patients with the satisfaction of knowing their hard work has paid off because they have clinical data as evidence. It is suggested that assessing muscle strength before and after could give patients the motivation to put in effort and adhere to the exercise programme because they know they are going to be assessed again at the end.

> *"it gives them [patients] a comparison so that they can actually feel that they've gone to this course, this pulmonary rehab course, and actually they've improved their strength, they've gone from two kilos at the pre assessment to four or five kilos at the end. So that's going to give them that sort of satisfaction, isn't it?... they've got something to compare, they've got the evidence to compare the benefits and what work they've put in during pulmonary rehab is paying off. So it gives them the satisfaction." (Elizabeth)*

> *"with the weights, people they were more open to following the program, they wanted to follow the program because they've been assessed for it and they know you're going to assess them at the end to see if there's been any improvements and they wanted to see improvements with what had happened*

as well. Everyone likes to know that they've improved from when they started." (Phoebe)

3.4.4.2 Uncertainty of Strength Assessment Usefulness and Relevance

Despite acknowledgment of the importance and perceived benefits of SA, some participants show uncertainty about its usefulness and relevance, which seems to stem from previous experience and the current criteria for clinical practice and outcome measures.

Some participants express reservations about the usefulness of SA, based on their experience of using one within their service. As previously described in the methods section 'PR Service Context' (page 118), this service trialled a SA in a prior research study. The SA was used to prescribe an optimal load and a progressive ST programme, specifically for the bicep curl exercise. Participants question how useful such an assessment and prescription protocol is, as there are many strength-based exercises included in the exercise programme, yet the assessment and prescription of load is only conducted for one specific exercise. They are unsure why this bicep curl SA was chosen specifically. Therefore, if staff do not know why something is implemented and conducted in clinical practice, then it is understandable if doubt and uncertainty is present.

"I couldn't tell you why it's specifically the bicep curl" (Emily)

"they're only using the hand weights for bicep curls and nothing else. Which again, I find a bit bizarre because if you're using resistance, you should use it for all of your upper body… you would do your biceps with the hand weight that you were given and then you would increase it further on in the program, but you would only do that on that one exercise. Well, for me, that isn't enough. If you're going to increase it, you increase it for everything… You don't just pick one exercise and only do repetitions on this one." (Claire)

Another reason for this uncertainty is the usefulness and relevance of SA in relation to the PR outcome measures that are currently used in clinical practice. PR success is judged on the improvement of several outcome measures, both physical and psychological. The main physical exercise test used at this service is the ISWT. Sophia explains that the walking test "*has always been the standardised assessment".* Therefore, participants may question how useful and relevant a SA would be if it does not help improve walking distance, and thus exercise tolerance/capacity. Although a patient may benefit from improvements in strength, by having their strength assessed and individualised loads prescribed, if it is not a standardised assessment across PR, and success is judged on a different criterion, then is it worthwhile and important enough for staff and services to focus on this.

> *"also making sure that we can meet the criteria that we need to meet with pulmonary rehab, so making sure that we can help with their exercise tolerance as well as helping with their- mentally as well with the exercises." (Yasmine)*

> *"I think the difficulty is that our assessment is a shuttle walk test, is a bleep test. So obviously, if they're doing a tailormade hand or leg weights, yes you know, they're strength might well get better, but it wasn't actually improving the outcome of walking. So really in terms of, for us, it wasn't really making any difference to what we would class our final outcome, which is a shuttle walk test, is them walking a further distance. (Claire)*

Despite these uncertainties, participants still show openness to using SA within clinical practice, stating its implementation and use within PR "*needs to be looked at more*" (Yasmine) and "*definitely needs reviewing… as a service we need to think about how we can actually implement it*" (Claire). However, emphasis is placed SA being evidenced and researched to ensure safety and effectiveness. Participants state it is important that anything introduced into PR should benefit and have a positive impact on patients. If evidence is available which supports SA in PR, then this would likely reduce these uncertainties.

"if we could see definitely, right doing all these strengths assessments and strength prescriptions really make a huge difference there would be no- that would be it, that's it. But I think because the data is a bit unsure whether we're getting huge amounts of differences. And so I think people sort of feel a bit unsure about it really" (Helen)

"I'm quite open to incorporate, well trying new things as long as it's safe to use and we've obviously looked into that. Yeah, you want what's best for your patients and if it helps to improve the outcomes, why would you not try and incorporate that in your classes." (Phoebe)

This theme provides insight into varying opinions about the importance of SA, and its usefulness and relevance within PR. It outlines reasons why participants believe it is important and the perceived benefits it offers to stakeholders involved. Yet, it also considers why some hold reservations and uncertainties. Overall, participants acknowledge the advantages, but question its use within the parameters of current clinical practice.

3.4.5 Theme 3. Challenges for pulmonary rehabilitation and strength assessment

As discussed in the preceding theme, participants express uncertainty regarding SA in PR. Further reasons contributing to these reservations are the challenges encountered when delivering PR programmes. Participants outline the difficulties they face while running the classes, and how these same problems are regarded as limitations for the implementation and use of SA into clinical practice. The following challenges are discussed: time constraints, high workload and demands, and limited equipment access and availability.

3.4.5.1 Time Constraints

The majority of participants state one of the main difficulties they face in PR are time constraints. One specific aspect is the short amount of time allocated to conduct pre/post

assessments. As stated by Maria and Claire, there is not enough time to get through all that is necessary in a patient assessment.

> *"we've such a short time to assess a patient" (Maria)*

> *"If you've only got 30 minutes for an assessment it's not enough time to fit everything in." (Claire)*

Another contribution to constrained time are the hired halls and venues used to host PR programmes. Venues are only hired for a certain amount of time, after which they must be vacated. Therefore, participants explain that it is not possible to overrun a class if more time is needed, as additional costs would be incurred. This puts pressure on staff to get all necessary tasks completed within the strict time frame.

> *"And it's a time factor as well, you know, you sort of getting them in, you wanted to get them started because you know you have to be finished at a time, and you know you have to be out of the hall at a set time as well." (Laura)*

> *"The time we have in the halls and things like that and it might be that some of our halls are quite fixated on making sure we're only in at a certain time and that we don't overstay our welcome because they then charge us more." (Yasmine)*

Due to these time constraints, participants show concerns about using a SA. They are apprehensive as they foresee it to be a time-consuming process, and fear it taking up valuable time. There is concern that adding in another component is only going to rush patient assessments more. Staff are already pushed for time in these classes, so adding in another task is going to constrain time even further, putting additional pressure on staff.

> *"I think we don't get a lot of time for assessments as it is, they're really rushed, and I feel the patients don't get enough time for assessments already." (Laura)*

"I think people sort of feel a bit unsure about it [SA] really, whether it would be- whether its- because it's quite time consuming. When you already have a limited amount of time to do things, it's quite time consuming." (Helen)

3.4.5.2 High Workloads and Demands

Time constraints are also linked with high workloads and increasing demands. The majority of participants state PR is a busy and demanding environment, with many duties required of them within the given time, such as setting up the venue, conducting multiple patient assessments, running and supervising exercise classes, dealing with unexpected patient drop ins, preparing educational material and refreshments, answering patient questions and concerns, and tidying up the venue. Emphasise is placed on the need for "*multitasking*" (Maria) and having to "*juggle*" (Phoebe) all these responsibilities, as most occur simultaneously. Dealing with high workloads in a busy environment is likely to be difficult at the best of times, however coupled with restricted time it is likely to become even more challenging. Claire and Denise provide further insight into their high workloads, by briefly explaining how over the years the amount of work required of them is ever increasing, yet they are not given additional resources to compensate for this rise in demand.

"we're being pushed for targets but not actually given the time to do them properly. And that's my view, that they want targets, and they want better outcomes, but they don't actually want to give us the staff or the time to achieve it." (Claire)

"But it just feels like everything else at work, every year you get more and more thrown at you with less and less time and resources to do it." (Denise)

With consideration for these challenges, it is understandable that participants feel the use or introduction of a SA would inevitably increase their workload. Adding in another assessment would likely put further strain and pressure on staff to meet demands and targets

within the limited time allocated for each class. Participants offer up a simple solution to compensate for this increase - more time. Therefore, if a SA was introduced, they would have the means and resources to conduct all patient assessments properly, and at the depth necessary.

> *"And yes, it would take more work so we would potentially need more time to do it." (Claire)*

> *"I think it would be feasible if we gave ourselves more time to be able to come up with it and make sure that we had the time and the things to do it, but it might be that we just might need a little bit longer for like their assessment and things like that, so we give ourselves extra time to be able to assess that patient a bit more in depth." (Yasmine)*

Some participants speak from experience, justifying these concerns. As previously described in the method section 'PR Service Context' (page 118), this service trialled the use of a SA within their programme as part of a previous research study. However, they explained that this SA is no longer used at Site 2, primarily due to the additional time and work required. The classes were already pushed to the limit, meaning the increase in workload was not manageable.

> *"[Site 2] was doing that and then because the classes are just so busy it was dropped because there just wasn't time to fit that in with everything else to do." (Laura)*

Claire makes a relevant point regarding the accuracy of SA if additional time is not provided. If extra time is not given to compensate for the additional work, will the SA be carried out correctly? This supports their notion for more time if additional measures were included in the programme. Staff should have the resources they need in order to carry out their duties and responsibilities without the potential need to cut corners or compromise on quality.

> *"And then I wonder whether actually, is it being done properly? So actually, is the patient any better off having a strength-based assessment for rehab because it's going to probably be very slapdash… So, I think it would have a place, but I think again it's just time. It's actually being given the time to actually do all of this stuff thoroughly enough that it's done properly and not slapdash." (Claire)*

Consequently, participants are concerned with the quality of patient supervision, as time and workload constraints can result in difficulty providing and dividing attention between patients. PR classes are hectic and busy, with multiple duties requiring staff attention. Not to mention some patients needing or requesting more attention than others. As a result, participants explain they have limited capacity to constantly observe and supervise. They are frequently taken away from the group to deal with individual patient needs and other job duties. They express the difficulty they face trying to divide their time between patients, which can raise concerns regarding the impact limited supervision can have on patient care and safety.

> *"But it's a time factor. We're so pushed in these sessions, and I think sometimes the patient gets forgotten in the session, which sounds silly, but I see it happen, and I can see why it happens… the classes are full to capacity and you've got 16 patients and it only need one patient to be unwell or to need more attention and then your attentions taken away from the class." (Laura)*

> *"I think it's more looking at everybody, if we've got quite a big class and there's only me and another colleague and they're busy with an assessment or something it is quite tricky to keep an eye on everybody all at the same time… sometimes it can be quite hard to make sure you're dividing your time between everybody." (Yasmine)*

Therefore, if limited time and high workloads are already causing concerns about patient supervision and safety, then adding in a SA, or another element, to the PR programme would likely increase these concerns further.

3.4.5.3 Limited Equipment Access and Availability

Another challenge is limited equipment access and availability. As explained in the methods section 'PR Service Context' (page 118), this service is comprised of three sites, which are all based at different venues and locations. Consequently, all participants explain that the facilities and equipment available "*varies depending on each venue*" (Yasmine), and are "*dependent on the location*" (Denise), resulting in differences and inconsistency across sites. The variety of venues used range from church halls and community centres to gyms and leisure centres. Participants state running classes at gyms and locations alike is an advantage, describing themselves as "*lucky*", due to the access and availability of exercise and weighted equipment (e.g. dumbbells). Whereas other venues with limited equipment, are seen as unfortunate. If venues have access to equipment it is utilised, if not, services typically have to supply some themselves, in this case defaulting to using exercise resistance bands (e.g. TheraBands™).

> *"Let's see, where we're based specifically at Site 1, it is in a leisure centre so we have access to lots of various different weights… unfortunately, with Site 2 and Site 3, it'd be lovely if we had the resources there as well, find it probably would be beneficial to them as well, to be honest… But we are very lucky at Site 1 with what we've got." (Emily)*

> *"So I think it depends if they're hiring a community hall without gym equipment, then they'll go for the bands. If they're lucky enough to get a studio in a gym where there's all the equipment there, then they'll use the equipment that is supplied with the hirer of the hall or the gym." (Elizabeth)*

Participants state a barrier to SA would be these equipment restrictions, especially at the sites which are lacking. Specifically, this would be difficult if an assessment required a specific type of equipment, such as weights, as this may not be achievable at every PR site. Additionally, the quantity of equipment available may be an issue, as if a SA is used to prescribe

exercise load, the venue might not have enough equipment to accommodate all patients within the session (e.g., if the same weight is needed by multiple people).

> *"The only other limitation is equipment, you need the equipment available to be able to do these assessments… so that's one of the only other limitations, you've got to have the equipment ready to be able to use." (Phoebe)*

> *"Obviously having the actual equipment [laughs]. So, for example, depending on what venue you are at… So I think the limitations would be having the lack of equipment, it's sort of equipment as in terms of where, the venue, but also the amount of equipment that you have depending on how many patients you have as well." (Helen)*

This inconsistency would likely make standardisation across sites and services problematic. Standardising a SA within a service would only be possible if sites had the same equipment, or if the assessment did not rely on a specific type of equipment at all. Participants note if SA is used then standardisation is important because it ensures all patients receive the same benefits and care, as well as staff conducting the assessment properly and consistently from site to site, and even service to service.

> *"Obviously in an ideal situation we'd all be able to do exactly the same across the board, but that can't be done because of the different venues that we use." (Helen)*

> *"I do personally think that if you're all consistent and all doing and following the same guidance, using the same equipment and the patients are all getting the same benefit and care. So I think it is right to be standardised. I mean I've worked in other sort of localities as well, and they do things differently as well. So it is- there's no consistency throughout the UK or even different places within the same locality. So it'd nice to have it all standardised." (Elizabeth)*

This theme outlines the challenges faced while delivering PR, and how the use of a SA would likely contribute to or enhance these difficulties. These findings provide further

understanding as to why some participants have reservations about SA into PR, as it is already a busy environment with stretched resources. This theme highlights potential areas for improvement within the programme to help staff, but also issues to consider if SA was to be implemented or used in clinical practice.

3.4.6 Theme 4. Considerations and Support for Patients

Despite the challenges faced in PR, participants still have to ensure they provide essential support to patients. Participants explain how they must consider the physical, educational, and psychological limitations of patients, especially when patients are exercising and ST. They explain how staff support plays a vital role in meeting patient needs and making sure their experience is as beneficial as possible. Emphasise is also heavily placed on the importance of peer support offered by fellow patients within the group.

3.4.6.1 Individualised Exercise Support

All participants explain that when it comes to patients exercising and ST, what they can and cannot do is dictated by the severity of their condition, symptoms (e.g., dyspnoea), and co-morbidities. As the typical patient population who attend PR are of older age, this means many suffer from additional health ailments, such as arthritis, aneurysms, high blood pressure, mobility difficulties, past surgeries, frailty, joint problems, oxygen use, and chronic pain. These can be barriers to exercise, especially ST, making it challenging for patients. Therefore, PR practitioners need to account for these barriers and limitations when prescribing exercise. Participants explain that they must support patients through the exercise sessions to ensure exercises are manageable and achievable. It is important that staff are aware of physical limitations within this population and how to adjust for them. Although the exercise programme is a standard template, it is important for it to be adapted and individualised to each patient,

with consideration for level of difficulty and physical ability. Some participants explain that if a patient is struggling with an exercise they will intervene to help, providing modifications. It is the practitioner's role to support all patients so they can exercise safely, but effectively.

> *"I will try and look at the individual and say well okay what are your key issues and let's change your exercises slightly, as well as obviously adjusting them if they've got health problems." (Claire)*

> *"Well, so they've all got the same set of exercises, but then, like I said, if you're working with these patients you can see like they're all doing the same exercise, but some are finding it very easy and some are really struggling. So the ones that are struggling, you bring it down a level and say just try doing it this way, or just do a bit less than the time that they're meant to do it, and vice versa. If it's too easy, you try and step them up a bit. So it's individualised in that way." (Laura)*

Although participants emphasise the importance of modifying exercises with easier substitutions, they also acknowledge that patients have different needs, with some requiring encouragement to work harder. They explain how they support patients by actively stepping in and pushing them to reach their full potential. Sometimes the PR practitioners need to push the patients and encourage them to work harder, especially if they know the patient is capable of progressing further. At the end of the day, patients are at PR to improve their health. Therefore, they need to put in the hard work to reap the benefits. The participants see it as their job to support patients during the exercise sessions, whether it's offering easier variations or suggesting a higher difficulty.

> *"everything's targeted to that individual patient, but like I said to you, when you're involved in the class if you spend time with these people, you can see if they're finding something too easy and it's not a challenge, but it's your job to intervene then and push them harder… like if you said to them, 'How are you getting on with that?', and they'd say 'oh it's fine, it's fine'. I think then you just have to say, well try one that's just a little bit harder just to see how you get on with it. You know, it's gentle encouragement." (Laura)*

3.4.6.2 Educational and Psychological Support

Aside from exercise support, participants also explain how they address issues and support patients on an educational and psychological level. They state patients can have limited understanding about exercise and ST, particularly why they need to build strength and work their arms and legs. Patients do not necessarily see the importance of this when it is their lungs which are the main problem.

> *"I just try to explain it to patients because sometimes they do get a bit confused as to why you're sort of trying to work out their arms and their legs if this is focused on lungs" (Emily)*

> *"I don't know if they fully understand why they need strong arms or why they need strong legs. But yeah, they can't fathom it, they're a bit like, what's all this then, and why" (Sophia)*

Furthermore, the majority of participants explain patients can have concerns and worries about exercising, which is likely a result of their condition, physical restrictions, and limited understanding. They explain how patients can feel intimidated and anxious when first attending PR, especially the thought of having to exercise and exert themselves. It is a new environment, and many are inactive and deconditioned. Most patients have not exercised in a long time, so they fear exacerbating their condition. Participants emphasise patients are especially concerned about getting breathless, which is usually something they are trying to avoid.

> *"So, say you've got 20 patients in there, two members of staff, and they don't know the environment and they're already worried about that they can't do these exercises because they can't breathe. So I think it's a very intimidating environment for them to come in and then have to start and exercise and do things that they've never done and that are making them breathless. And I think that must be, you know, must provoke anxiety" (Laura)*

> *"And patients often- they're often reluctant to exercise because they get into this vicious cycle of anxiety and breathing and breathlessness. They're scared that it's going to cause them to exacerbate or become breathless" (Elizabeth)*

Consequently, participants emphasise the importance of explaining things to patients and providing reassurance. Education is a key component of PR, and it is the practitioner's role to support patients during the programme to ensure they understand what they are doing and why it is important, particularly with regards to exercise and their condition. Participants describe how simply explaining why and providing a rationale can positively impact patient motivation and willingness. Patients can benefit by knowing why they are doing it and how it is helpful to them, if not, effort is likely to be minimal.

> *"And I think once they understand why we're doing what we're doing, and we're not just doing it. A lot of patients will say, 'Oh they just come along and they did this or they did that', and they don't explain, that's a big problem, you have to explain what you're doing and why." (Bridget)*

> *"Once you actually sort of explain why you're doing it, the relevance behind it, you do get a 'oh, I didn't realise that', and they do actually put a bit more effort into it. I think if they were more aware, they knew what it was for, they knew how it was going to help them, they would pay more attention to it." (Denise)*

Participants also state additional support is provided via the organised structure of the programme. Patients benefit from regular contact with staff, meaning any concerns and questions can be raised and answered quickly throughout the programme. PR provides a safe and "*controlled environment*" (Claire), which is particularly important when it comes to vulnerable patients exercising, especially if they have not exercised before or in a long while. If patients know they have HCPs supervising, they are more likely to push themselves when exercising. Whereas, doing this alone could be deemed a risk by patients, evoking and increasing exercise concerns and worries.

"the support that the staff provides if you're going there twice a week and you've got any issues you can just raise that with the staff working there." (Phoebe)

"rehab in particular I think it gives them the motivation to improve their lung health and they won't just- and in a safe controlled way so they don't feel that they're putting themselves at risk, which I think they would if they were just doing it like for themselves. So, that's the difference it makes, if they have a structured rehab program." (Sophia)

3.4.6.3 Peer Support

Aside from staff support, PR also offers patients the opportunity to socialise and receive support from fellow patients within the group. The participants consider this another important aspect of the programme, alongside exercise and education.

"Obviously the exercise and education, but actually I also feel that there is a very- the social aspect is quite a big impact for quite a few patients" (Helen)

Participants describe how many patients encounter isolation and loneliness due to their condition, as well as the physical limitations and anxieties that commonly come with it. However, PR breaks this seclusion and gives patients a reason to venture outside. Support is gained from being in a group with people who have similar conditions, prompting "*the feeling that the patient is not alone*" (Bridget). PR is an intervention specifically designed for those with chronic lung conditions, and as a result it offers a setting which brings patients together, creating a small community of people who are living through similar experiences. As described by Denise, this is particularly important as the support needs of patients during these times cannot always be provided solely by their friends and family, or even staff. Instead, understanding and compassion is needed from others who have first-hand experience of what they are going through. Participants describe how it has resulted in friendships, which have continued beyond the programme.

"Possibly the social side of things, people meeting other people so they don't feel quite as isolated because they can have friends and family who can imagine what they're going through but meeting people that actually are in the same situation and who can compare stories and relate to each other." (Denise)

"the classes are very sociable so they're in situations where they're not the only one is that experiencing those symptoms. They've got that support of others around them and quite a lot of them do make friends within the classes as well." (Phoebe)

Although the social aspect of PR greatly benefits patients, participants state that it can cause challenges for staff when delivering exercise sessions. Specifically, that some patients can get distracted by the social environment and forget the seriousness of PR.

"Patients treat it as a bit of a get together, it's not the hospital appointment, serious, because we have fun there, they think it's just a bit of fun, they don't see it for the seriousness that it is" (Denise)

"The whole time you've got however many patients in the background seizing the opportunity- they're like naughty school kids, ceasing the opportunity to stop what they're doing and sort of, until I look back [laughs]." (Laura)

A similar issue is the negative influence patients can have on others around them, such as patients copying each other or trying to help others during exercise. However, what is right for one patient is not necessarily right for another, especially when using weighted equipment. Therefore, it is vital PR staff explain and education all patients on the premise of individualised exercise and ST loads.

"I feel like some patients have powered through with that and you can see them struggling and because most other people are doing it, so it's trying to take them aside and just seeing what's best for them, just trying to get them to adapt their exercise and understand that actually not everyone is the same and that everyone should be doing it at their own at their own pace and at their own capacity." (Emily)

> *"They do copy each other as well, they like the same things. Or we get people that when they walk into the class will get weights for everybody else, especially if you've got some gentlemen who like to show off their muscles and show they can lift heavier weights, they'll go and look after the ones that aren't as mobile and just get them any weight. So, you've then got to charge around trying to sort out the correct weights." (Denise)*

This theme demonstrates the vital support and benefits patients receive while attending PR, from both staff and peers. It highlights the important role staff have in ensuring patients are given suitable care, and therefore emphasises the need for PR practitioners to have the necessary knowledge, understanding, and skills to successfully achieve this.

3.4.7 Theme 5. Practitioners Need for Further Training

Participants outline their experiences and varying extents of training received both prior to PR and while working within this field. Many do not have formal training related to exercise and ST, with most staff 'learning on the job' when they first started in their roles. Differences between staff backgrounds and education are also discussed, highlighting that training needs will likely vary. Participants support further training, stating it would benefit all PR staff involved and their patients.

3.4.7.1 Training was 'learning on the job'

Over half of participants explain that they do not have, or have never received, any specific or formal training related to the understanding, delivery, and prescription of ST. They describe how the method of training offered while working in PR is predominately 'learning on the job', relying on other staff within the team to help with training through shadowing and asking questions. When first starting out in a job role, they observe and participate in existing PR classes, so they can understand how a class is organised and run. Details about the PR

exercise programme is covered during this initial training and learnt over time, but information on ST is not necessarily covered.

> *"I've never been offered it [training for ST]. But I have been able to attend, when I first started, other rehab classes, to see how they work." (Maria)*

> *"I think you pretty much learn on the job and like being obviously with them for like seven years you kind of get to know what you need to do and why you need to do that strength test is to then build up those muscles to then help you recover quicker with like a chest infection and things like that. So I think it's more learning on the job and then if you have a question you can just ask within the team." (Yasmine)*

'Learning on the job' can be a useful and beneficial training method, primarily due to its practical application and exposure to patients. Using this approach provides staff with a realistic insight into what the job entails, and the duties and responsibilities required of them. It allows staff direct contact and face time with patients in their natural working environment. Emily explains her training was 'learning on the job', which is her preference as this first-hand practical experience is absent from classroom-based learning.

> *"So, I think learning on the job is probably a lot better because you don't always, especially like I say, if you were classroom based and do qualifications, you don't always come into direct contact with patients, and patients that you would particularly see. Learning on the job you get to learn like individual cases and how you see certain patients with certain conditions and things like that… so it was just learning on the job" (Emily)*

However, 'learning on the job' may not provide the most suitable environment to learn and understand the underlying fundamentals of specific concepts and topics. Instead, it might be beneficial to allow staff a formal structured setting away from patients where they can focus, learn, and reflect on their training without the pressure of having to work

simultaneously. This would allow time for detailed and focused training. Denise describes her training experience as being thrown in "*the deep end*" and explains that learning in the presence of patients can be embarrassing as staff are seen as the educators. Elizabeth also notes that 'learning on the job' can be overwhelming when you first start, with a lot of information to absorb. This can result in failure to remember and recall information provided.

> *"Just some form of sitting down without the patients looking at you, watching you sort of going 'why don't you know this, you're meant to be teaching me and you're being taught'. Just something, even just like 10 minutes away from the patients, just like this is what we need to do, this is how we do it." (Denise)*

> *"I don't think I've got anything specific, no, it's only what I've looked up in my own spare time. Yeah, I haven't- or when you go and do rehab for the first time it's probably been mentioned, but obviously when you're doing something for the first time it's all a lot to sink in. So I'm sure people have told me, done some teaching with me, but I don't remember anything specific I'm afraid." (Elizabeth)*

It is understandable that 'learning on the job' could be the easiest method of training to implement within PR, especially considering the challenges, constraints and pressures already discussed. However, if PR struggles with limited time and high workloads, it does question if it is achievable to provide 'learning on the job' that is high quality.

3.4.7.2 Perceived Differences in Professional Knowledge and Training

PR can be delivered by different staff with varying job backgrounds (e.g. physiotherapists and nurses). This means the extent of knowledge, expertise, and prior training can vary among the team. Participants emphasise that not all staff have the same level of knowledge and understanding when it comes to delivering and prescribing exercise, particularly ST. They explain that physiotherapists have the most relevant experience, as it is usually touched on in their qualification or degree.

"I know a lot of the team are physio background and so they have like so much information with regards to the exercises." (Emily)

"So as a physiotherapist obviously we look at muscle groups and sort of well training, obviously we learn about anatomy etc. And so that with my respiratory knowledge together works well for pulmonary rehab." (Helen)

However, this is not necessarily the case for other staff, such as nurses, who are unlikely to have covered exercise programming and prescription during their education. Nurses, physiotherapists, and assistants alike note this division and make comparisons between staff knowledge and understanding of exercise.

"I'm in a luxurious situation in the sense that I feel like I've got more experience in terms of exercise. You might have say Laura who's a nurse that covers my class say if I'm on holiday, that's got no real background of exercise at all, and therefore she would struggle with something like that. She isn't going to be able to individualise somebody's exercise program, she's not a physio, she's a nurse." (Claire)

"our physios are exercise physios, you know, they've all got a lot of background whereas us nurses haven't had that." (Laura)

"I think sometimes there can be a bit of a division between physio and nurses… if you do compare yourself to a physio, they will have a much broader knowledge about the effects of one thing linking to another thing or if there's discomfort in this area it might be because of this muscle group here. Whereas the nurses will be like, I'm a respiratory nurse." (Sophia)

3.4.7.3 Staff Support for Training

Overall, the majority of participants showed support for further training related to the delivery and prescription of exercise and ST. The perceived differences in professional knowledge and training highlights the need for some staff, like nurses and assistants, to receive

additional training. If staff are delivering and supporting PR exercise, then there is a necessity to at least bring those with limited understanding and skills to a reasonable baseline level.

> *"I think it [staff training] would also benefit quite a lot of the nurses that help to run it as well because that's something they wouldn't necessarily have done in their undergraduate work as well. But yeah, I think that definitely would be something that would be really interesting, but worth doing." (Helen)*

> *"So I think as a team it's [staff training] worth looking at, but certainly we do have nurses in the team, so they do cover us from time to time." (Claire)*

In fact, participants state all staff would likely benefit from further training, as it is important to keep updated on advances in knowledge and practices. They also note this extra guidance would particularly benefit those who only deliver and assist PR programmes infrequently.

> *"Actually all of us getting a bit of an update on current exercises that are out there that actually work really well for all sorts of things from balance to strength, to everything, I think it's important to update our skills, really important." (Claire)*

> *"I think nobody knows everything and people always become complacent in their roles. I think for members of staff who have been away or only work a couple of times a week and then they come back into it and it would be very handy for them." (Maria)*

More specifically, half of participants state there is a need for additional training and improved knowledge regarding the assessing patient muscle strength. They note the success of implementing and using SA in PR is reliant on adequate training and staff having the necessary understanding to conduct it correctly.

> *"I would feel okay [using a SA]. I would feel okay with doing it, with a little bit more input with training and things I think I would be absolutely fine with*

doing that… I think most of us would probably say that more training and knowledge on it is probably what we all need within the team" (Yasmine)

"But it's like anything if you haven't had the right training or correct guidance and the constant follow up then it's not going to be any good. In fact it will be waste of time because you don't know what you're looking for, all you're doing is you're being a robot and you're just recording the results, but the more information you can get from it, the more benefit you will be." (Maria)

Aside from training benefiting staff, some participants emphasise the additional advantage it would have on patients. By staff having better knowledge and understanding this will consequently improve and advance the support they offer. As previously discussed in the theme 'Considerations and Support for Patients' (page 153), staff provide vital exercise and educational support, particularly through guidance, encouragement and explanation. Patients look to staff for information, direction, and reassurance. Therefore, specific training regarding exercise and ST will likely give staff the confidence to handle patient questions and concerns. All staff will then have the background knowledge and understanding to better the care and experience given to patients.

"it would up skill us all wouldn't it? It would make us a lot- a bit more knowledgeable and then I think that would have a knock-on benefit to the patients because then we'd be able to let them completely understand why they're doing these sorts of exercises. So yeah, I think it would just be win win for us and for them." (Sophia)

"So it would be nice to sort of be able to go into a bit more depth around how strength can improve their resilience and improve their lung health... It'd just make me more confident to know more about it as well. I know it's good, but I don't know the exact ins and outs of it." (Elizabeth)

This theme showcases some important points about staff training in PR, providing insight into opinions on different methods and the extent of further training needed within the team. A key role required of practitioners is exercise support and education, emphasising the

need for staff to have the knowledge and understanding to pass onto patients. These findings highlight potential areas which could be targeted for improvement, benefiting both staff and patients.

3.5 Discussion

3.5.1 Summary of Findings

This study provided, to the best of the researcher's knowledge, the first qualitative investigation of SA and ST in PR, from the perspective of practitioners who deliver and work in this healthcare field. In summary, ST is seen as important and beneficial within PR, and is a key part of the programme alongside other components. However, emphasis is placed on gender differences, particularly how male and female patients may perceive and accept ST as part of the exercise intervention. Additionally, participants recognise the importance of SA, and the benefits it can offer staff and patients. However, there is uncertainty regarding its usefulness and relevance within the parameters of current clinical practice.

Further reasons which may contribute to these reservations are the challenges faced when delivering PR, including time constraints, high workloads and demands, and limited equipment. Additionally, participants emphasise that the support offered within PR has to account for the physical and psychological variability among patients – which are key considerations when prescribing and delivering exercise and ST. Aside from staff support, the social group structure is noted as another important aspect, providing patients with essential peer support. Lastly, participants outline the need for further staff training, related to the prescription and delivery of ST and assessment of muscle strength. Practitioners have an essential supportive role for exercise and education, emphasising the need for staff to have the necessary training, knowledge, and understanding.

3.5.2 Theme 1. Strength Training is Important

Participants view ST as an important component of PR, positively benefiting and impacting patients. Similar perspectives are observed in practitioners prescribing exercise in oncology rehabilitation (407). Substantial evidence supports this perspective and understanding held by participants. COPD patients have reduced muscle strength (93), especially when compared to controls (100-104, 107), and is shown to decrease with disease severity (106). Muscle weakness is associated with a number of relevant COPD outcomes, including an increase in mortality (112-114) and healthcare use (115, 116), as well as reduced physical activity (117), exercise tolerance (51, 59, 118), performance of ADL (120) and HRQoL (87, 88). Therefore, it is important to build and maintain muscle strength - if not, it can have a negative impact on a patient's physical ability and prognosis. Research shows ST, either alone or in combination with AT, significantly improves muscle strength for individuals with COPD (181, 317-320). Consequently, all PR guidelines recommend and advise the inclusion of ST within exercise programmes (36, 141, 151, 154, 394). Evidence suggests that the combination of ST and AT is the optimal strategy within PR to improve outcomes overall. ST is the superior intervention to improve muscle strength, but when compared to AT it does not lead to additional benefits in HRQoL, dyspnoea, and exercise capacity (394). Some participants demonstrate this understanding, as although a positive attitude and consensus is held towards ST, some argue it is not 'the be all and end all' - there are other components of importance which require time and attention as well. This emphasises the need for ST, or any new components, to benefit and compliment other PR aspects.

Within this theme, a sub-theme outlined the observation of gender differences among patients in response to ST. Participants observed that muscle strength and ST is potentially more important to men than women, with men more likely to want to do ST whereas woman

are less inclined. Similar findings are reported by Witcher et al. (397), which explored staff perceptions of factors affecting PR exercise participation among individuals with COPD. Results revealed perceived differences between male and female patients, particularly regarding the approach to exercise. Women required more encouragement and support, whereas men were more willing to use and increase load. A reason speculated for this is that women of an older population lack exercise experience and familiarity, whereas men are more willing as it is seen as an inherently and natural part of being a man. The present study reported similar observations of patients holding 'old-fashioned' views of gender stereotypes. These observations are supported in part by Papp et al (216), who explored the experiences of physical activity and exercise among women with asthma and COPD. Gender roles of women were described as a hinderance to exercise, with many taking on the care responsibility of others, suggesting a need to include a gender perspective when promoting exercise to women – a potentially relevant proposal for ST in PR.

There is limited research investigating gender differences related to attitudes and experiences of ST in COPD populations. However, research conducted with general populations prove insightful. A systematic review and meta-synthesis conducted by Vasudevan and Ford (445) investigated motivational factors and barriers towards initiating and maintaining ST in women. A frequently observed barrier within studies were gender-based stigmas and segregations, for example that ST is reserved for men and is perceived to be a more masculine activity. This evidence suggests that although gender difference is only touched on briefly within the present study, participants views of gender differences related to ST do hold substance. Therefore, consideration should be had for how ST is presented, explained, and delivered to PR patients, particularly to women. It is important to ensure correct messaging is provided to patients during PR, aiding behaviour change both physically and mentally to

support exercise and ST continuation beyond the programme. Further research investigating gender differences related to ST in COPD and PR is warranted. In particular, a focus on the barriers and facilitators experienced by women in this setting, the messaging used throughout PR, and the dissemination of accurate information to counter misconceptions and increase understanding.

3.5.3 Theme 2. Is assessing patient muscle strength important?

This theme presented contrasts in participant views about SA in PR. The importance and benefits were acknowledged and recognised, yet uncertainty was expressed regarding the usefulness and relevance within current PR practices. Perceived SA benefits included the provision of a safe and individualised guide for ST, a method of tracking programme effectiveness and patient improvement, and the potential to help patient motivation. As discussed in Chapter 2 (page 53), there are a variety of different methods for assessing muscle strength (230). Specifically, this PR service used a m-RM test to predict 1-RM (using Epley's formula), which was subsequently used to prescribe an individualised load and progressive ST programme for the bicep curl exercise (298). PR guidelines in the UK emphasise that exercise and ST should be individually prescribed and progressive (36, 141, 151, 154, 394), which can be achieved by assessing strength. One perceived benefit of SA is the potential to motivate patients throughout the PR programme, with adherence and completion of exercise sessions influenced by awareness of re-assessments and experiences of improvements in health and physical function. This observation is corroborated by previous research, with improvements in health outcomes facilitating patient motivation and thus treatment completion (446, 447). Stone et al. (448) identified that any patient who experienced an exercise test as part of their initial consultation for PR were more than three times likely to complete the programme. Furthermore, Reijnder et al. (449) found patients who showed a stronger decrease in disease-

specific fears improved more in PR outcome measures. Future exploration of patient perspectives and experiences would be valuable and complementary to the present study's findings.

A repetition maximum test (e.g. m-RM or 1-RM) is a comprehensive SA, and unlike other methods can be utilised for both exercise prescription purposes and as an outcome measure (235). They are shown to be safe and well-tolerated by COPD populations, with no adverse effects (240). A m-RM test is considered easier and more feasible when compared to a direct 1-RM test because it is less time consuming and does not require the individual to lift maximum weight, which may be more appropriate for untrained individuals who are unfamiliar with ST protocols and practices. However, a main caveat is having the necessary exercise equipment available to perform a repetition maximum test. Consequently, this could be a determining factor for why a bicep curl SA is conducted in this PR service, as there is limited equipment at the site of conduction. It could be argued that the bicep muscle is not the most relevant for assessing strength in COPD. Upper body strength is reported to be better preserved compared to the lower body (143), with literature emphasising the importance, relevance, and priority of lower limb strength in COPD, specifically the quadriceps (394). Quadricep strength is seen as an important systemic marker for COPD (394), and is often used as an outcome measure in related research studies (234). This questions the suitability of a bicep SA in PR, especially as research has shown mixed results regarding the responsiveness of upper body strength to ST programmes (181).

Although Barlow et al. (298) did report significant increases in bicep strength using the predicted 1-RM and prescription method, no control group was included for a comparison. Furthermore, it is not clear how only assessing and individually prescribing load for a bicep

curl exercise translates to the prescription of other ST exercises - contributing to some participants uncertainty. This surfaces further questions as to why this SA is being used, how it is being used, and if it being used effectively. However, assessing quadricep strength using a m-RM or 1-RM can be challenging when equipment is restricted. Many studies and reviews describe the measurement of knee extension strength using weighted machines (110, 234). However, such equipment is not a frequent commodity in PR services (164). Instead, a bicep curl m-RM is likely to be easier and more feasible in a PR setting, if the minimum equipment needed is available.

Another reservation participants held was how SA fits into a patient assessment and the outcome measures already used. The primary assessment of physical function in PR is functional exercise capacity, measured using walking tests (e.g. ISWT, 6MWT) (314, 315). There is lots of guidance and agreement regarding the use and conduction of these walking tests, with clear standardised guidance and instructions for use in PR clinical practice (450, 451). However, this is not the same for the assessment of muscle strength. Although assessing strength is advocated in PR guidelines and relevant literature, there is markedly limited guidance on which SA should be used and how to use it. Emphasis is placed on the chosen measurement being accurate, sensitive, and reliable (234), however there is little consideration for feasibility within PR and the variation in settings and circumstances of services. Most reviews provide their own recommendations for clinical practice, such as a strain gauge (93, 231) or a HHD (228, 234). However, as reported by the NACAP PR audit, of the 41.2% of services in England which assessed strength, the most used method was a 1-RM or 5repS2S (164) – a stark contrast to the literature recommendations. Consequently, in light of vague and inconsistent guidance it is not surprising to find participants are uncertain of SA use in PR. Research has shown that the attitudes and beliefs of HCPs can influence clinical practice and

decisions, such as the uptake and adherence of guidelines (452, 453). This emphasises the influence practitioners hold, further promoting the importance of clear guidance and PR-specific resources, as well as how it is disseminated and accessible to services. Despite limited guidance, the prevalence of SA is slowly increasing in PR services in England (164, 166, 385), demonstrating that PR guidelines need to catchup with current practices. Further research is needed to assess the feasibility of different SA methods in PR settings, as well as the development of clearer and updated guidance and resources for the implementation and use in clinical practice.

3.5.4 Theme 3. Challenges for pulmonary rehabilitation and strength assessment

A number of challenges experienced by PR practitioners were stated, which were also perceived barriers for the implementation and use of SA in clinical practice. Specific factors included limited equipment, time constraints, and high workloads and demands. Organisational, environmental, and external barriers like these are frequently reported in related research studies, particularly the implementation of interventions, such as exercise training (395, 407), establishment and delivery of rehabilitation (396, 405), self-management strategies (403, 454, 455), a standard set of COPD outcomes (400), a patient needs assessment (406), and use of hand-held fans (398) and spirometry testing (399, 401, 456).

As discussed above, equipment access and availability is likely to determine which SA method is chosen and used. This particular PR service had varied equipment across all three sites, meaning the implementation and standardisation of SA is not feasible unless additional equipment is provided. Obviously, a key determinant, and thus barrier, to assessing muscle strength in PR is actually having the equipment needed, whether this be exercise equipment or

specific SA devices/apparatus (230). Other studies have reported this same barrier as a hindrance for spirometry testing (456), implementation of a hand-held fan intervention (398), and use of a standard set of COPD measurement instruments (400). However, even if equipment is available, time constraints and workplace pressures can still hinder use. This PR service previously participated in a study which incorporated individually prescribed 1-RM training loads, where one site assessed bicep strength and another site assessed quadriceps strength (298). In the current study, participants explained that although a leg extension machine was available to assess quadriceps strength, this assessment was not sustained due to time restrictions. Throughout this study discussion and concern regarding service-related barriers, such as time, workloads, and demands on staff were paramount. It is evident that that these challenges are widely experienced and reported within healthcare research, with limited time named as a common barrier (396, 398-401, 403, 454, 455), for example restrictions due to limited consultation times (406) and increased time and workloads for setting up exercise sessions (395).

It is important to consider how long it takes to conduct a particular SA, as some are more time-consuming than others (230). However, it is also vital to consider how the implementation and use of SA impacts clinical practice and the staff involved. Literature has primarily investigated and discussed SA methods in terms of validity and reliability (228, 230-232), but more focus and investigation on ‘real world’ feasibility and stakeholder acceptability is needed, for example integration into the existing PR framework and the adjustments and resources needed to successfully achieve this. PR guidelines recommend SA (141, 151, 154), but consideration is needed for how PR services can successfully fulfil this in clinical practice – guidance should reflect the variability among PR services.

3.5.5 Theme 4. Considerations and Support for Patients

The importance of support in PR and exercise sessions is emphasised, particularly the role and impact practitioner support has on physical and psychological patient factors. When prescribing individualised exercise, practitioners must consider the physical limitations and ability of their patients. A strategy described by participants is the modification and adaption of exercises to ensure they are manageable and achievable. However, it is also important to individualise exercises on the basis of adequate and effective intensity, with a particular focus on progression, as outlined by PR guidelines (36, 141, 151, 154, 394). ST is shown to be safe and well tolerated by individuals with COPD (181-183), but physical limitations and comorbidities are still reported as barriers (446, 457, 458). It is very common for COPD patients to have multiple comorbidities (16), however many studies exclude individuals on these grounds. A recent Cochrane review concluded there is a lack of data from clinical trials on treatments for people living with COPD and comorbidities (459). Patient physical limitations and comorbidities may be a barrier to ST, but it is still possible to prescribe strength exercises for a range of conditions (235). Exercises should be adapted around other health issues, while still ensuring individualised and effectively prescribed intensities.

Another important role of PR practitioners is providing educational, psychological, and emotional support to patients, particularly for exercise. Many people with COPD experience anxiety and fear exercise will exacerbate their condition and their breathlessness (66, 73, 74). One study found women with COPD also had fears and insecurities about errors and incorrect performance of exercises, which could be mitigated through repeated instructions and feedback from instructors (216). Therefore, reassurance and encouragement from staff is important so patients understand that exercise is possible and achievable (454). Sufficient exercise explanations are also shown to lead to increased patient engagement (404). PR practitioners

must be aware of patient concerns and implement strategies to counter these. Another important aspect of support is the structured PR environment. In this study, participants believe patients benefit from the organised structure of the programme, as it is deemed a safe and controlled environment for exercise. Similar findings are found in previous research, with emphasis placed on the safety and supervision provided by HCPs during PR and exercise programmes (195, 215, 460). Support from HCPs aids patients in exercise adherence with one study reporting that it inspired patient confidence in their ability to exercise with minimal or no supervision (215). However, this is not always the case with another study reporting that some patients still needed support from physiotherapists for motivation and safety, stating they were not confident continuing to exercise without supervision (219). It is evident that when it comes to prescribing and delivering ST and exercise in PR, that consideration is needed for both the physical and psychological limitations of patients. Staff support is multifaceted, emphasising even further how important and influential their role is. Therefore, it is important practitioners have the understanding and training needed to support patients during PR, but also helping arm patients with the tools needed to self-manage their condition beyond completion, which includes continued exercise and ST.

Aside from staff support, perceived benefits of the group structure is also reported, providing an opportunity for patients to support and socialise with their peers. Previous research has also identified the importance of these social relationships in PR, particularly for coping, motivation, and adherence (215, 216, 219, 446, 460-462). A key factor of this social environment is being around others with similar conditions, where feelings, experiences, and advice can be shared (461, 463). The majority of research has focused on the patient experience of social support, but HCPs also recognise the social benefits, such as connecting and creating bonds with others who share similar circumstances (397, 461, 464, 465). However, there are

negative implications which practitioners should be mindful of, for example patients feeling uncomfortable or self-conscious while exercising in a group setting (463), or negative perceptions due to social comparisons (466). Although, an element of comparison could provide an incentive to work harder and complete the training programme (458). Even if exercise and ST is individually prescribed to patients, it is also important that time and care is taken to ensure patients understand what this means and why it is important to adhere to the programme prescribed to them.

3.5.6 Theme 5. Practitioners Need for Training

Participants describe the need for further training related to ST and SA in PR, outlining the predominant method of workplace training is 'learning on the job', as well as the potential differences in professional knowledge and training within the team. Limited staff training, knowledge, and understanding is a common barrier reported when investigating and evaluating interventions within COPD and PR, for example, the use of behaviour change interventions (402), exercise training (395), self-management interventions (403, 455), referral and promotion of PR (464, 467), and even provision of UK cardiac rehabilitation (405). The samples of these studies include a variety of healthcare professions, such as physiotherapists and nurses, demonstrating the presence of this barrier across a number of practitioner groups. A frequently suggested solution is the development and utilisation of bespoke and formal training interventions, which can produce positive results, but consideration is needed for implementation and practical factors, such as time (468, 469).

Formal or specific training related to the prescription and delivery of ST was limited within this sample, with training predominately 'learning on the job'. As described by Watkins and Marsick (470) workplace learning consists of formal and informal learning. Formal

learning is structural teaching with specific goals, whereas informal learning typically occurs through observation and experiential opportunities in the working environment (i.e., 'learning on the job'). Informal training, or 'learning on the job', is beneficial by providing practical experience and application in the clinical working environment, along with direct contact and interaction with patients (471). However, it heavily relies on the knowledge and understanding of other staff and colleagues, and may not be the most suitable method to allow for reflection and in depth understanding of the underlying fundamentals of a topic (471). Similar findings were reported by Whittaker et al. (402), who explored NHS HCPs experiences of using behaviour change interventions in pulmonary and cardiac rehabilitation. Findings revealed there was also a reliance on experiential learning, with competence in delivery reliant on colleagues and previous training received (e.g., at university). If this is the case in PR, then it is important to consider what previous training and education staff have received, and how long ago it was completed. In the current study, differences in professional knowledge and training were highlighted, particularly comparisons between physiotherapists and nurses. Previous training and education curriculums could vary drastically, especially depending on professional background and job role. On average, participants had worked in PR for 5 years, therefore if no formal standards of training are provided many are relying on previous education from years ago. Not to mention that this previous training is unlikely to be specific to COPD populations or PR settings. Workplace learning is shown to directly link to employee job satisfaction in the NHS, with frequent, formally scheduled departmental teaching enhancing staff job satisfaction (472). Therefore, by focusing on workplace learning *and* organised education, it can increase satisfaction, as well as knowledge, beliefs, and clinical practice behaviours (468).

This is not to say that 'learning on the job' is unsuitable, but it is emphasising the need for such training to be relevant and high quality. All training is not equal and 'learning on the

job' does not guarantee correct and adequate teaching due to variations in staff practices. This was demonstrated among Australian PR HCPs conducting the 6MWT (396), and general practitioners performance and interpretation of spirometry testing (401). Regardless of which method of training is used, either formal or informal, it needs to be the 'right' training, which is high quality and relevant to the patient population and clinical setting. PR guidelines state practitioners should have relevant expertise and adequate training when prescribing, supervising, and delivering ST (31, 53, 141). Therefore, if PR programmes are assessing muscle strength, and prescribing and delivering ST, then staff should be adequately trained. These study results suggest that this responsibility falls to PR services, as reliance on previous education and informal workplace learning may not be appropriate alone. Other findings from this study support staff training and the positive impact it could have on clinical practice and patient care, for example increasing practitioner understanding and decreasing uncertainty, as well as providing support to patients by passing on this understanding through education, support, and appropriate messaging. Future development of a training intervention, in collaboration with PR stakeholders, could positively impact the implementation and use of SA and ST in PR programmes.

3.5.7 Strengths and Limitations

The strengths of this study include exploration of SA and ST in PR from a practitioner perspective, which to the best of the researcher's knowledge, is the first qualitative investigation in this specific area. It has identified specific factors which help and hinder the use of SA and ST in PR clinical practice, outlining areas which can be targeted in future interventions and clinical practice. Importantly, it emphasises the value of practitioner involvement and collaboration in research. HCPs are the frontline workforce in healthcare

services, like PR. They have ‘real-world’ experience, which offers an important source of insight and information.

Although the sample size target of 12 participants was not reached, the final sample size (*n*=11) was deemed sufficient to fulfil the study aims within the parameters of the project. A sampling limitation was the recruitment of only female practitioners. Exploration of male practitioner perspectives and experience could have offered additional and varying data. However, only females exclusively worked in this PR service, meaning recruitment from another service would have been required. Finding and recruiting another service and their staff would have required more time and resources, which was not feasible within the timeframe and circumstances of this research project.

Initially, the interviews were going to take place face-to-face, however due to the Covid-19 pandemic and restrictions placed on person-to-person contact, an amendment was submitted changing the method of conduction to remote video calls. Although this offered convenience for both parties, it does eliminate the benefit of seeing non-verbal cues and establishing enhanced rapport prior to the interview commencing. Relatedly, participants were asked to discuss clinical practices retrospectively, recalling SA and ST use in PR before the Covid-19 pandemic. Interviews took place 4-5 months after the start of the pandemic, and therefore recall bias could be present. Lastly, to ensure full transparency, ‘member checking’ or ‘respondent validation’ was not conducted in this study. This strategy involves asking participants to comment on the analysis and/or findings, which can be used to enhance validity and credibility of qualitative research (413, 443). Although this can be a useful way of further engaging participants in the research process and ensuring representation, it is not always feasible or appropriate. Typically, such procedures are situated within a realist framework,

underpinned by the assumption of a single true reality that can be discovered by the researcher and confirmed by the participants. This is not in keeping with the critical realist position of the study, which states that people experience different aspects of reality and can only provide a partial account mediated through their perceptions, interpretations, and experiences. As a result, this may cause a dispute as to whose interpretation should prevail if participants were to disagree with the researcher's findings. In addition, it is possible that participants could provide accounts during the interview stage that they later change or deny in response to this new information. Overall, this technique was not deemed appropriate with the qualitative methods utilised, as well as practical and pragmatic challenges, such as requesting more time from practitioners and having enough time to complete it within the project's timeline.

3.5.8 Study Implications and Future Research Recommendations

This study has a number of implications for PR clinical practice and future research. Further understanding has been gained about the implementation and use of SA and ST in PR, identifying specific factors for consideration and improvement. This can help services who are already assessing strength to reflect on current practices, as well as services looking to introduce a SA in the future. However, further research investigating the feasibility of SA in 'real-world' clinical practice is warranted. Presently, PR guidelines and relevant literature offer limited advice and recommendations for PR services, with little recognition for the variation in settings and resources. These study findings can be used to inform and develop future research and interventions, for example feasibility trials or guidance resources for use and application. Additionally, further exploration of stakeholder perspectives and experiences would be beneficial, for example patients, male practitioners, services which use different SA methods or take place in different settings, and even practitioners from services who do not assess strength. Data from a variety of sources will further shape understanding and provide

scope for more generalisable and applicable findings. Involvement and collaboration with service stakeholders in future research is recommended to ensure targeted and relevant investigation. Additional areas of focus include staff training, for example the development and evaluation of a training intervention (e.g., educational resource). Importantly, this study highlights the challenges healthcare services face and the impact it has on practitioners and their patients. These findings are relevant to other rehabilitation programmes (e.g., cardiac and oncology rehabilitation), and healthcare areas which assess patient muscle strength or those which may benefit from assessing strength.

3.5.9 Researcher Reflections: Self-Reflexive Statement

Self-reflexivity is an important part of conducting qualitative research, particularly reflexive TA, and is integral for study transparency. The researcher should consider how their own background, views, and experiences may have influenced the research process and explicitly outline their positionality within the qualitative research conducted. My educational background is based within the field of psychology, through the completion of an undergraduate degree in psychology and a postgraduate degree in health psychology, as well as professional experience routed within a research setting. Therefore, I am not a physiotherapist, nor am I a practicing healthcare professional. My past experiences are restricted to research conduction and interactions with research participants, not with patients or within a working healthcare setting. Furthermore, my knowledge and experience of pulmonary rehabilitation was limited before I started this research project. I feel this was a benefit to the study as I did not have prior experiences or ideas about this healthcare service, placing me in a position of exploration. I wanted to learn and gain knowledge from the practitioners and patients to further influence the subsequent research being conducted within this project. I also feel my psychology background was advantageous, as my way of thinking

naturally goes beyond the practicalities and function of a phenomenon, with consideration for the individuals involved and the intangible influences that can be present. However, due to my minimal experience of this healthcare area, this may have limited the depth of understanding and interpretation, and the avenues explored, throughout the stages of this project. The design, analysis, and interpretation of these qualitative studies may have resulted in different outputs if it was carried out by a physiotherapist or PR practitioner.

However, I did have experiences and views about the specific subject matter of interest (i.e., ST), and therefore I believe my own views and experiences of ST will have influenced the collection and interpretation of the data. ST is an important and enjoyable part of my life, and an exercise modality I am relieved to have found. I am an advocate of ST and have firsthand experience of the benefits it can offer - physically and psychologically. Consequently, at times during the study process, I found it challenging to stop my thoughts and feelings from influencing my reactions and interpretations, particularly when differing opinions were expressed. Therefore, I made a conscious effort to remain neutral and welcoming of any views during data collection and analysis – both positive and negative.

One event, in particular, further emphasised the need for such awareness. During an earlier interview, one participant (Denise) stated that she knows I am in support of SA and ST, but that she felt differently. I was not aware that I had given off that impression. In later interviews, I made sure to emphasis to participants that this study was interested in all opinions and views, and that their accounts were important regardless. Furthermore, at the start of data analysis, I noticed I had the tendency to overcompensate for my positive perspective by focusing more on the negative and difficulties experienced in PR clinical practice. Taking reflective notes allowed me to notice this pattern early on. Upon this realisation, I paused

analysis and went back through the transcripts and codes with this in mind. This allowed me to view all data with a fresh perspective, ensuring I was not giving more weight to the negative or positive, but instead giving all data equal attention and consideration.

3.6 Conclusion

This study provides insight and understanding into the use and impact of SA and ST in a PR programme, from a practitioner perspective. Overall, participants express positive views and opinions of SA and ST, recognising the importance and benefits they offer services and patients. However, a number of factors were identified as hinderances, including uncertainty of SA in current practices, the need for staff training, physical and psychological limitations of patients, and service-related barriers (e.g., limited time and equipment). These findings emphasise the need for these factors to be considered in PR clinical practice when implementing and using a SA, and prescribing and delivering ST.

Chapter 4. A qualitative exploration of patient perspectives and experiences of strength assessment, strength training, and exercise in pulmonary rehabilitation

4.1 Chapter Overview

This chapter explores patient perspectives and experiences of SA, ST, and exercise in PR. A qualitative study design was taken using semi-structured interviews, and analysed using reflexive thematic analysis. Twelve patients took part who had successfully completed a PR programme. Six themes were constructed: 1) Understanding and perceptions of strength training, 2) Strength is important for daily function, 3) Usefulness and relevance of a strength assessment, 4) Staff support and exercise facilitation (during PR), 5) Psychosocial benefits of pulmonary rehabilitation, and 6) Exercise adherence and challenges (after PR). Overall, participants demonstrated misunderstanding and misconceptions about ST, and named daily function as an important outcome and drive to improve muscle strength. Participants showed mixed views towards SA, with some recognising its advantages and others questioning its relevance. Staff and peer support were identified as facilitators of exercise, although the absence of support, supervision, and structure was a challenge for exercise adherence after PR, highlighting the potential lack of education and support focusing on independent exercise.

4.2 Introduction

In Chapter 3 (page 108), practitioner perspectives and experiences were explored, but it is also important for research to involve and reflect other stakeholders, particularly patients.

However, there is limited research exploring patient perspectives and experiences of SA and ST in PR specifically.

Regarding ST, studies have investigated patient perspectives and experiences in similar areas and contexts, for example, exercise programmes and interventions (215, 216, 219-221), experiences of PR (157, 216, 461, 473, 474), and exercise after PR (218, 397, 475). However, some fail to report sufficient detail of exercise programming, providing no indication if ST is included (219, 461, 475). Whereas others do not investigate or collect data related to ST specifically, despite it being an included component in the exercise programme (215, 216, 397). The studies most relevant to ST include those published by O'Shea et al. (220, 221), Meshe et al. (215), and Papp et al. (216). These provide useful insight and understanding from related contexts, particularly physical, psychological, and social benefits.

Two key studies, published by O'Shea et al. (220, 221), explored qualitative outcomes and factors affecting COPD patient adherence to a 12-week progressive resistance exercise programme (476). Participants (*n*=54) performed six exercises using resistance bands (Therabands™) three times per week, once in a hospital-based setting and twice at home. However, low completion rates (44%) were reported, indicating health issues and participant ability and willingness are influential factors that are just as important as intervention efficacy. The authors stated that strategies to maximise exercise adherence after periods of illness need to be considered by clinicians when prescribing progressive resistance exercises in this patient population. Following this exercise intervention, participants (*n*=22) reported improved strength and dyspnoea during daily activities, improved confidence, and the benefit of social support during the group training sessions (220). Short-term exercise adherence was facilitated by expected outcomes, self-motivation, supervision, and group support, whereas health issues

and the weather were identified as major barriers (221). Removal of environmental support at 12 weeks was a key factor and may have contributed to poor exercise maintenance, with participants identifying group support and regular monitoring by HCPs as important factors. Similar findings have been reported in other studies with COPD patients (215, 216, 218, 219, 397, 461, 475) , as well as other chronic respiratory conditions, such as interstitial lung disease, pulmonary fibrosis, asthma, and bronchiectasis (157, 219, 473, 474, 477), and healthy older adults (478-480). Although O'Shea et al. (220, 221, 476) conducted relevant research on ST for COPD, it was not PR-specific. The resistance exercise programme shared some similarities with the structure of PR exercise but does not reflect current UK clinical practices.

More recently in 2020, Meshe et al. (215) conducted a study in England that aimed to understand COPD patient (*n*=12) experiences of the benefits, barriers, and facilitators of attending a supervised community-based exercise programme, which included ST and AT. Patients were referred to this after completion of an 8-week hospital-based PR programme. Facilitators included ease of access, perceived benefits, convenient programme components, and social support. Identified barriers were poor physical health, family commitments, and transport difficulties. The authors concluded that supervised exercise motivates participants to attend and exercise regularly, with sustained adherence preventing a decline in perceived health benefits. Despite including ST in the programme, the study did not investigate or discuss ST specifically. Nevertheless, it provides useful insight into patient experiences of an exercise programme that included ST - particularly one that is similar to recommended PR exercise in the UK. Similar findings have also been reported by McNamara et al. (219), who explored the experiences of other chronic respiratory conditions (e.g., bronchiectasis, lung cancer, pulmonary fibrosis, and asthma) in response to an 8-week supervised community-based rehabilitation exercise training programme. Particularly, that patients perceived benefits of

improved fitness and physical function, and emphasised that the social interaction provided motivation and facilitated adherence to the exercise programme. However, this study too lacked sufficient detail about the exercise programme and the inclusion of ST.

Another study, conducted by Papp et al. (216) in 2022, explored how women with COPD or asthma (*n*=15) experienced PR to promote physical activity, which included either strength and endurance training, or a yoga exercise programme. Findings revealed that participants wanted to exercise in their daily lives, and that support from family, HCPs, and other participants had a positive effect on motivation. However, there were several barriers identified, including health problems, insecurity, time, and the weather. Although the study only included women, it offers some insight into patient experiences of varying exercise programmes in PR, and shows similar experiences and barriers are reported from patients with other chronic respiratory conditions (i.e., asthma). However, the primary focus was on the promotion of physical activity after PR, not on the exercise programmes themselves, such as ST.

Although this literature does not specifically explore ST in a PR context, it does provide some insight and understanding into patient perspectives and experiences in related contexts. There are a number of overarching findings mirrored throughout these studies which are likely relevant, with physical, psychological, and social factors reported. These include health and physical benefits (e.g. strength, breathlessness, and performance of daily activities) (215, 218-221, 461, 475), patient motivation and confidence (216, 218-221, 397, 461, 475), and support from peers and HCPs (216, 218-221, 397, 461, 475). In particular, a common discussion point and challenge reported throughout this body of literature is patient adherence and continuation of exercise after PR programmes and exercise interventions (215, 218-221, 461, 475). These

findings have been reported within COPD populations, but also among patients with other chronic respiratory conditions (e.g., pulmonary fibrosis, asthma, bronchiectasis, and interstitial lung disease) (157, 219, 473, 474, 477), showing similar experiences and barriers may be widespread across the populations who participate in PR and exercise programmes. However, it is evident that literature is lacking investigation and exploration of patients experiences of ST in PR specifically.

Regarding SA, some research has explored the views of stakeholders, which include patients. Verburg et al. (400, 481, 482) set out to develop a standard set of outcome domains and proposed measures for COPD, providing an outline of quality indicators. In 2019, an eight-step consensus study (481) was conducted, which collected data using survey and interviews methods from relevant stakeholders in Dutch primary care practice (e.g. patients, physical therapists, researchers, and policy makers). Five outcome domains were selected for COPD that included muscle strength, specifically quadriceps strength measured using a HHD (Microfet™). This domain gained 100% consensus for inclusion in the final outcome set. Despite patients (*n*=9) being included in the development process through the use of semi-structured interviews, involvement was minimal, with data primarily collected from experts and HCPs representing patients with COPD. Findings from the patient interviews did not address the topic of muscle strength, but it did emphasise important requirements for quality treatment and care, such as the need for facilities to be adequately equipped for exercise, being coached by well-educated and specialised practitioners, and a focus on patient-centredness.

Contrary to this, Souto-Miranda et al. (314, 465, 483) reported different results regarding the measurement of muscle strength in PR. They set out to develop a core outcome set for PR in patients with COPD to generate consistency and decrease risk of bias in research

studies, by standardising outcomes. Similarly, data was collected from relevant stakeholders, such as patients, HCPs, researchers, and policy makers. An initial qualitative study (465) using semi-structured interviews was conducted, which identified a list of 44 outcomes from PR, such as 'improving functional performance' and 'reducing and taking control over dyspnoea'. Outcomes were only recorded if mentioned spontaneously by participating stakeholders during interview. Muscle strength was not mentioned or addressed, meaning it was not represented within the outcome set at this initial stage of development. However, subsequent studies within the project, which included a systematic review (314) and a multicentred qualitative interview study (483), led to its inclusion represented by the measure of handgrip strength. This was mentioned by about 20% of stakeholders – of which none were patients. However, a focus on handgrip strength is contradictory to PR guidelines and evidence, which stress the importance of quadriceps strength in COPD (33). Results revealed conflicting views within and between stakeholders for a number of outcomes, which included muscle strength, where some people considered it crucial and others not. Similar to Verburg et al. (481), patients with COPD did not contribute significantly to the discussion. Findings revealed patients were less vocal about measurements and had no strong opinions on the best measures used, stating they felt assessments were well-chosen by their HCP. Importantly, participants expressed outcomes need to be meaningful to people with COPD and show the benefits of PR.

There is markedly limited research exploring patient perspectives and experiences of PR outcome measures, particularly muscle strength. Available literature primarily investigates, discusses, and reviews SA methods in relation to measurable qualities, such as validity, reliability, and efficacy, and is predominately presented from the viewpoint of HCPs, researchers, and experts (228, 230-232). However, SA could benefit patients beyond individualised training and metric properties, as improvements in health outcomes can facilitate

motivation and thus treatment completion (446-448). It is recommended that patient involvement is needed in future research to determine outcome measures used in PR, with a focus on what is valued by patients(483).

In summary, there is markedly limited research investigating patient perspectives and experiences of SA and ST in PR. The literature provides some insight but focus and contexts of these investigations are contrasting. To the best of the researcher's knowledge, a study specifically investigating patient perspectives and experiences of SA and ST in PR has not been conducted before. Therefore, this study aims to explore patient perspectives and experiences of PR, with a particular focus on SA, ST, and exercise. It aims to gain understanding of the impact of these on patients and identify potential barriers and facilitators. By gathering this information it will help inform future research and discussions regarding the implementation and use of SA, and the delivery and prescription of ST, in PR.

4.2.1 Research Aims

This study aims to explore:

- Patient perspectives and experiences of strength assessment, strength training, and exercise in pulmonary rehabilitation
- The impact of strength assessment, strength training, and exercise on patients
- Factors which help and hinder the use of strength assessment and strength training in pulmonary rehabilitation

4.3 Methodology

4.3.1 Study Design

A qualitative study design was used with semi-structured interviews. The same methodology was chosen and conducted as described in Chapter 3 (page 113). One-to-one interviews were conducted as it allows for in-depth exploration and discussion, and eliminates the influence of other participants and stronger characters on what is said and shared (417, 418). Focus groups could have been an alternative data collection method, but due to restrictions on person-to-person contact (Covid-19 pandemic), these would have required conduction via video call. However, this was not possible as many participants did not have a computer or the technical knowledge to use videocall software. Similarly, this study adopted a critical realist ontology and contextualist epistemological position. PR can be argued as being a real and true reality. It is a healthcare service and intervention programme with a specific and determined format, dictated by standards for structure and content. Patients who attend PR experience this structured format, but will have their own subjective perspectives and experiences. Context is important as PR is the anchor in which the study was designed and conducted, and which the findings will be applied. Furthermore, patients are usually of an older demographic and are living with a chronic respiratory disease – this context matters so the findings can be applied appropriately. This study is investigating SA, ST, and exercise within the context of PR, but exploring and appreciating subjective accounts of this. It focused on people and objects (realism), but also considered perspectives and experiences (relativism), as a result a critical realist position was appropriate, with emphasis on the contextual nature of how knowledge is created and produced.

4.3.2 Sample

4.3.2.1 Participants

The study sample were patients who had completed at least one PR programme. The sampling technique was purposeful, with all prospective participants recruited through a local PR service. A description of the PR service context and setting is provided in Chapter 3 (page 118). Patients are eligible for PR if they have a chronic respiratory disease with persisting symptoms and an MRC dyspnoea score of grade 3 or above (33, 143, 156). The majority of patients referred have a diagnosis of COPD, but PR is also an appropriate intervention for other chronic respiratory diseases, such as pulmonary fibrosis and bronchiectasis (141, 149, 158, 159).

4.3.2.2 Inclusion and Exclusion Criteria

The inclusion criteria specified all participants must be ≥18 years, willing to participate in a recorded interview, capable of making their own informed decisions, and able to speak and understand English. Participants must have completed at least one PR programme before the interview took place, specifically completing the baseline and final assessments. This was determined using the same PR service criteria of a 'successful completer', classified as attending 75% or more of PR sessions (36). The exclusion criteria specified people who were not successful completers, and anyone who was taking part in any conflicting study.

4.3.2.1 Sample Size

Twelve participants was deemed suitable and thus aimed for. Determination of this target followed the same considerations as outlined in Chapter 3 (page 120).

4.3.3 Research Procedure

4.3.3.1 Recruitment and Study Process

Recruitment took place between 23rd June and 6th August 2020. A flow chart of the patient recruitment process is presented in ***Figure 7***. Participants were recruited from three PR sites managed by a local PR service. Initial contact was carried out by a practitioner of the PR team via phone. Potential participants, who had successfully completed a PR programme within 2-3 months prior to the pandemic (i.e., before March 2020), were contacted to inform them of this research opportunity, to provide study information, and gauge interest. If interested, they were given the option to either contact the researcher directly themselves or give consent for the practitioner to pass their contact details on. Predominately, the latter was chosen. Once initial contact was made between the potential participant and researcher, the PIS (Appendix P) was sent, with consideration for preference and circumstance (e.g., via post or email). To ensure further ease, the researcher offered to get in contact a few days later to check the PIS had been received and to answer any further questions. Once confirmation of interest was received, eligibility was screened using the study inclusion and exclusion criteria. This was carried out either by phone or email and took no more than five minutes to complete. If eligible, informed consent was then obtained (Appendix Q), after which details of the interview (e.g., date, time, and method) were arranged to suit the participant.

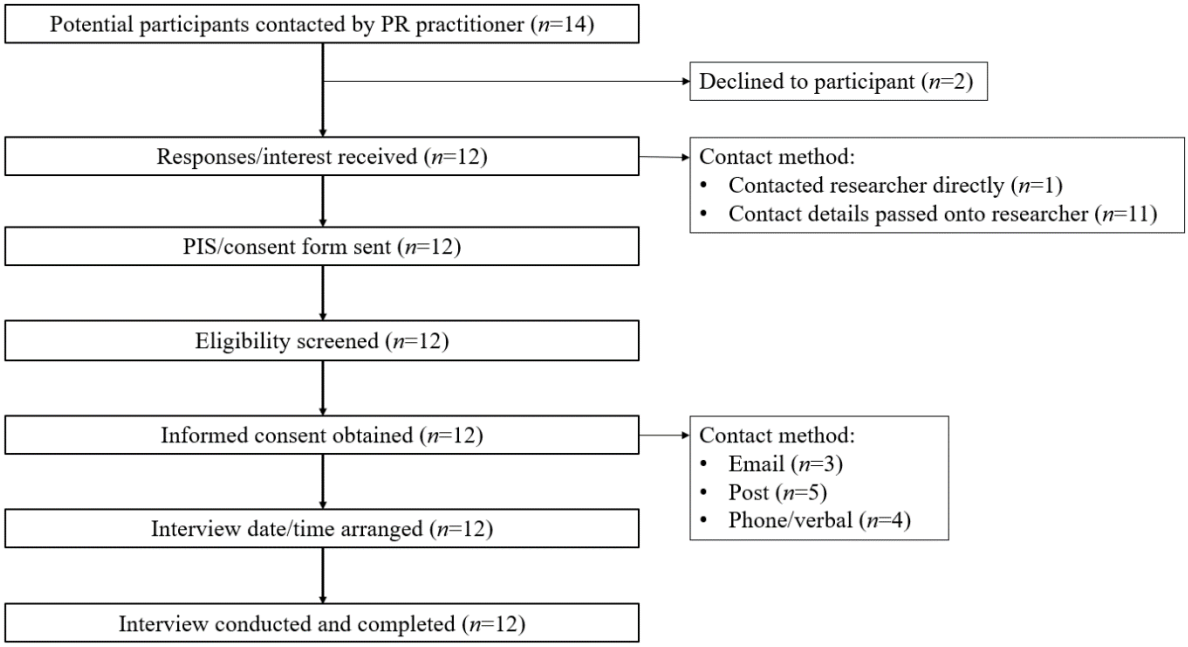

Figure 7. Patient Recruitment Flow Chart

4.3.3.2 Data collection

Data was collected from 10th July to 6th August 2020, and all interviews took place via telephone. The average interview length was 50 minutes (*SD*=17), ranging from 29 to 86 minutes, and was audio recorded using a Dictaphone (SONY ICD-PXA70 digital dictation machine). If required, notes were made during the interview. Following each interview, the audio recording was downloaded from the device and stored in a safe and secure folder on the cloud-based platform 'Box' (Box, Inc), with access restricted exclusively to the researcher. The original recording was then permanently deleted.

4.3.3.3 Ethical Considerations

Ethical approval was requested and granted within the same ethics applications submitted for the study in Chapter 3 (page 122). All the same ethical considerations apply.

4.3.4 Materials

A bespoke interview guide was created, outlining the content and structure of the topics and questions (Appendix R). This was developed from initial observations of PR sessions and informal discussions with PR staff and patients. Throughout its development, regular consultation was employed with the PhD supervisors to ensure key topics were covered and research aims were addressed. Further consultation and confirmation were provided by the manager of the participating PR service, to ensure the interview questions were relevant and understandable. Inspiration was also drawn from behaviour change frameworks and theoretical models, specifically the Theoretical Domains Framework (TDF) (427, 428) and the COM-B Model (429). Note, these were not used extensively or exclusively to develop the interview questions but instead provided a starting point to aid the formulation of initial question topics and fuel further thinking. Further detail of this is provided in Chapter 3 (page 123).

Topics within the interview guide covered exercise and ST, exercise support, assessments, and experiences of improvements (e.g., muscle strength). At the beginning of the interview background questions were asked to build rapport (e.g., their referral to PR, and previous PR experience). This allowed time to ease the participant into the conversation and provided a natural segway into discussing more specific aspects of PR (i.e., SA and ST). In addition to the interview questions, basic demographic information was collected including age, gender, diagnosis (self-reported), and the number of times they had attended a PR programme. Once the interview guide was developed a pilot interview was conducted with a rehabilitation patient. Following this, minor adjustments were made, such as changing question wording and phrasing to aid comprehension and delivery.

4.4 Analysis

The interview audio recordings were transcribed verbatim, after which the transcripts were checked thoroughly against the recordings for accuracy. The transcripts were anonymised before analysis, such as names, locations, and other recognisable details that could compromise confidentiality. The qualitative data analysis computer software package NVivo (version 1.3) was used to support and organise the analysis process, with data analysed by the PhD researcher. TA was the chosen analytic approach, using the six-phase framework outlined by Braun and Clarke (423, 434). The decision to use TA is outlined in Chapter 3 (page 125), along with a detailed description of the analytic process. See Appendix S for an example of sentence-by-sentence coding using Microsoft Word, and Appendix T for an example of a strategy used to help generate candidate themes, specifically electronically annotated notes/lists of theme development.

4.4.1 Quality in Qualitative Research

As the methodology used in this study was the same as Chapter 3, Yardley's (442, 443) criteria for quality evaluation was also employed. This criteria broadly groups into four key dimensions: 1) sensitivity to context, 2) commitment and rigor, 3) transparency and coherence, and 4) impact and importance. All quality dimensions in this study are the same as those discussed in the previous chapter (see page 130), aside from a few sample/study-specific differences.

In terms of 'sensitivity to context', the researcher made a conscious effort to come across as understanding and compassionate to the participants circumstances surrounding their chronic respiratory condition and exercising experiences. Additionally, interviews were conducted with consideration for participants availability, taking place at a date and time which

was easy and convenient to them. Various communication methods were also offered when sending the PIS, obtaining consent, and conducting the interviews, which showed consideration for preference and technical/computer literacy. Many participants where older adults with no access to a computer or smartphone device. In terms of 'transparency and coherence', the same strategies were employed to enhance transparency and evidence the stages of the research process and the analytic decisions made. The final theme definitions are provided within the findings of this chapter (page 197). Evidence of the initial analytic process and theme development is provided in Appendix S and Appendix T, which present a coded transcript extract and an early thematic map. Lastly, as reflexivity is an important part of study transparency, the researcher maintained a reflexive stance throughout and considered their influence on the study and the findings produced. This was facilitated through reflective note taking, which is summarise on page 236.

4.5 Findings

4.5.1 Participant Characteristics

In total, 12 participants were recruited, all of whom took part in an interview and provided data. As shown in **Table 11**, eight participants had completed one PR programme, and four participants had completed between two and four. Eight were male and four were female, with a mean age of 74 years (*SD*=5.6). All participants self-reported a chronic respiratory diagnosis, specifically COPD (*n*=9, 75%), of which three participants further specified emphysema, and pulmonary fibrosis (*n*=3, 25%).

Table 11. Participant/patient characteristics (*n*=12)

Pseudonym	**Age (years)**	**Gender**	**No. of completed PR programmes**	**Diagnosis (self-reported)**
Charlotte	82	F	1	Pulmonary Fibrosis
John	76	M	2	COPD (Emphysema)
Edward	74	M	1	COPD
Gary	83	M	1	Pulmonary Fibrosis
Simon	69	M	1	COPD
Iris	75	F	1	COPD
Tommy	73	M	3	COPD
Margaret	81	F	1	Pulmonary Fibrosis
David	67	M	2	COPD
Gillian	68	F	1	COPD
George	66	M	1	COPD (Emphysema)
Trevor	74	M	4	COPD (Emphysema)
	M = 74 (*SD*=5.8) *Range* = 66 - 83	Male = 8 (66.7%) Female = 4 (33.3%)	1 = 8 (66.7%) 2 = 2 (16.7%) 3 = 1 (8.3%) 4 = 1 (8.35)	COPD = 9 (75%) Emphysema = 3 (33.3%) Pulmonary Fibrosis = 3 (25%)

4.5.2 Themes

Six themes were constructed during the analysis: 1) Understanding and perceptions of strength training, 2) Strength is important for daily function, 3) Usefulness and relevance of a strength assessment, 4) Staff support and exercise facilitation (during PR), 5) Psychosocial benefits of PR, and 6) Exercise adherence and challenges (after PR). These themes are described in detail alongside selected excerpts from the interviews. A summary and description of each theme are outlined in **Table 12**.

Table 12. Summary of patient interview themes

Theme	Description
1. Understanding and perceptions of strength training	This theme demonstrates that participants have a basic understanding of ST i.e., to build and strengthen muscles, but also show elements of misunderstanding. It provides insight into their views and perceptions regarding ST, specifically the perceived association with attending 'the gym'.
2. Strength is important for daily function	This theme outlines the importance of daily function. Participants acknowledge and describe the benefit of ST, which primarily focus on the consequences of improved strength i.e., their ability to carry out daily activities.
3. Usefulness and relevance of strength assessment	This theme discusses the mixed views and opinions regarding the use of a SA. Some participants think it would be useful due to perceived advantages e.g., tracking improvement, prescribing individualised exercise, and motivation. Whereas others feel it would not be relevant and meaningful to them.
4. Staff support and exercise facilitation (during PR)	This theme outlines the support participants receive from staff, and how this helps facilitate exercise during PR. Participants describe these support methods, which include supervision, demonstration, and exercise modification. Although they note this support and guidance can be restricted by limited time and large class capacity, resulting in reliance on their peers.
5. Psychosocial benefits of PR: "it's not just about your body strength, it's about the mind as well"	This theme outlines the psychological and social benefits gained from PR. Although PR provides physical benefits, there are additional advantages which participants emphasise as having a positive impact.
6. Exercise adherence and challenges (after PR)	This theme outlines adherence to exercise after leaving PR, and the potential challenges faced. PR offers many benefits e.g., structured exercise, motivation, and support. However, once participants leave the programme this help ceases, meaning many face the challenge of exercising independently.

4.5.3 Theme 1. Understanding and Perceptions of Strength Training

This theme shows that participants have a basic understanding of ST, but there is also evidence of misunderstandings and misconceptions. Participants understand that ST builds and strengthens the body's muscles, associating it with the use of weights (e.g., dumbbells) or working against a resistance - a common description of ST is "*lifting things*". It is worth noting, when participants talk about ST, some describe it using different phrases, such as "*weight training*", "*muscle training*", "*resistance training*", and "*weight lifting*".

> *"Well, really dumbbells and stuff like that, perhaps squats, stuff to build muscle." (George)*

> *"strength training is muscle training and like lifting things and- what else can I say? Or pulling things and that. Strengthening your arms and your legs, and your thighs, and the muscles that you need to use every day. (Margaret)*

However, there is evidence of misunderstanding. In particular, the grouping of strength exercise with aerobic exercise. As shown below, Charlotte believes all PR exercises are strengthening to some extent, as well as Edward explaining that the pressure on a cycling machine could help muscle strength as it is pushing against resistance. It is understandable why participants may think this, as aerobic exercise and the use of aerobic machines may strengthen the legs to some degree, especially if the individual is deconditioned.

> *"Well the weights we had, there were various- you know they're like little dumbbells, various weight... So, I think of things like that were you're lifting things. We had step-ups, cycling, and the push-ups from the wall… Things like that I call strengthening. Well, I suppose they're all strengthening, aren't they?" (Charlotte)*

> *"Well I suppose it relates to like weights or cycling where you set the pressure and also, obviously, what do they call it? The treadmill, you set that at a certain speed and therefore you- yeah, that's how I relate it anyway, up to those sort of exercises." (Edward)*

Findings also reveal negative perceptions (or misconceptions) of ST and exercise, evidencing further misunderstanding. Some participants associate ST with going to the gym, and that exercise with the purpose of gaining strength and muscle is typically undertaken in this setting, for example "*strength training, I think it's like when you see the people at the gym."* (Gary). This view could be a result of thinking ST predominately involves the use of weighted equipment or specialised facilities. Consequently, some participants state the idea of attending a gym is not something they would or could do, as demonstrated by Trevor saying *"I'm not one for going down the gym and things like that."* Simon provides an explanation for this view, highlighting potential generational and cultural differences regarding exercise. He explains that ST was not typically carried out in their youth, nor was the use of gyms. In the past, exercising in a purposeful setting was not necessarily the norm. Instead, exercise was achieved through playing sports, recreational activities, working, or exercising outside. This is very different to today, where there is a prevalent exercise and fitness culture, especially surrounding the use of gyms.

> *"I don't go to a gym because- because I don't. You're young and you have a different mindset to stuff. I, you know- 40, 50 years ago, when I was a bit younger, lot younger, we didn't have gyms, didn't go to the gym, you went to work- exercised because I played sport, but I'd never dream of going to a gym. But that's become more prevalent in the last, I don't know, 20 years I suppose." (Simon)*

Another perception is the association between 'the gym' and a young demographic. It is perceived that young and fit people go to the gym, who are likely to be exercising to intense and "*crazy"* (Simon) levels - which is not something they would or could do themselves. John

and Simon compare the gym with PR, stating gym exercises are not the same as those performed by patients at PR. To them, PR exercises are designed for older people with health conditions, therefore they are deemed easier and less strenuous. As a result, they seem to perceive a gym setting and associated exercise as unsuitable for their age and patient population.

> *"These are all old peoples one's, right. Bicep curls, star jacks, upright row. They were the ones with the bands, I think. Oh, side arm raises. Yeah, they're not what you would find people doing in the gym." (John)*

> *"Only that it's designed for people who- it's not strenuous. Like if you go to a gym, which you probably do at your age, and you're charging around doing crazy things. To me that would be crazy because I wouldn't be able to do it." (Simon)*

This theme shows participants have a basic understanding of ST (i.e., to build strength and muscle), but it also evidences some misunderstandings and misconceptions. It highlights participants have negative perceptions of ST, such as associations with a gym setting, and younger fitter people who are exercising to high intensities - which is not something participants would want to do, nor something they deem capable of doing.

4.5.4 Theme 2. Strength is Important for Daily Function

This theme shows that participants recognise ST and having strength as important, but primarily due to the improvements and benefits related to daily function. They acknowledge and comment on strength-based exercises improving their muscle strength and the feeling of being stronger, however, they emphasise and describe this in relation to their functional ability and performance of routine daily activities, such as walking, hoovering, gardening, and carrying shopping. Particularly, how strength translates into their daily lives, and what this offers them and allows them to do. So, although ST improved their strength, they discuss the consequences of this in relation to better daily function.

> *"Quite a bit [important] because of lifting things in ordinary, what you say, housework, bending and arms, getting up if you have to use your arms to up and off a chair and your legs and that. I think it [ST] is important really because it's like anything else if you don't use it, you lose it." (Margaret)*

> ***"****I'd never really thought about it before until I went to the class and then I actually realised that they [strength exercises] are important… Well it's like my mum, I have to lift her out from the chair to the wheelchair and into bed and stuff like that. I feel I'm stronger now being able to do things like that." (Gillian).*

George and Margaret stress the importance of daily function, stating the aim is not to become really strong or a "*bodybuilder*", but instead to have enough strength to go about their day-to-day lives. Strength is not needed in excess, but having enough strength is important.

> *"I'm 66, I'm not there to run the Olympics, I'm there to see if I can make it easier to exist day by day, to carry on doing what I like doing and what I want to do. So my aim wasn't to be a bodybuilder, it was to be better than I was and to be able to do more than I was doing" (George)*

> *"I mean we don't want these bodybuilder muscles, but it's nice to have a bit of strength that you can open a jar that's heavy, that's stuck, or you can lift your shopping in and out, and you can pick things up that are a bit heavy about the house." (Margaret)*

George provides further insight, emphasising that the goal for strength has to be realistic and meaningful to this patient population. They are not concerned with lifting extreme weights but instead seeing improvement in relation to physical function, which could make a huge difference to their daily lives e.g., standing from a chair or walking up the stairs. So, instead of the goal being maximum strength, aiming for functional strength may be more significant and relevant.

> *George: "See, we're talking about people here that struggle to get upstairs in their house or struggle to get up from the chair, if they can see that that's*

> *improved, that's what matters, not lifting a dumbbell 50 foot above your head, it's a different goal.*
> *Interviewer: So it has to have meaning to you? And translate into your normal day to day function?*
> *George: It does, yeah. That's what's important, or it certainly is to me, and I would think it would be for most of the people there, none of them went there to get built up into a huge bodybuilder"(George)*

This is supported further by participants talking about improvements in their strength, but describing them in the context of their daily lives. They provide examples of improvements where they could do more, or carry out specific daily tasks more easily e.g., walking up the stairs, mowing the lawn, hoovering etc. Again, although they comment on positive differences in their strength, it seems these participants do not refer to improvement, or necessarily see improvement, in terms of direct or specific exercise progression, such as an increase in exercise weight or number of repetitions. Nor do they discuss such improvements in relation to PR or the exercise programme they completed. For someone who is reasonably fit and in good health, progress and improvements are unlikely to be seen or based on the ability to carry out daily activities. Instead focus may be placed on performance-based indicators to track improvement e.g., increases in weight lifted or duration running. However, this patient population are typically older adults (≥60 years) with a respiratory condition, of which many can find day-to-day tasks challenging. Therefore, these improvements are likely to be noticeable to them, as they can positively impact and transform their lives. If they are able to walk further, carry heavier shopping, hoover for longer, then these are signs of significant success. Therefore, this shows functional ability is important to patients – it is meaningful and relevant to them.

> *"It did get me stronger… Well, going into [town] I could step up on the bus easier… I didn't have to get a hold of the bar and pull myself up. I didn't have to yank myself up the same, I could do it easier. So, certain things- and walking I could walk further. Yeah, it made me stronger" (Charlotte)*

> *I can carry shopping now, bits of heavier shopping now and lifting more that are awkward and- how else can I put it, I can walk longer, further, and that… yes, I do feel stronger" (Margaret)*

> ***"**Things are easier like getting up the stairs… I walk up the stairs much easier. Just general stuff, you know, I tried to cut the grass, I've got quite a large garden, I cut the grass. Now, I was starting to struggle doing that, physically struggle not just breathing, and that [ST] certainly helped that, there's a lot of things it helps." (Edward)*

This theme shows participants do see strength and ST as important, but primarily due to the improvements they experience in their daily function. The aim is not to gain extreme strength or extravagant muscles, but instead to be capable of completing the tasks and activities required of them in everyday life. Participants acknowledge improvements in their strength after PR but describe them in reference to functional strength and daily ability.

4.5.5 Theme 3. Usefulness and Relevance of Strength Assessment

This theme demonstrates mixed views and opinions regarding the usefulness of SA in PR and its relevance. Most participants show interest in having their strength assessed, with Tommy saying, "*I'd like to see that*" and Simon stating it would be a "*good idea, I'd be up for that*". One reason SA could be useful is for informing patients of how their strength has changed, and hopefully improved, over the course of the PR programme.

> ***"**it'd be handy, yes, to know the muscle side of it as well… it would be handy with the muscle as well, whether you've strengthen them or- you won't weaken them obviously, but just to let you know how your muscles are doing." (Iris)*

> *"I suppose there might be a way of testing the muscle. Well the muscles must be better, mustn't they? But if you were told they were better it would be good." (Charlotte)*

Participants note other perceived benefits, including motivating patients to continue exercising and encouraging them to work harder and put in the effort. If patients see objective improvement from a clinical assessment, then it could provide evidence that the exercise programme is effective, and that the exercises were preformed correctly.

> *"I think it would encourage people to continue doing it [exercise], yes." (John)*

> *"Well that would gee- if they were to see a little bit of an improvement written down or shown, that would gee them up a little bit more and they would try a little bit harder, really they would." (Tommy)*

> *"Well, you know then that you've done something right, hopefully [laughs]." (Iris)*

Margaret weighs the advantages and disadvantages of using a SA and how it could impact patient motivation, both positively and negatively. She states it could be advantageous as it provides patients with something to strive for, as being assessed offers a baseline to which improvement is measured against. Yet, this could have an opposing effect whereby the lack of improvement could demotivate. If a patient subjectively feels they have improved but the clinical assessment does not mirror or support this, then it could be discouraging.

> *"that would be interesting, before and after. I mean sometimes that's an advantage and sometimes it can be to a disadvantage, it depends on people's thoughts on that. Some people I think might be upset thinking they've got higher than what they have or they're not as- you know, I don't think- it's like everything, you've got to treat with gloves, if you know what I mean? Because some people get despondent and think 'oh well, I'm not doing any good I'm going to chuck it all up and the rest of it'. But, on the other hand I do think it's something to strive for actually." (Margaret)*

Another perceived benefit of SA is the potential for exercise to be individualised. It could help tailor and customise the exercises to ensure patients are not over or under exercising. Patients are attending PR for the purpose of exercising, so assessing their strength could help prescribe the correct weight and/or resistance, ensuring they are working within their ability to obtain the best results. Edward draws on previous experience of being assessed when first joining a gym, and how this could benefit patients if applied within PR.

> ***"****obviously if you're being lazy and you pick a much lighter weight it's not testing you, is it? I'm not saying people are lazy, I'm just saying because you've consciously gone there to do these things" (Simon)*

> ***"****Well, at the gyms that I've been going to, when you first join, they give you an assessment, they took you on a cycling machine and they put sensors on you and it tells them what your capabilities are and also- yeah, I think every individual should be assessed in that way so that they're not over doing it basically and they're not under exercising. So if it was assessed on that sort of basis, I think you get better results, don't you?" (Edward)*

Despite these positive perspectives, some participants are uncertain. When Gillian and George were asked if SA would be useful, they expressed that it might not be relevant, especially for people in their age group. They state that having their strength assessed and knowing the outcome is not necessarily something that is seen as important. As discussed above in Theme 2 'Strength is Important for Daily Function' (page 222), participants emphasise the priority of functional strength and being physically capable of meeting the demands of daily living. Therefore, knowing how strong their muscles are from a clinical standpoint might not be useful or meaningful to them.

> *"Interviewer: Do you think it would be useful to know if your muscle strength had change from beginning to end?*

> *Gillian: I think to a certain degree, I think you- as you get older your muscles do decrease anyway, don't they? So I wouldn't have thought so, it wouldn't have made much difference to me." (Gillian)*

> *"No, I would think for most people- I mean you're talking about- I'm talking about my age group, it wouldn't be of any relevance. What you're after is to be able to do stuff, how strong your muscles are is really not of much importance in that way, if you know what I mean. Like a youngster would want to know they could pick up half a house, I don't really care, I want to be able to do what I want to do. So, it's a bit different, the aims are a bit different." (George)*

Both participants continue to discuss SA in relation to the walking test (ISWT), stating that this is a good example of a useful assessment. The walking test could be viewed as more meaningful and relevant, as it is a familiar functional movement.

> *"It's the mobility part that I needed, I suppose your muscle do come into it, but I found the walking, the bleep test useful." (Gillian)*

> ***"****I thought it [walking test] was a good gauge because they were like- well me I mean, I'm 66, I'm not there to run the Olympics, I'm there to see if I can make it easier to exist day by day, to carry on doing what I like doing and what I want to do. So my aim wasn't to be a bodybuilder, it was to be better than I was and to be able to do more than I was doing, and the walking test is probably the best gauge of that." (George)*

This theme provides some insight into participant views regarding the usefulness and relevance of SA in PR. Advantages are stated, such as helping track improvement, individually prescribing exercise, and aiding patient motivation. However, limitations are also noted, stating awareness of strength metrics is not necessarily relevant or meaningful, as well as knowing changes in muscle strength could be detrimental if patients have not improved as much as they thought they had.

4.5.6 Theme 4. Staff Support and Exercise Facilitation (During PR)

Participants outline the support they receive during the PR programme, particularly from staff, and how this helps facilitate exercise. Overall, participants praise PR staff for the work they do and the help they offer, stating they do "*a grand job*" (Gillian) and "*a real good job*" (Gary). They express how helpful staff are during the programme, noting the positive relationship between patient and HCP. In particular, Trevor compares PR to going to a "*normal doctor*", suggesting the care and rapport shown at PR was a more positive experience.

> *"I mean they are helpful and not only that, if I needed to know something or was worrying me or anything they said, not to just me but people in general or the rest of the clientele, you might as well say. I mean nothing was too much trouble for them, they'd go out on a limb for you if necessary. I mean you couldn't meet a better group of girls." (Margaret)*

> *"It's nice to know that somebody's there that cares about you, if you know what I mean. When you just go to a normal doctor, you're just another patient, aren't you? And they tend to know all your names and that, and they have a good rapport shall we say. Yeah, it's good, I like going." (Trevor)*

Participants positively discuss the support they receive during the exercise sessions, describing the methods used by staff to assist and facilitate exercise. Firstly, they comment on supervision and how staff oversee the exercise sessions. They describe how staff walk around checking on patients, making sure the exercises are being conducted correctly and safely, as well as ensuring patients understand what they are doing. Linked to supervision, is demonstration and explanation. Participants explain that staff provide demonstrations, showing them how to do the exercises, along with explanations if they are unsure or are performing them incorrectly.

> *"Well they walk around and talk to people as they were doing it and making sure that everybody knew what they were doing. If they didn't know what they were doing they would show them how to do it and it was very good" (Tommy)*

> *"they show you how to do them, she'll demonstrate how you've got to do it, and then if you're doing it wrong she'll come and tell you and show you. They were pretty good." (Trevor)*

Participants explain how the exercise programme is not "*a one size fits all*" (George), as exercises are modified and tailored to fit the individual and their capabilities. Staff help patients work around their breathlessness or other health issues, allowing all patients to participate in each exercise regardless of their physical level or capability.

> *"if you couldn't do the exercise that was given to you or something, they'd try and modify it round, so they'd find another way of doing it. You did the exercise but, in another way, which I found was helpful. Nobody was, what I call, left out… they were coached round to find a way that they could do it, and when they found out they could do it, it was a breakthrough for them." (Margaret)*

One aspect of staff support that participants seem to appreciate, is when it came to exercising, staff did not push them. Exercise was not a regimented programme but instead self-regulated, where patients could go at their own pace and even select their own exercise load/resistance. However, this does question the nature and purpose of individualised exercise – is it to prescribe effective intensities or simply modify exercises? Nevertheless, participants understood if they could not complete an exercise, they were not obligated, and taking needed rests was appropriate. Staff were there to supervise patients and to ensure they were exercising safely, not forcing them to exercise to unreasonable extents.

> *"But the point is, what shall I say, you can do it at your own speed. There's no, how you say, 1-2-1-2, you can do it at your own speed, you can regulate*

> *things yourself. If you feel a bit out of breath or anything you slow down or take a bit of a rest or something." (Iris)*
>
> *"They don't push you, you can go and pick, like with a dumbbell, you go and pick your own one, you can pick what you want, so you can pick a small one or a large one, whatever suits you, and you can make it fit you, if you understand what I mean." (George)*

Although participants describe the essential support staff provide within the exercise sessions, they note this can be negatively impacted by limiting factors, such as time, class capacity, and staff numbers. Consequently, this leads patients to rely on their peers for help and guidance. Participants describe how they observe and learn exercises from each other, particularly from those who have been participating in the programme for longer. As this service used a rolling programme approach for referrals, new patients started each week, resulting in staff primarily focusing their attention on the latest arrivals. As discussed above in this theme, exercise support from staff is an important component of the programme. Therefore, not receiving sufficient guidance and supervision throughout the course could have a negative impact on improvement and PR outcomes.

> *"Every new person that comes just watch what the other people do and they join in and that's it, that was the beginning and the end of it… the thing why they didn't because they were to the maximum number of people, so I don't suppose they had the time" (Gary)*
>
> *"Let's put it this way, you got no- you could have done with more guidance when you first went in… Show them how they think they should be done, because you walk in and you saw 15 or 20 people and they'd say heel raises and you just look to your neighbour and you follow them, and if you've got one of these that wasn't that interested or was really interested in the social side, you didn't really find out how to do the things properly… You looked left or right and followed them" (John)*
>
> *"That's an awkward one to say because really you learn quite a bit off what other people were doing… They'd [staff] come round and check-up occasionally. Let's face it they can't be everywhere at once because you*

> *only had one, because the other two or one nurse was doing- sussing other people out to join the assessment course, you know people for assessments where they could." (Margaret)*

Another influential factor participants mention is the use of equipment within exercise sessions, particularly the potential lack of equipment available, for example dumbbells, weight machines, and general gym apparatus. They emphasise that the service and staff "*do their best with the equipment that they're allowed to use*" (Trevor), and recognise availability is likely dependent on the facilities hosting the PR programmes. They reason that the lack of equipment could be a consequence of limited funding. Participants do not necessarily emphasise this as a main limitation of the exercise sessions, but it highlights patients awareness of the implications.

> *"Well, we don't use a lot of equipment, a lot of it is our own equipment… Well I mean it's us using our arms and legs and things like that, which you don't need- well you might need a chair occasionally and a wall. But I mean that's not what I call equipment, I call like dumbbells or a ball or something like that equipment. No, I don't think they can do more than what they can because of their hands are probably tied with money and that, I don't know. I don't know what else they could- I mean unless they could bring some easy-going gym stuff. But then again, you've got to remember that it's all got to be carted there and taken away" (Margaret)*

> *"I don't think there were too many real strength exercises, not like what you'd get at a normal gym where you'd have the pulldown weights and things like that, you know the bench presses and leg curls, you know that sort of thing, because they didn't have the facility there to do those sort of things… they [dumbbells] range from half a kilo up to 2 and half kilos." (Edward)*

This theme outlines how staff support patients and help facilitate exercise during PR. Participants describe helpful methods carried out by staff to achieve this, such as supervision, demonstration, correction, and modification. Unfortunately, participants note that this support and guidance can be restricted by limited time and large class capacity, resulting in reliance

on their peers. If consistent support from HCPs is not provided, then it could have a negative impact on improvement and PR outcomes.

4.5.7 Theme 5. Psychosocial Benefits of PR: "it's not just about your body strength, it's about the mind as well"

This theme describes the psychological and social benefits gained from PR, emphasising advantages are not solely physical improvements. Overall, participants praised and complimented PR, describing their enjoyment and the positive experiences they had while completing the programme. One main benefit contributing to their enjoyment was the social aspect. The majority describe PR as a social event, which gives them an opportunity to interact with other people who share similar attributes and experiences. Emphasis is placed on PR not just being about the exercise and the physical benefits gained, but also the societal advantage. The programme offers a setting that brings patients together, allowing them to provide and receive support from one another.

> *"It definitely isn't all about the exercises. Obviously, I'm really good, but when it comes to mixing with people, I met- of all different kinds, men and women. I don't know, it just felt part of a very cosy club and I was really sad when I left it because I had to say goodbye [laughs]." (Gillian)*

> *"If you're reclusive or if you've got an illness that is a problem when you go out, it's very difficult to mix, it's very difficult to get into things. I mean you tend to have a few friends as a group who understand the problems you have, but when I went to that [PR], there were a lot of people there with the same problems, so it became almost a social event… It's about feeling not isolated so much because suddenly you see other people with exactly the same issues, and it becomes quite an event and that in itself is a big help." (George)*

Furthermore, participants stated how they were able to laugh and joke with peers and staff, making PR a fun experience. George describes how this environment helped him enjoy even the hardest of exercises. A few participants even described PR as being like a "*family*" who are all in it together - caring and supporting each other in a collective group.

> *"I think the whole thing was good, I think the whole thing was really good… everybody was friendly, everybody was having a laugh if you like. The women that were running it were fantastically funny, everything was done with a real laugh, and it was just light-hearted and brilliant to do… the whole thing was enjoyable. I mean even the things that were hard like squats and stuff like that, which are frankly for a person my age is hard work. But even that became a laugh, it became fun." (George)*

Participants also discussed how PR facilitated friendships. Many made connections with others attending the sessions, with some forming relationships that lasted beyond the programme duration.

> *"Well we still keep in touch now, so we phone each other… it's amazing how it makes you feel, you actually feel like you've [laughs] actually got lots of friends." (Gillian)*

> *"I found it an incredibly social event actually [laughs], surprisingly enough. I mean many of those people I still talk to. So it does have huge benefits in both directions, and I can't really stress enough how important that is, the social side of it as well as the physical side." (George)*

Another benefit is the positive impact PR has on their psychological and mental wellbeing. Participants describe how PR improved their outlook, attitude, and mood. They were happier and felt generally better in themselves after completing the programme.

> *"I'm happier, much happier than I was. I felt as if I was in a dark place and going there has opened the door." (Gillian)*

> *"I was more confident, you know you sort of stand up straight and you feel good, that's how I felt anyway… I just felt better in myself. I can't explain it really. I just felt good, I felt more sort of alive really, it's the only word I can use." (Iris)*

A large contribution to this benefit is the social interaction and support. Many patients can feel isolated, but PR breaks this seclusion and gives them the chance, and a reason, to get out of the house. An opportunity to meet new people and form new connections they otherwise would not form. PR not only offers physical benefits, but it also exercises the mind. It gives patients the opportunity to converse with others and experience human interaction, which many may be lacking in their daily lives.

> *"Because I'm on my own here, I found it invigorating to be able to talk to people and hold a conversation about what we were doing down there. See the thing is, it's not just about your body strength, it's about the mind as well, isn't it? Because some people are stuck in houses and homes and unless they talk to people then you're not going to be coherent and not be able to get on with life basically." (Edward)*

> *"So the overall experience of it was a social event with huge benefits in- there were people that had no confidence at all that were there, that were very shy, that hide in the corner, and you saw them loose that over a few weeks, which to me is one of the major things. It's actually extremely good from that point of view, and if you're going to do that, if you're going to try to make things better from a physical point of view, if you can be happy doing it, you're halfway there and that's what was happening." (George)*

This theme shows that PR benefits and positively impacts patients beyond the physical, but also psychologically and socially. PR is a fun and enjoyable experience, which provides patients with an opportunity to socialise and interact with people of a similar age and with

similar health conditions. It is a place where they can feel part of a collective group and receive and provide peer support throughout the process.

4.5.8 Theme 6. Exercise Adherence and Challenges (After PR)

This theme discusses adherence to exercise after leaving PR, and the potential challenges faced. Participants state a key take-home message was the need to exercise, saying the course "*taught me that I need to do a lot more exercise*" (Tommy) and "*that I should exercise more"* (Iris). Some describe carrying out the PR exercises at home, however the extent of adherence seems to vary, with limited detail specifying exactly how they are exercising (e.g. number of exercises, frequency, duration, intensity, volume etc). This questions whether participants are exercising effectively once they leave PR.

> *"I do it every morning now, I do wall presses and I made it my target to do 200 a day. And then while I'm sitting in a chair, I just move my arms and legs about." (Gary)*

> *"I was doing a little bit of the strength exercises in my conservatory. Not very often… So I could do most of the strength ones, the push ups and the sit ups and the bicep presses and things like that, I could do that. And the walking up and down the garden." (Tommy)*

Although participants show awareness of continued exercise after PR, they note that achieving this is down to them and the individual patient. Staff advise them to keep the exercise sheet used within the sessions and to carry them on at home, but aside from this there is no continued support beyond programme completion. Participants seem to talk about this in a matter-of-fact manner - as what else can they be offered. They see it as being solely up to them.

> *"They give you a list and they ask you to do some- like some every morning when you get up, but it's up to you whether you do them or*

> *not… they do ask you to carry on with some of the exercises at your leisure at home, that type of ex- they ask you to do that. But not much else they can do really, is there? It's got to be up to the individual a little bit to help themselves, I should have thought." (Trevor)*

> *"Once you've finished, you've finished… you're left to your own devices. I don't remember them giving me anything" (Simon)*

Consequently, some found adhering to exercise after PR challenging. Participants state a benefit of the PR programme is the structured weekly sessions, which provide motivation and accountability. Attending sessions twice a week on a scheduled basis meant they had a specific reason to exercise. As stated above, once patients leave PR, exercise is down to them. They need to find their own motivation to continue, which could be difficult for those who relied on the PR sessions to exercise. Therefore, once they leave this organised environment, exercise adherence is more challenging.

> *"I looked forward to that twice a week, I thought that was brilliant, and that gets you up and going and things like that. When you finish that, then you come home you think 'oh no, I'm not doing that today'." (Tommy)*

> *"I mean I thoroughly enjoyed being up there, I'd go every week if I could because it not only gets you out, it makes you do things because sitting at home you can get a bit, or staying at home even if you're moving about at your own pace and that, you get a bit lazy you can do." (Margaret)*

Another challenge is the switch from group to independent exercise. Some participants express a preference for exercising in a group setting, as it provides peer support. As stated by Edward and Iris below, having the exercise sheet from the PR programme is not enough to prompt adherence when a key motivator is the group dynamic. As discussed above in Theme 5 'Psychosocial Benefits of PR' (page 212), participants benefit from being in a group-based programme because they can exercise with other people, which is motivating. This highlights

a potential challenge for exercise adherence after PR, as many patients may be more accustomed to exercising in this specific environment or group-based exercise may be their only experience. Therefore, jumping to autonomous and independent exercise could be difficult as the peer support and guidance which was offered has now ceased.

> *"But she said you've got the exercise sheet if you carry on at home, but to be honest it's more- when you're with other people it spurs you on to sort of carry on with it basically. I've been doing some of them, but if you're in a group it does help to energise you, if you know what I'm saying [laughs]." (Edward)*

> *"Not that I've done it while I've been at home, I've done it a couple of times, but I think when you're with a group it's a bit different. The other day I thought I really must start doing this because I've got the paperwork here of the exercises that I actually done… I think it's because everybody was doing it and everybody's in the same boat. But, when you're at home on your own you just lose interest." (Iris)*

Some participants state they attempted to find an alternative group exercise class after PR. Something which was similar to the PR programme, which they could attend weekly. However, Iris and Margaret stated options were limited.

> *"They were trying to find a keep fit class for us girls to go to for a while and we were sort of looking into it… There's not many places that you can actually go to after the rehab. But I know the girls were going to look for us and let us know, but they didn't get back to us." (Iris)*

> *"There's few and far between that specialise in that type of thing." (Margaret)*

PR offers multiple benefits for patients, such as structure, motivation, support, guidance, fun, and enjoyment - making it a desirable exercise environment. As a result, the majority of participants said they wished PR was continuous so they could attend weekly exercise sessions

on a permanent basis. Margaret offers a solution of successive or progressive exercise classes for those who complete PR, expressing willingness to pay to carry on, although this might not be feasible for all patients.

> *"I really looked forward to that exercise, as you know I wish I could keep it up all the time. I wish I could go there 52 weeks of the year, put it that way." (Tommy)*

> *"the only way I think anything would work is if we could have a progressive class after to go to… slightly more difficult and like in that respect, or the same if necessary. Just to keep everybody going that want to because I mean I know I'm not the only one. I mean a lot of people I've met up there, we've all got our little groups like and that, we all say we'd like to carry on and we'd pay for it, but then I don't know how other people would feel about it." (Margaret)*

However, it is not possible to attend PR permanently. Instead, participants explain that they are invited back and given the opportunity to complete PR on an annual basis. However, descriptions of this seem to suggest some participants might see this as a fail-safe or contingency plan. In other words, if they do not continue exercising or fail to adhere to guidance taught within the course, they have another chance to complete it if they wish.

> *"Because you do it at the school [PR], once you leave it's pretty much down to you to either continue it or not. But the thing with it is in 6-month time you're eligible again, so you can do it, you'll be invited to do it again. So, if you like it's- you get the course every year if you want to do it." (George)*

> *"Interviewer: So has completing the pulmonary rehab programme taught you anything at all?*
> *Gillian: Yeah, wait to get an invitation to go back [laughs]."(Gillian)*

> *"Because you can go back next year, or this year I should say for me, and you can do the class all over again… I've been lazy and I haven't exercised, so I actually feel I've deteriorated, but I'm not to the stage*

where I've given up completely, I'm going to go back and try again." (Gillian)

This theme shows that participants do continue exercise after PR, at least to some extent. However, they describe challenges faced that can make adherence difficult. PR offers many benefits, such as structure, motivation, and support, which can make exercise easier and more accessible for patients. However, when patients graduate from the programme this support ceases, resulting in many finding independent exercise challenging.

4.6 Discussion

4.6.1 Summary of Findings

This study provided, to the best of the researcher's knowledge, the first qualitative investigation of SA and ST in PR, from the perspective of patients who participate in this intervention. In summary, participants demonstrate a basic understanding of ST, but there is evidence of misunderstandings and misconceptions, such as associations with a gym setting and younger fitter cohorts. Furthermore, a key perceived benefit of ST and improved muscle strength was on daily function and activities, which participants held in high regard. Regarding SA, there were mixed views and opinions about its usefulness and relevance. Some recognised the advantages, whereas others felt it was not relevant or meaningful to them. Further findings emphasis staff support as an important facilitator of exercise during PR, although support and guidance can be restricted by limited time and large class capacity. Psychosocial benefits of PR were reported, particularly peer support as a key factor facilitating exercise. It emphasised that the psychological and social advantages of PR are just as important as the physical benefits. Lastly, challenges to exercise adherence and continuation after PR are evidenced, particularly difficulties with independent exercise once structure, support, and supervision are removed.

These findings emphasise the importance of patient education for increasing knowledge and understanding, as well as the need for strategies to aid exercise adherence after PR so patients can succeed in successful behaviour change and self-management of their disease. In particular, these should be considered when ST is presented, delivered, and prescribed to patients during PR, as well as when and how a SA is implemented and used.

4.6.2 Theme 1. Understanding and Perceptions of Strength Training

Participants demonstrate a basic understanding of what ST involves, such as building and strengthening muscles, but there is evidence of misunderstandings and misconceptions. These findings show that understanding and perceptions like these could be barriers to ST within this patient population and PR. McNamara et al. (219) found that a supervised exercise training programme in a community gym led to high levels of satisfaction and positive experiences among individuals with COPD. The gym environment promoted a sense of normality and instilled confidence in some to continue exercising at a similar venue post rehabilitation (219). However, Meshe et al. (215) found COPD patients participating in a similar structured community exercise programme reported feelings of intimidation and being unsafe when having to exercise in a gym - although participants praised this community gym exercise programme overall. Furthermore, a study involving a UK cohort of older adults, found ST in a gym environment was perceived to be isolating, unappealing, and lacking enjoyment, as well as ST requiring more skill, knowledge, and use of equipment (480). These contrasting views could be the result of differing experiences and understanding of ST or exercise in a gym environment, as people's views after a ST or gym programme may differ from those who have never experienced it before.

Misunderstandings and negative views of ST have also been reported in previous studies, comparable to those presented here, with COPD patients and older adults demonstrating misconceptions and limited awareness of ST benefits (461, 480), inaccurate knowledge (484), and negative beliefs (218). The concept of compassionate ageism was reported in a previous study, which explored the engagement of older adults and their understanding of ST recommendations within the UK (480). This concept portrays older adults as a group requiring protection from the high-intensity efforts involved in exercise and ST. Consequently, this could be a barrier to ST, as if people hold this view it could lead to the misconception that growing older automatically and inevitably leads to physical vulnerability, reinforcing the idea that there is a need to avoid ST. If older adults in the UK hold this misconception, then the presence of a chronic and inhibiting condition, like COPD, may enhance this negative view. This concept is comparable to the results in the present study, with some participants viewing ST and 'the gym' as activities for people who are younger and fitter. Overall, this could demonstrate that misconceptions about ST are a systemic issue, as they are not only demonstrated in patient populations but also wider cohorts of older adults.

A proposed solution to ST misunderstandings and misconceptions is a focus on patient education by increasing awareness, knowledge, and understanding, as well as improving messaging about ST and exercise throughout PR. PR is the place where patients should learn about the benefits of ST and exercise, and practical strategies to better cope with their disease through physical activity (461). Practitioners play a vital role in this, as they are the teachers and influencers in this scenario, demystify negative beliefs and perceptions, and reducing initial fear and anxiety about exercise engagement (397). The contribution of PR staff to patient learning is reported as important for patient self-management (465). The perceived health benefits of exercise are commonly reported as facilitators of exercise for individuals with

COPD (215, 218-221, 461), as well as information and education to increase understanding of health benefits shown to facilitate physical activity after PR (218). Consequently, it is important that educational content explains the benefits, dispels myths, and corrects misconceptions of ST.

4.6.3 Theme 2. Strength is Important for Daily Function

Muscle strength is emphasised by study participants as being important for the function and performance of daily activities. Therefore, PR exercise should aim to fulfil this outcome, with physiological responses translating into improvements in ADL (485). Research has shown that ST can improve ADL and functional performance in people with COPD, such stair-climbing, sitting to standing, and arm elevation tasks (318, 319, 357, 358, 486, 487). However, some evidence suggests that ST alone may not yield significant improvements in ADL for COPD patients, but instead a combined strategy with AT yields greater benefits (317, 488). Unfortunately, there are large inconsistencies in the outcomes used to measure ADL, making results unclear and comparisons difficult (317-319, 489). Further research is needed to investigate the impact of ST on the performance of ADL, especially because patients place great importance on strength for daily function.

Within this study, participants often described the performance of daily activities as an indicator of improvement, particularly for muscle strength. Similar findings have been reported in previous studies with COPD patients (215, 219-221, 461, 465, 475). O'Shea et al. (220, 221) found after a progressive resistance exercise programme, individuals with COPD experienced increases in muscle strength, with improvements described in the context of activity and task performance, including self-care, household duties, hobbies, and roles (e.g. looking after grandchildren). Such importance may be placed on daily function because the inability to

perform ADL can result in the loss of independence and increased need for care (490), as patients can report feeling like a burden to their care givers (455, 460), as well as limited function and a lack of independence leading to isolation and social withdrawal (460, 461).

If daily function and activities are important to patients, then ST should be programmed and prescribed to reflect this. When ST is delivered, presented, and explained during PR, benefits and relevance to this should be drawn upon, with emphasis on meaningful and functional strength. Consequently, increased patient understanding and awareness of benefits could facilitate ST and exercise adherence, both during and after PR (215, 221). As if an individual believes an action or behaviour will decrease the seriousness of a health condition they are more likely to engage – in this instance with ST and exercise (491). On the other hand, it is important to highlight that if patients are relying solely on subjective experiences to gauge improvements in strength and ADL, it could be a barrier. For instance, if a ST programme does not elicit direct, meaningful, or expected improvements, a lack of benefit may be perceived, leading to reduced motivation and adherence (446, 447). Robinson et al. (218) conducted a systematic review of qualitative studies exploring the facilitators and barriers of physical activity following PR in COPD, and reported that when individuals notice personal improvements they are often more engaged or motivated by the outcomes, whereas not recognising improvements was perceived as a barrier. Individuals became unmotivated as they believed that the exercises were not worthwhile or helpful. Therefore, objective physical indicators of change could be a useful addition, such as the use of SA. Nevertheless, it is essential that ST programmes and PR outcomes address aspects that are meaningful to patients, which in this instance is daily function and activities.

4.6.4 Theme 3. Usefulness and Relevance of Strength Assessment

Study findings show mixed views regarding the usefulness and relevance of SA. Participants perceive SA to be useful, however, some question if it is actually relevant and meaningful. In the literature assessing muscle strength for COPD is reported to be important and useful, offering many benefits, which include the prescription of exercise intensity and load, identification of muscle weakness, insight into disease progression and prognosis, and evaluation of intervention effectiveness (93, 226, 228, 231, 234). Participants recognise and describe similar advantages to using SA in PR, with the additional facilitator of increasing patient motivation. This is consistent with previous research that shows COPD patients are more motivated to heed advice, undertake tests, and be assessed when sufficient information about importance and benefit is provided (400, 492), for example patients were found to be less active when physiotherapists did not provide information about the importance of physical activity (492). Future investigation into the psychological impact of SA would be beneficial, providing useful implications for the implementation and use in PR and how it is presented and explained to patients.

Previous research has included patients in the discussion about outcome measures used in PR and for COPD (465, 481, 483), however patient involvement is limited, with selection commonly dependent only on the views of HCPs and researchers (483). It is understandable that decisions must be made based on available evidence (e.g., validity, reliability, and efficacy), for example, if a SA is used then it must be valid and reliable, along with consideration for feasibility in the desired setting and environment (e.g., PR clinical practice). However, this study highlights consideration for patient acceptability. The value placed on outcomes can differ between HCPs, researchers, and patients (465, 493), therefore consideration is needed for how SA is perceived by patients, with emphasis on measures being

meaningful to people with COPD (483). As reported in this study, a walking test may be seen as useful and meaningful due to its familiarity and relevance to daily life, whereas a SA could be perceived as meaningless without the accompaniment of appropriate explanation. Therefore, this questions if participant reservations about SA are a result of limited understanding, as relevance may not be directly obvious. If SA is implemented or used into PR clinical practice it is important to explain why it is being used and how it benefits both the patient and the service. Further investigation into how patients perceive, feel, and respond to different assessments of strength would be beneficial for development and application in PR.

4.6.5 Theme 4. Staff support and Exercise Facilitation (During PR)

In this study, staff support is identified as a key facilitator during PR, especially for exercise. Participants praise practitioners for their supportive role, particularly during the exercise sessions. These results are consistent with previous research, which has frequently reported the supportive nature of staff and the exercise environment, both within PR and exercise programmes (215, 216, 218-221, 397, 461, 475). The presence of HCPs is reported to instil a sense of safety, reassurance, trust, and comfort for patients (218, 461), with individuals feeling less fearful of being overwhelmed by their symptoms and comforted by the opportunity to ask questions (218, 494). Additional examples of staff support include guiding patients in formulating measurable and achievable goals, helping patients to reach their exercise goals, providing encouragement, listening and answering questions, explaining how to work equipment, and demonstrating professional competence through skilled lecturers and guidance (215, 218, 221, 397, 460, 461, 495). Previous research has explored exercise beliefs among patients with COPD, reporting feelings of insecurity and unsafety (496), with concerns for personal safety reported as a barrier to attending exercise programmes (475). However, such findings were not reported in the present study. Regular support, supervision, and monitoring

by an instructor or HCP is shown to instil a feeling of safety, as well as making exercise fun and less daunting (215). Staff support during PR and exercise training programmes is reported as a key facilitator for exercise performance, attendance, and adherence among COPD patients (215, 221).

As emphasis is placed on the facilitation of staff support and supervision, it is not surprising that its absence is identified as a barrier to exercise and physical activity among individuals with COPD (218, 494, 497). Similar findings are reported in the current study regarding exercise adherence. During PR, participants describe how staff and environmental support can be disrupted and negatively impacted by service-related factors, such as limited time, large class capacity, low staff numbers and restricted equipment access. Consequently, this limits the support offered and provided by staff, leading patients to seek help and guidance from other patients – who might not have the necessary knowledge and understanding. This suggests that patients could be reliant and dependent on staff and others for exercise support. PR aims to promote long-term adherence to health-enhancing behaviour, which includes exercise as part of disease management (53). Therefore, it is important to acknowledge and utilise the supportive role of the HCP, but not to the extent of dependency. This further highlights the importance of patient education and understanding, as well as patient confidence, self-efficacy, and autonomous ability.

One study explored COPD patient experiences of PR and guidance by HCP, reporting patient motivation converted to autonomous motivation by the end of PR, as opposed to controlled motivation at the start, which aided exercise adherence (461). Similarly, another study stated that for some participants the support provided by the exercise instructor inspired confidence in their ability to subsequently exercise and use gym equipment with minimal or

no supervision (215). However, such findings were not reflected in this study, which reported a reliance on staff for exercise support and guidance during PR, with a negative impact on adherence once such support ceased. This could highlight differences in the type of staff support provided during exercise training programmes. Although these findings do not relate directly to ST, it emphasises the vital role of staff during its prescription and delivery, and the need for staff to have the necessary resources to provide care and support to all patients during exercise sessions. Future investigations should focus on appropriate strategies for successful adherence and maintenance of ST after PR, capitalising on the support offered during PR programmes and combining it with a focus on independent and autonomous exercise.

4.6.6 Theme 5. Psychosocial benefits of PR

Participants described how PR goes beyond just the physical benefits and offers psychological and social benefits as well. As discussed above, staff play an important supportive role during PR exercise, however participants also place emphasis on the social support received from peers, and its contribution to the positive PR experience. PR and exercise training programmes are shown to improve health and psychological status, measured using quantitative patient-reported outcomes, such as HRQoL and mental wellbeing measures (i.e. anxiety and depression) (33). Qualitative studies support such improvements, with COPD patients describing psychological benefits, such as increased confidence, motivation, sense of control, knowledge, and mood (215, 216, 218-221, 397, 461, 475). A key factor likely to contribute to improvements in psychological status and mental wellbeing is the social aspect and group setting in which PR and exercise programmes are conducted. As outlined in the present study, participants describe the positive impact and benefit of the social setting, which includes the opportunity to meet and interact with people with the same condition, to form friendships, be a part of a collective group, and have an enjoyable and fun experience. These

social benefits have also been reported in previous studies, in particular how the development of camaraderie and social support networks can encourage and sustain regular programme attendance (215-217). Group exercise can motivate patients by providing an incentive to work harder, commit, and complete the training programme (220, 221). Furthermore, support from fellow patients, offers an opportunity to share feelings, experiences and advice, and encourage each other during exercise training (461). It makes exercise more enjoyable and helps individuals conquer feelings of loneliness (218). This social benefit and connectedness between patients it not only perceived by the patients themselves, but also observed by PR staff and other stakeholders, who acknowledge its supportive and motivational role for individuals with COPD (215, 216, 219, 397, 446, 460-462).

Although not reported in this study, previous research has reported a negative impact of group exercise on participants, such as feelings of insecurity, embarrassment, and intimidation (216, 497). This highlights that group exercise may not be the preferred environment of all patients, and consideration is needed for these negative effects during PR, exercise, and ST, with appropriate exercise support offered to account for this. Nevertheless, social support is reported and recognised as an important facilitator for exercise during PR and exercise programmes. Consequently, it is not surprising that participants experience difficulty continuing exercise once this structured and supportive group environment stops (218, 461). Similar to staff support as a facilitator, peer support was not discussed in relation to ST or other specific exercise modalities, but rather the overall PR and exercise experience. This is similar to previous studies which have explored qualitative outcomes of ST programmes (220, 221) or exercise programmes which included a ST component (215, 216, 397). Further research investigating the impact and role of social support specific to ST programmes in COPD patients would be beneficial. One pilot study investigated whether older adults who were provided with

a peer when participating in ST were more likely to be participating in ST 4-weeks post-intervention, compared to those receiving ST alone (498). Results found peer support with ST did not significantly increase participation, with comparable completion rates reported for both groups (over 50%), as well as both groups showing significant improvements in lower limb strength and mobility. Further qualitative investigation was conducted with these participants (499, 500), which reported differing views about the peer support component, with some finding it enabling and others finding it unhelpful. This suggested that peer support and mentoring could be beneficial if offered as a choice. This could be a potential strategy worth exploring in the future for COPD patients after PR, to promote ST participation and adherence.

4.6.7 Theme 6. Exercise Adherence and Challenges (After PR)

A key theme identified are the challenges and difficulties participants experience related to exercise adherence after PR. The benefits gained from PR, exercise, and ST programmes are shown to diminish over time, demonstrated through a decline in clinical outcomes (334, 501-503) and reported patient experiences (215, 220). Therefore, exercise adherence is important for maintaining the benefits and improvements gained. PR guidelines emphasise the importance of exercise adherence beyond programme completion, and recommend services encourage patients to continue exercising and provide opportunities after graduation (33). However, research has reported that many patients find exercise adherence after PR challenging, leading to many studies investigating associated barriers and facilitators (195, 215, 218-221, 475). The present study found that participants were aware of the need to continue exercising after PR, but that adherence was challenging. Previous research reports that participants recognise the benefits gained after PR and the importance of maintenance, however intention, awareness, and desire does not always transfer to successful behaviour change, highlighting an intention-behaviour gap (216, 218, 221). Papp et al. (216) found

women with COPD expressed wanting to exercise and be physically active, yet struggled to accomplish this because of environmental factors, feelings of insecurity, and life situations and roles. Therefore, consideration and appreciation of the factors influencing adherence after PR is essential for developing strategies to promote long-term exercise.

As mentioned above in the discussion of Theme 4 (page 225) and Theme 5 (page 212), a key facilitator for exercise is staff and peer support. Consequently, many studies report the absence of external support as a barrier to exercise adherence for COPD patients (218, 220, 221, 397, 495, 497). Another facilitator is the structure and the expectation to conform to pre-set times and activities, therefore when patients leave the rehabilitation programme they are suddenly deprived of this safe and motivating environment, making them vulnerable to relapse into old habits and routines (218, 461). The current study findings are consistent with this, highlighting difficulties faced by participants when there is no continued support or structured programme to provide motivation and accountability. One strategy to overcome this barrier are opportunities to attend local group exercise classes after PR, however some participants in the current study expressed difficulty finding suitable options for COPD patients. Difficulty accessing a rehabilitation programme is shown to independently predict poor attendance (504), with ease of access identified as an important facilitator for programme attendance (215). Available opportunities for exercise classes are likely dependent on location, proximity, timings, personal preference, and the associated costs and fees with attending exercise classes or joining gym facilities (218, 219). Furthermore, a particular challenge after PR is the transition from group exercise to independent and autonomous exercise (215, 218, 505), with a lack of self-motivation identified as a barrier to exercise after a group programme (218, 219, 221). It is understandable that many participants want to continue PR as it offers structure, motivation, support, guidance, and enjoyment – making it a desirable environment for exercise.

However, PR is a short-term healthcare intervention, which aims to provide patients with the tools to self-manage their condition, including continued exercise (53). Therefore, appropriate strategies during and after a PR programme should be implemented and utilised, with the aim of helping successful and continued behaviour change, particularly for exercise adherence. If not, a continued cycle of deterioration and PR referral will ensue.

It is important to address that although the present study aimed to explore patient perspectives and experiences of ST in PR, participants did not necessarily discuss adherence to strengthening exercise directly, but instead in terms of their overall PR and exercise experience. Despite the lack of ST specificity, these findings highlight the importance of ST adherence, both during and after PR, and the potential barriers individuals with COPD may face. It could be argued that ST is a more complicated modality compared to aerobic exercise (e.g. walking), particularly if an individually prescribed and progressive ST programme is used, which can involve a variety of exercises, intensities, and equipment (235). Although, a meta-analysis examining factors affecting exercise attendance and completion in sedentary older adults reported that ST predicted higher attendance rates compared to aerobic exercise (505). This only emphasises the importance of exploring ST adherence further in COPD, particularly barriers and facilitators. O'Shea et al. (221, 476) did explore adherence factors to a 12-week progressive resistance exercise programme for people with COPD, which involved one supervised and two independent exercise sessions at home per week. Exercise adherence was facilitated by expected outcomes, self-motivation, supervision, and group support, whereas health and weather factors were major barriers. Despite the training programme being predominately unsupervised, results showed the provision of external support was important for participants, and that long-term adherence declined when group support and regular monitoring by a HCP was removed. Unlike O'Shea et al. (221, 476) and other studies (215,

216), health and weather barriers were not identified in the present study. Additionally, patients often report it is harder to maintain progressive resistance exercise at an adequate intensity once supervision is no longer provided (33).

Despite a lack of literature in COPD populations, some studies have explored perspectives and experiences of ST in community-dwelling older adults (478-480), reporting findings which are consistent with the present study and related COPD literature already discussed. Similarly, psychological and social factors were identified as motivators, for example, peer encouragement, social bonds, knowledge acquisition, perceived health benefits, enhanced wellbeing, and professional support. Whereas barriers identified included affordability, environmental factors, health concerns, limited understanding and misconceptions (478-480). Further investigation into COPD patient attendance, completion, and adherence to ST is needed, which could have important implications for designing effective ST interventions, and its inclusion and delivery in PR programmes.

A common strategy and intervention studied is the implementation of supervised exercise programmes after PR (215, 217, 497, 506). A meta-analysis conducted by Beauchamp et al. (213) found supervised exercise programmes after PR appeared to be more effective than usual care in the medium term, but not in the long-term. Results showed exercise capacity was preserved for six months, but this benefit was not maintained after 12 months and there was no significant improvement in HRQoL. It could be argued that offering and providing exercise maintenance programmes is only a partial solution, as these interventions focus on support and supervision facilitators, and typically copy the structure of exercise already undertaken in PR. This may not be sustainable in the long-term, as these interventions primarily rely on others. Instead, the addition of behavioural change strategies that focus on self-management and self-

regulation may be beneficial, such as education, motivation, goal setting, problem-solving, and practical application (221, 491, 507). Patients should have a basic understanding of how PR exercise, particularly ST, is programmed, prescribed, and progressed – simply telling them to do the exercise or patients copying others may not be conducive to adherence. This could be why many rely on the structured group format, as they do not have the autonomy, confidence, or motivation to exercise independently. A number of self-management education programmes have been published and are now offered as care options in the UK for COPD patients, such as 'Living well with COPD' (508) and 'SPACE for COPD' (509). These programmes are reported to have good attendance rates and lead to significant improvements in HRQoL, dyspnoea, and exercise capacity (508, 509). Therefore, the addition of specific and tailored educational content and self-management strategies could help facilitate exercise and ST after PR, particularly if used in conjunction with an individualised exercise programme. The time and duration of a PR programme should be utilised effectively by guiding patients through the behaviour change process, such as providing tailored advice, appropriate promotion and messaging, teaching self-management skills, and applying autonomy-supportive counselling (461). Patients should leave PR equipped with the necessary tools to successfully continue and adhere to exercise and ST long-term – without having to rely solely on the support, supervision, and presence of others.

4.6.8 Strengths and Limitations

The strengths of this study include the exploration of patient perspectives and experiences of SA, ST, and exercise in PR, which to the best of the researcher's knowledge, is the first qualitative investigation in this specific topic and context. It highlights the influence of patient understanding and perceptions, and the support received from staff and peers. It also demonstrates the challenges patients face when adhering to exercise, particularly the lack of

autonomous and self-management skills. These are important to consider when ST is presented, delivered, and prescribed to patients, as well as when and how SA is used and implemented. This study acknowledges the importance of patient involvement and collaboration in research. Patients are the stakeholders who attend and complete PR, offering a valuable source of insight and information about healthcare that is provided and delivered to them.

There are some limitations to the study methodology. Firstly, as the participants were purposefully sampled from a local PR service, it is not possible to generalise these findings to patient experiences in services due to variations in clinical practice. Participants were deemed appropriate as they had successfully completed a PR programme at a service which included ST and had a history of assessing muscle strength. However, on conduction of the interviews it became apparent that participants had limited experience of having their strength assessed and so were unable to draw from direct experience. Nevertheless, valuable data was gathered about their general perspectives and views of this as a proposed idea. This highlights that there is a lack of SA use, even in a PR service that reports assessing patient muscle strength. Furthermore, it is important to highlight that one participant (David) did not provide adequate enough data to allow for usable extracts in text. The reported themes were identified in the transcript, but answers were short and lacking sufficient description in comparison to the other participants extracts used. This interview is discussed in the section ‘Researcher Reflections’ (page 236). It is also important to address that although this thesis focuses on COPD specifically, not all participants in this study had a COPD diagnosis, with three specifying the chronic respiratory disease pulmonary fibrosis. However, symptoms of both diseases are similar (e.g. dyspnoea) (510), with PR being suitable for both and referral criteria being the same (141). The study inclusion criteria specified participants who had successfully completed a PR programme, as it was concerned with the PR experience. Previous research, which has

also explored and reported experiences of PR, have included a diverse sample of respiratory conditions (157, 219, 473, 474, 477).

Initially, the interviews were going to take place face-to-face, however due to the Covid-19 pandemic and restrictions placed on person-to-person contact, an amendment was submitted changing the method of conduction to telephone calls. Although this offers convenience for both parties, it does eliminate the benefit of seeing non-verbal cues and establishing enhanced rapport prior to the interview commencing. Unfortunately, technical issues were experienced within some of the telephone interviews, which caused disruption to conversation, due to stopping and starting. Relatedly, participants completed PR shortly before the Covid-19 pandemic, with interviews taking place 4-5 months later. This means interviews took place at the height of the pandemic when a nationwide lockdown was enforced. It is possible that responses were influenced by this unusual situation, and therefore recall bias could be present. Lastly, to ensure full transparency, 'member checking' or 'respondent validation' was not conducted in this study (413, 443). Justification for this is outlined in Chapter 3 (page 177).

4.6.9 Study Implications and Research Recommendations

This study has a number of implications for PR clinical practice and future research. It has identified factors of influence that will help improve the implementation and use of ST and SA in PR, helping to direct future research, the development and design of interventions, and the application in PR programmes. It has emphasised the importance of patient education in PR, not just the acquisition of knowledge, but how it impacts understanding, perceptions, and behaviour. Future research should focus on the development and impact of educational content,

resources, and messaging throughout PR, particularly regarding ST. Utilisation of staff is recommended to facilitate this due to the importance placed on their role within PR.

Furthermore, it highlights the positive and negative impact of external support. Support from staff and peers is perceived as a facilitator of exercise, both during and after PR, with its removal identified as a barrier to exercise adherence once PR is completed. However, such emphasis questions if this facilitation is a preference for exercise, or if patients are reliant on the structure and support offered within PR. Patients should leave PR armed with the tools needed to self-manage their condition, which should include the ability to exercise independently and autonomously. Future research should investigate this concept further, focusing on strategies to increase independent exercise. The PR environment would be an ideal setting to facilitate this, as patients have access to support and resources over the course of the programme.

Lastly, this study has reported findings directly related to the assessment of patient muscle strength in PR, outlining potential areas of consideration if SA is implemented and used, for example the importance of explaining its usefulness and relevance to patients. Further investigation into the impact of SA in PR on patients would be beneficial, such as exploration of the psychological implications and acceptability before and after implementation.

4.6.10 Researcher Reflections: Self-Reflexive Statement

The reflexive statement outlined in Chapter 3 (page 180) also applies to this study. Particularly, my educational and professional background, and my increased awareness of giving all data equal attention and consideration, whether it be positive or negative.

It is important to state, that a key influence on the collection and interpretation of the data, is my own experience of a chronic respiratory condition, which causes breathlessness and physical limitation. Thankfully, it can be temporarily treated with surgery, but the symptoms gradually return over a short period of time. I feel this aided study conduction as I can relate and sympathise with patients who experience similar struggles, and I understand the frustration and anxiety that comes with it. However, I had to make sure that I was not transferring my own experiences onto the data or giving more weight to patients who expressed similar experiences to mine. On reflection, I think my own interest in ST stems from the fact that regardless of how progressed my breathlessness gets, I can always do it to some degree and still experience progress, which is very motivating. Because ST helps me, I believe that it can help others. However, I had to remind myself during this study process that everyone has different experiences, and not everyone will enjoy it or see the benefits as much as I do.

Regarding conduction of the interviews, the majority were productive and enjoyable, but a couple were challenging. This made me realise that not all participants are equally forthcoming and therefore you must adjust interview tactics. My interview with David was particularly challenging, as he did not offer up answers with much dialogue. On reflection, I could have asked further probing questions and left him more room to answer. Although leaning into the silence can feel awkward, I found in subsequent interviews that it led to participants adding further description to their answers.

4.7 Conclusion

This study provides insight into patient perspectives and experiences of ST, SA, and exercise in PR. Findings reveal participants demonstrate misunderstandings and misconceptions about ST, such as associations with a gym setting and a younger fitter cohort.

Nevertheless, an important consequence of ST and improved muscle strength is the positive impact it has on daily function and the performance of daily activities. Mixed views are reported about the usefulness and relevance of SA in PR, with some recognising its advantages and others questioning its relevance. Support from staff and peers is identified as an important aspect of PR, especially during exercise sessions. However, the absence of support, supervision, and structure is a challenge for many when trying to continue exercise after programme completion. This highlights the potential lack of support focusing on the skills needed for independent exercise, which is an important aspect of disease self-management. These findings provide useful implications for the implementation and use of SA and ST in PR, as well as exercise adherence beyond graduation. In particular, consideration for patient education and self-management strategies is needed to facilitate engagement and adherence to ST and exercise during and after PR, as well as for the conduction and performance of a SA in clinical practice.

Chapter 5. An online survey investigating strength assessment and strength training in pulmonary rehabilitation services in England: descriptive statistics

5.1 Chapter Overview

This chapter investigated the use of SA and ST in PR services in England, and explored barriers and influential factors. A cross-sectional survey study was conducted with practitioners who had a job role either running, managing, or assisting in PR. Results show ST is included in the majority of PR programmes, whereas SA use is low. Overall, there is large variation in the methods used to assess patient muscle strength and prescribe ST. Barriers included service-related factors (i.e., time and equipment), staff training, and patient physical limitations. This chapter outlines details of SA and ST use which has not been reported before, and emphasises the need for clearer PR guidance, with consideration for variability, feasibility, and barriers within clinical practice.

5.1 Introduction

PR is the gold standard non-pharmacological intervention offered by healthcare services to individuals with chronic respiratory conditions, specifically COPD (2). It is a structured programme comprised of two key components: exercise and education. Exercise training is widely regarded as the cornerstone of PR, and aims to improve overall physical function by combining ST and AT (53). Initially, exercise delivered in PR was predominately aerobic (176), however research has since evidenced ST as a valuable addition, producing significant improvements in skeletal muscle function, specifically muscle strength (181, 182,

227, 317, 318, 320, 511). This is a key benefit for COPD patients, who commonly suffer from muscle weakness, particularly of the lower limbs, such as the quadriceps - which is considered an important systematic marker of the condition (33, 93). Therefore, a combination of both training modalities is the best strategy to yield overall improvement in relevant outcomes, including muscle strength, exercise capacity, dyspnoea, and HRQoL (33).

Research has demonstrated that ST is effective at improving COPD muscle strength (181, 226, 227), however, an optimal ST prescription strategy is not yet determined. Contributing to this is the wide variation in its prescription and delivery (53, 360, 512). There are key training variables involved in the prescription of ST, including frequency, intensity/load, volume, rest periods, muscle actions, velocity, exercise selection, and exercise order (235). However, a systematic review found that many published RCTs and observational studies fail to report even the basic details about the prescription of ST for COPD patients, providing incomplete and inconsistent descriptions of how ST is actually prescribed (513). Insufficient reporting makes it difficult to build on previous findings, compare prescription protocols, and conclude on optimal strategies. If essential information is missing it means practitioners and healthcare services cannot reliably replicate and implement effective interventions into clinical practice.

As discussed in Chapter 2 (page 86), PR guidelines support and recommend the inclusion of ST. However, like research studies, there is markedly limited information regarding how to prescribe ST for COPD in PR programmes. The only criteria referenced for COPD are the ACSM prescription guidelines for healthy older adults (235). These are the only formal ST guidelines published that address the key variables of prescription. Although they provide some general guidance, they are not COPD-specific, meaning what is considered

appropriate for a general adult population may not be transferable to those with chronic respiratory disease, especially COPD which impacts physical fitness and function. Statements published by respiratory organisations and societies in the USA and Canada reference these ACSM guidelines (53, 225, 387), whereas guidance published within the UK does not (33, 36, 141, 151, 154). Unfortunately, PR guidelines in the UK provide severely limited guidance and advice for ST prescription.

This is similar with regards to SA. PR guidelines published within the UK, address and recommend SA as an outcome measure of PR (33, 36, 141, 151, 154). However, guidelines are limited and vague, with a marked lack of guidance regarding which SA method to use and how to use it. SA has clinical and prognostic value and relevance for COPD and the literature supports and encourages its utility in routine practice due to its numerous benefits, which include the identification of muscle weakness, prescription of individualised intensity/loads for training, and evaluation of intervention effectiveness (93, 228, 230-232). Muscle strength has been used extensively as an outcome measure and evaluative tool within COPD research, particularly for ST and exercise interventions (234), yet has minimal use in PR clinical trials (314, 315). Key limitations of this research include heterogeneity in the assessment methods used, and a lack of standardisation and consistency in reported methodology and protocols. As outlined in Chapter 2 (page 53), there are many methods and approaches to assessing strength, but not all are appropriate or feasible in clinical practice. PR programmes can take place in a variety of settings, including the community, primary care, and hospitals (33, 166). Therefore, what is possible in a research setting may not be feasible in settings of low resource. When considering how to assess muscle strength in PR, and how to prescribe and deliver ST, it is essential to consider relevant factors which influence feasibility (230). Such factors include time, equipment access, patient understanding, and technical skill. There is minimal research

investigating barriers related to the provision of PR content and components, particularly SA and ST. Some studies have investigated the implementation of COPD-related assessments, such as spirometry testing (398, 456), and exercise training programmes (395). But the majority of research focuses on the referral and uptake of PR (454) and self-management of COPD (455). Barriers commonly reported within these studies include staff training, knowledge, awareness, and resource constraints due to organisational and environmental factors, such as time and equipment.

Overall, literature supports and recommends the inclusion of SA and ST in PR programmes, but there is a noticeable absence of guidance for the implementation, delivery, and prescription in UK PR. Therefore, it begs the question of how PR services are fulfilling such recommendations. As discussed in Chapter 2 (page 94), a number of surveys have investigated PR provision - both within the UK and internationally (USA, Canada, Australia, and New Zealand). In the UK, biennial clinical audits have been conducted and published, reporting on the provision of PR, including access, referral, structure, content, assessment, and outcomes (164, 166, 385). The most recent NACAP PR audit collected some data on the provision of SA and ST, but detailed information was lacking (164). This audit found, of the participating services in England (*n*=132), 41.7% (*n*=55) recorded muscle strength at PR assessment, which has steadily increased since preceding audit reports. Of the 55 PR services which measured muscle strength, the most used method was the 5repS2S (49.1%, *n*=27), followed by 1-RM (40%, *n*=22), 10-RM (21.8%, *n*=12), dynamometer (18.2%, *n*=10), and strain gauge (1.8%, *n*=1). Regarding the inclusion of ST and its prescription, results showed 100% of PR services in England offered ST during PR programmes and 94.7% (*n*=125) individually prescribed it. Of those which prescribed ST, the most used method was a Borg breathlessness or perceived exertion score (79.2%, *n*=99), with only 28.8% (*n*=36) using ‘a

measurement of 1-RM or strength'. Unfortunately, the audit does not elaborate on the meaning of 'measurement of 1-RM or strength'. Additionally, it reports equipment provided for ST, with the most used being free weights (97.7%, *n*=129), followed by resistance bands (47.7%, *n*=63), and then weight machines (22%, *n*=29). These results provide a snapshot of SA and ST use in PR services in England, but further detail is needed to produce a clearer picture. The addition of in-depth questions were likely outside the scope of this audit, due to the large quantities of data collected on all aspects of PR.

Additional and more specific information is needed to gain further understanding of how SA and ST in used in PR programmes. The audit does not address all essential prescription variables, such as exercise volume, rest periods, exercise progression, type of ST exercises, and body area/muscle(s) targeted. Furthermore, it does not address details of SA conduction, such as body area and muscle(s) targeted for assessment, timepoint of conduction within a PR programme, and clear stipulation of purpose (i.e., outcome and/or prescription). Therefore, this study aims to provide a clearer and more detailed picture of provision. It sets out to investigate SA and ST in PR services in England, collecting detailed information on the assessment of patient muscle strength, and the prescription and delivery of ST. Furthermore, it aims to improve understanding of its use, with a particular focus on influential factors within PR clinical practice, including practitioner training, attitudes, and perceived barriers.

5.1.1 Research Questions

1. Do PR services assess patient muscle strength? If so, how is it assessed?
2. Do PR services include strength training in their exercise programme? If so, how is it prescribed?

3. Do PR practitioners have training for assessing muscle strength and delivering strength training?
4. What are the attitudes and opinions of PR practitioners towards strength assessment and strength training in PR?
5. What barriers do practitioners face in PR concerning strength assessment and strength training?

5.2 Methodology

5.2.1 Study Design

The study used a cross-sectional questionnaire-based online survey design.

5.2.2 Sample

5.2.2.1 Inclusion and Exclusion Criteria

Eligible participants were HCPs who had a job role either running, managing, or assisting in PR programmes located in England. Specifically, they worked in PR conducting standard face-to-face exercise programmes before the Covid-19 pandemic (i.e., before March 2020). Participants were adults (aged ≥18 years) and were able to read and comprehend English. The exclusion criteria specified anyone who was currently taking part in any conflicting study.

5.2.2.2 Sample Size

Sample size was calculated by estimating the total staff working in PR services in England. This was calculated from the number of PR services identified by the most recent NACAP audit (164), which named 199 services located in England, and reported an average

of three sites per service. Moreover, according to an earlier audit (166), two members of staff typically run and supervise each PR programme. Therefore, if each PR service had an average of three sites and two staff per site (i.e., six staff per service), a maximum estimation of 1194 staff were calculated as working in PR in England. Note, this is likely a maximum estimation as it is not possible to identify the exact number of staff working in each service and at each site. An online sample size calculator (514) was used to estimate a representative sample size from this total. The following information was entered: population size of 1194, confidence level of 95%, and a margin of error of 5%. This determined a representative study sample size of 291 participants.

5.2.3 Recruitment Procedures

The sampling method was purposive, with participants primarily recruited via NHS Trusts and non-NHS organisations (e.g., Community Interest Companies, Integrated Care Organisations, and private healthcare providers) - all of which provided PR services in England. These service providers were identified from the most recent NACAP audit (164), which named 199 PR services provided by 144 NHS Trusts and non-NHS organisations. Of the 144 providers approached, 55 (38.2%) granted study approval within their PR services. ***Figure 8*** presents a flow diagram of this research site recruitment process. Recruitment also took place through relevant professional networks and contacts. No incentive was offered to participants for completion of the survey, nor was an incentive provided to participating research sites for their involvement.

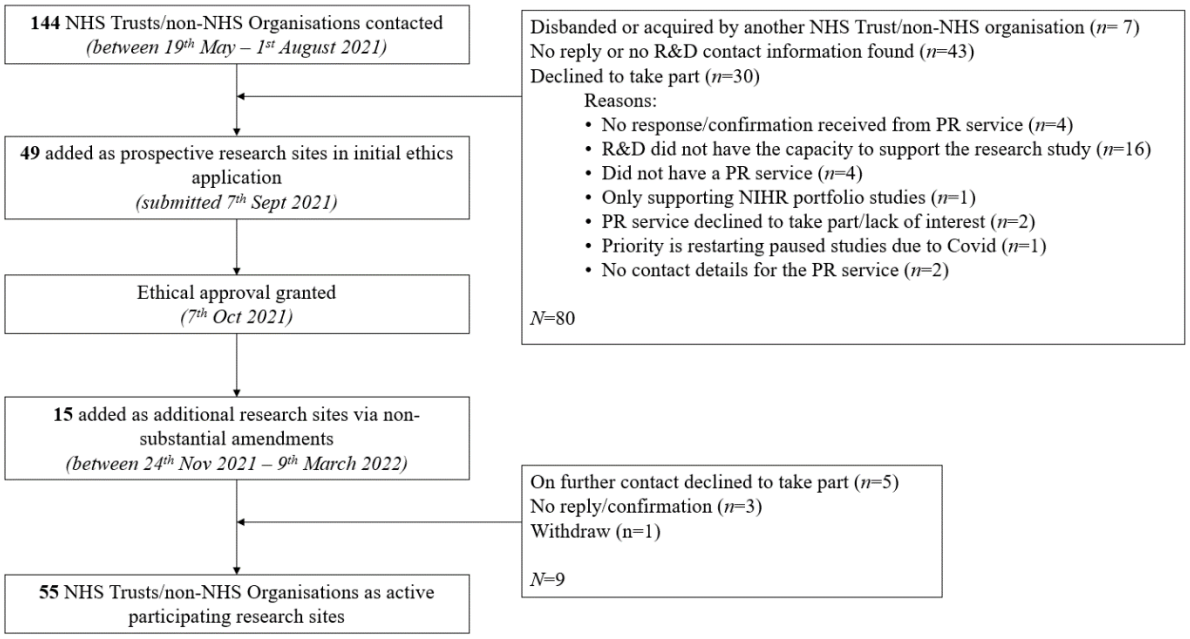

Figure 8. Recruitment flow diagram of NHS trusts/non-NHS organisations

Participant recruitment took place between 25th October 2021 and 6th May 2022. A flow chart of the recruitment process is presented in ***Figure 9***. All participants were directed to the survey using an online web link, which was sent within a recruitment email (Appendix U). Before starting the main body of the survey, participants were provided the PIS (Appendix V), and screened to ensure eligibility, using the study inclusion and exclusion criteria. If eligible, informed consent was obtained (Appendix W), ensuring all participants had read and understood the PIS provided and were fully aware of their contributions to this research. After which, participants were able to complete the survey, which had an estimated completion time of 20-25 minutes.

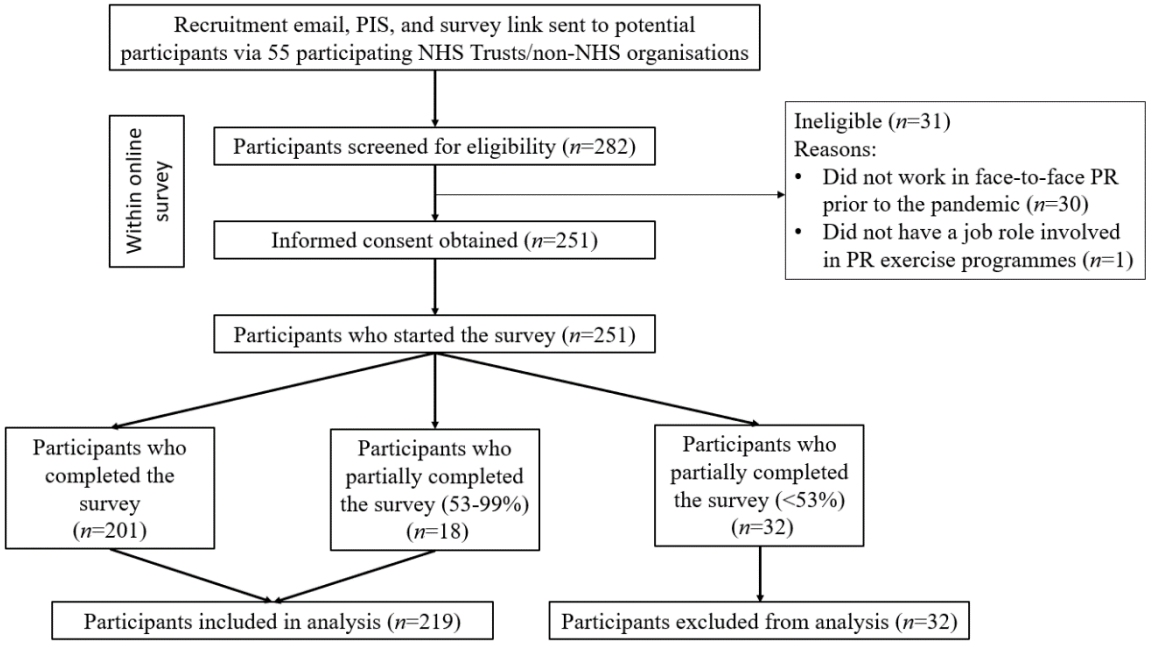

Figure 9. Participant recruitment and survey completion flow chart

5.2.3.1 Ethical Considerations

Ethical approval was granted by the HRA on 7th Oct 2021 (REC REF: 21/HRA/4032; IRAS ID: 302999) (Appendix X). After which, approval was granted by the University of Essex ethics subcommittee 2 on 16th Oct 2021 (REF: ETH2122-0177) (Appendix Y). Subsequent approval was obtained from the Research and Development department of each prospective research site i.e., the NHS Trusts and non-NHS organisations. In the initial ethics application, 49 providers were named as prospective research sites, with an additional 15 added via five subsequent non-substantial amendments (between 24th Nov 2021 and 9th Mar 2022). As shown in ***Figure 8***, 55 out of the 64 prospective research sites granted approval for the study to commence in their trust/organisation.

There were no foreseen risks in this study, as the survey subject matter did not cover any sensitive topics deemed to cause psychological discomfort or distress. Nevertheless, participants were informed taking part was entirely voluntary and they were free to stop the

survey at any time, no explanation necessary. Participants were also informed that their data would be confidentiality maintained and anonymised. Identifiable personal information was not actively collected from participants in this study (e.g., names, personal addresses, contact details etc.), but if such information was presented within survey responses, it was redacted or deleted to ensure anonymity and to uphold confidentiality.

5.2.4 Materials

5.2.4.1 Survey Development

Data was collected using a bespoke self-completed survey (Appendix Z). The survey was developed by drawing from and building on past published literature (164) and other research conducted in this thesis (i.e. Chapters 3 and 4). The survey was hosted, and data collected, using Qualtrics XM software (Copyright © 2021 Qualtrics). Before finalising the questionnaire, it was reviewed by the service manager of the collaborating PR service part funding this PhD project. The service manager is considered an expert in this field due to their long-standing position and involvement in this healthcare area, which includes 18 years' experience working in PR, an MSc in respiratory health, and a physiotherapy qualification (Phys Dip Ed). Additionally, the survey was piloted by six PR practitioners, working within the same PR service. This included two physiotherapists, two nurses, and two healthcare assistants. After which, feedback was provided, and appropriate amendments made, for example changes to question/response wording and the addition of questions to aid understanding and ensure more accurate responses.

As this study was concerned with the provision of standard face-to-face PR, participants were asked to answer most questions in relation to PR before the Covid-19 pandemic (i.e. before March 2020). At the time of this study many PR services had not yet re-established

"normal" clinical practice, as many face-to-face programmes were still impacted by the pandemic to some degree, for example some services were still only offering virtual PR, some had started transitioning back to face-to-face PR, and others were providing limited and reduced programmes. Therefore, it was important to outline a timeframe in which face-to-face PR was stable and consistent.

5.2.4.2 Survey Structure and Contents

As shown in **Table 13**, the survey was comprised of five main sections. The full survey is provided in Appendix Z, and each section and question topic is described in further detail below.

Table 13. Outline of survey structure and question topics

1.	Demographic and Job Details
2.	PR Service and Site Details
3.	Strength Assessment • Use of strength assessment in PR • Training relevant to strength assessment, both within PR and from other opportunities e.g. past job and experiences • Attitudes and opinions towards strength assessment in PR • Potential barriers faced in PR in relation to strength assessment
4.	Details about the PR exercise programme
5.	Strength Training • Delivery and prescription of strength training in PR • Awareness of strength training guidelines and recommendations for use in PR • Training relevant to strength training, both within PR and from other opportunities e.g., past jobs and experiences • Attitudes and opinions towards strength training in PR • Potential barriers faced in PR in relation to strength training

Demographics and Job Details

Demographic information collected included age, gender, and highest educational level. Additional descriptive data gathered included job role, duration working in the role and duration working in PR overall. The pre-determined job role categorises used were the same as those outlined in the 2020 NACAP audit (164).

PR Service and Site Details

Descriptive data were collected about the PR service the participants worked in, such as the number of PR sites, how many PR sites they regularly worked at, and the venue type of each. The pre-determined venue categories were the same as those outlined in the 2020 NACAP audit (164).

Strength Assessment Use

This section determined if patient muscle strength was assessed within the participant's PR service. To ensure understanding, SA was defined as 'a procedure/device used to measure, test, or assess a patient's peripheral muscle strength e.g., arms or legs'. If SA was used then further information was collected about the specific method and how it was conducted, such as duration, purpose (i.e., outcome measure and/or exercise prescription), timepoint of conduction within the PR programme, and body area and muscle groups assessed.

PR Exercise Programme Details

General questions were included to collect data about the PR programme and its exercise component. Items included duration of the PR programme (weeks), number of supervised exercise sessions per week, duration of exercise sessions (minutes), number of exercises in the programme, and types of exercise equipment used. As it was likely that many

participants would work at multiple sites, they were asked to answer these questions in relation to the predominant site they worked at.

Prescription of Strength Training

This section determined if ST is included in the PR exercise programme, and if so, how it is delivered and prescribed. Questions were developed by addressing each key prescription variable: exercise intensity and load/resistance, volume, rest periods, and exercise progression (235). Participants were asked to answer these questions in relation to the predominant site they worked at. To ensure understanding, strength/resistance training was defined as a form of physical activity that is designed to improve muscle strength (i.e., the ability to generate muscle force) by exercising a muscle or a muscle group against resistance (e.g., free weights, resistance bands or bodyweight) (175). This was to avoid confusion and incorrect reporting of exercise modality, which was experienced by a previous PR survey (387). In addition, participants were asked if the prescription of ST met the ACSM guidelines for healthy older adults, which has been recommended in COPD (235). This criteria is outlined and discussed in Chapter 2 (page 102).

Awareness of Strength Training

Items were included to assess awareness of guidelines and recommendations for ST in PR. Participants were asked the extent of their awareness of the recommendations by the BTS, ATS and ERS to include ST within PR exercise programmes (33, 53, 141), the ACSM ST guidelines for healthy older adults and their use within COPD populations (235). All items were measured on a 5-point rating scale: 1 = ‘not at all aware’, 2 = ‘slightly aware’, 3 = ‘moderately aware’, 4 = ‘very aware’, and 5 = ‘extremely aware’.

Staff Training

Questions were included to collect descriptive data on the extent of training completed by participants for the assessment of muscle strength and delivery of strength training. Focus was placed on training received while working specifically within PR, as well as from other opportunities and experiences (e.g., past jobs and education). This was deemed an important factor to investigate as quality of clinical practice is reliant on adequately trained and/or experienced staff (141). Moreover, it was a key finding found in previous research conducted in this thesis (i.e., Chapters 3 and 4). Additional items were included to assess participants opinions on the benefit of training and their confidence. These were measured on a 7-point rating scale of agreement: 1 = 'strongly disagree', 2 = 'disagree', 3 = 'somewhat disagree', 4 = 'neither agree nor disagree', 5 = 'somewhat agree', 6 = 'agree', and 7 = 'strongly agree'.

Practitioner Attitudes

Items were included to assess participant attitudes and opinions about SA and ST in PR. This was deemed an important factor to further investigate as the findings of Chapter 3 reported it as a potential facilitator. Participants were asked to indicate their level of agreement towards the importance, usefulness, safety, ease of use, and standardisation of SA in PR. In addition to, the importance, benefit to patients, safety, ease of delivery, individual prescription, and standardisation of ST within PR. These items were measured on a 7-point rating scale of agreement (same as above).

Barriers

Items were included to measure the presence of potential barriers faced by participants and their PR service when assessing muscle strength and delivering ST in PR. These barrier statements were constructed from considerations for use in clinical practice (Chapter 2) and

findings from research previously conducted in this thesis (Chapters 3 and 4), for example the emphasis of service-related factors (e.g., time and equipment), and patient-related factors (e.g., physical and psychological). Participants were asked to indicate their level of agreement toward statements related to patient, colleague, service, and individual practitioner barriers. Service-related barriers included time, workload, staff numbers, class size, funding, and exercise equipment. Patient-related barriers included compliance with directions/instructions, physical limitations, and psychological limitations, such as concerns/worries and understanding. Colleague-related barriers and individual practitioner related barriers both included training, knowledge and understanding, uncertainty of safety and uncertainty of benefit. All items were measured on a 7-point rating scale of agreement (same as above).

5.3 Analysis

Analysis was conducted using IBM SPSS Statistics (version 27). Prior to analysis, ineligible participants were removed from the dataset, and data was cleaned. Participants were deemed ineligible if they did not meet the inclusion criteria. It was decided that incomplete survey responses would still be included in the analysis if they were ≥53% complete (see ***Figure 9***). Henceforth, such cases will be named 'partial completers'. This specific criteria was set because it marked successful progression through all questions related to the first main topic of the survey (i.e. SA). This was put in place to ensure as much of the data collected was used and included as possible. Furthermore, where appropriate, data was manipulated in SPSS prior to analysis to create new variables, aiding analysis and reporting of results. New variables included:

- Duration working in job role and duration working in PR: Both questions were initially formatted as two separate variables for years and months. A new interval level variable was

created combining this data and recoding it into the equivalent of years e.g., 1 year and 6 months was converted into 1.5 years.

- Staff training received while working in PR and outside PR: Information on staff training and the type of training received was separated across a number of questions in the survey. A new categorical variable was created to represent the prevalence of training overall e.g., training received (both within PR and outside PR) and no training received.
- Free-text responses: Where appropriate, new categorical variables were created by grouping similar free-text question responses together. One example is the reporting of different S2S test variations – new variables were created to acknowledge and separate 1minS2S, 30secS2S, and 5repS2S.
- Prescription of ST volume: Participants were asked to select a pre-determined category for how exercise volume is prescribed (e.g., repetitions, sets, and/or time), and were subsequently asked to provide further information in a free-text response. New categorical variables were created to represent these free-text responses and how each method was prescribed.

Outliers within variables were explored, and responses where the value appeared too high or too low, to an extent that it was highly unlikely to be accurate, were removed from the data. One example is a participant stating the length of the PR programme was 50 weeks. As a PR programme typically lasts 6-8 weeks (33, 164), this seemed highly unlikely, and so was removed and noted as missing data.

Descriptive statistics were used to describe the sample characteristics and answer all research questions. Such data was reported using frequency distributions (*n* and *%*), and measures of central tendencies. For interval and ratio scale data the mean (*M*) and standard

deviation (*SD*) were used to report the average, and for ordinal data the median (*Mdn*) and interquartile range (*IQR*) were used. If scale data was found to be not normally distributed, then the median and IQR were reported instead. Free-text questions were analysed, were appropriate, for the purpose of providing further detail and context to the quantitative data collected. The quantity of qualitative data collected was not enough to conduct a formal qualitative analysis. Instead, data was organised into similar topics, categories, and themes, with brief summarises of each presented alongside direct quotations to demonstrate the data collected. The qualitative data analysis computer software package NVivo (Version 1.3) was used to support and organise this analysis process.

5.4 Results

5.4.1 Sample Characteristics and Response Rate

As shown in ***Figure 9***, 282 responses were collected. Ineligible (*n*=31) participants were removed from the dataset, of which 30 had not worked in face-to-face PR prior to the pandemic and 1 did not have a job role involved in PR exercise programmes. Survey responses <53% complete (*n*=32) were also removed from the dataset. This left 219 (*N*) participants included for analysis, of which 18 were partial completers (i.e., 53-99%). As partial completers were included in the analysis, missing data was expected. To ensure full transparency of this, the proportion (*n* and *%*) of missing data, if applicable, is reported within the results of each analysis, as the sample size does vary. Participants were asked to provide the name of the PR service they worked for, allowing the number of PR services represented by participants to be determined. A total of 74 PR services in England were represented by at least one participant in this study, with a median number of 2 participants recruited per PR service (*IQR* 3).

5.4.2 Participant Demographics and Job Details

More participants were female (*n*=180, 82.2%) than male (*n*=37, 16.9%), and age ranged between 22 and 65 years (*M* 42.8, *SD* 10.2). Over half (*n*=113 51.6%) stated the highest level of education received was an undergraduate degree, followed by a quarter with a postgraduate degree (*n*=55, 25.1%). Full details of participant demographics are provided in Appendix AA. The predominant job role among participants was a physiotherapist (*n*=135, 61.6%). Moreover, they had a median duration of 6.67 years (*IQR*=8.7) working in their job role and 7.75 years (*IQR*=8.6) working in PR overall. Full results of participant job details are provided in Appendix AB.

5.4.3 PR Service and Site Details

The mean number of PR sites within a service was 4.15 (*SD* 2.62), with participants working regularly at an average of 3.03 sites (*SD* 1.64). The PR site participants predominately worked at, were located in variety of venues. Over a third of PR sites (*n*=75, 34.2%) were based in a church or community hall, followed by 20.5% (*n*=45) in a local leisure centre or gym, 17.8% (*n*=39) in an acute hospital, 11% (*n*=24) in a community hospital, 8.7% (*n*=19) in a health centre, and 0.5% (*n*=1) in a GP surgery. Additionally, 6.8% (*n*=15) selected ‘other’ and 0.5% (*n*=1) was missing data. Full results of PR service and site details can be found in Appendix AC.

5.4.4 PR Exercise Programme Details

According to participants, the average duration of a PR programme was 6.58 weeks (*SD* 1.2). It included 1.93 supervised exercise sessions per week (*SD* 0.27), with each exercise session lasting an average duration of 66.3 minutes (*SD* 21.4). Participants were asked what equipment or training modality is predominately used by patients in PR exercise sessions. This

question was formatted as 'tick all that apply'. As shown in **Figure 10** and **Table 14**, the most used resistance equipment was free weights (96.8%), with nearly all participants selecting dumbbells and nearly half selecting ankle weights. Resistance bands were selected by over a third of participants (36.3%), specifically the use of TheraBands™. Whereas weighted machines or multiple gym apparatus was the least used, with only a fifth (19.9%) of participants selecting this equipment option.

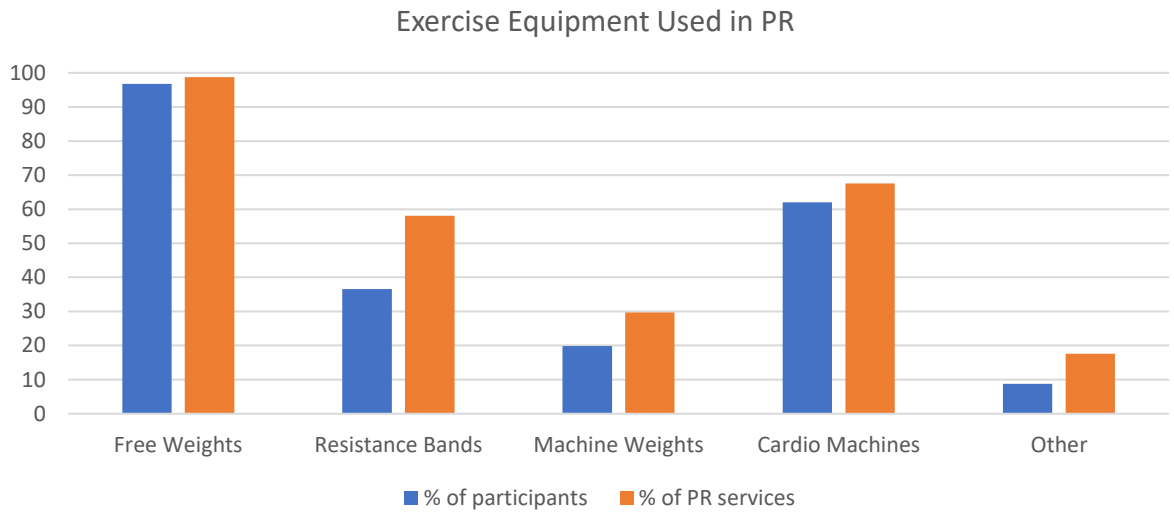

Figure 10. Exercise equipment predominantly used in PR exercise, according to the percentage (%) of participants (*n*=216/219) and PR services (*n*=74)

Aside from resistance equipment, participants also reported the use of cardio equipment (*n*=134, 62%), with stationary exercise bikes and treadmills being the most used (see **Table 14**). Overall, nearly 10% selected 'other' (*n*=19, 8.8%), describing additional exercise equipment, such as steps, foot/arm pedals, balls, and trampettes.

Table 14. Exercise equipment/training modalities predominately used in PR exercise sessions

	***n* of participants (%)**	***n* of PR services *(%)***
Free Weights	209 (96.8%)	73 (98.7%)
Dumbbells	208 (99.5%)	
Barbells with/without weight plates	14 (6.7%)	
Weight plates alone	5 (2.4%)	
Kettlebells	34 (16.3%)	
Ankle weights	98 (46.9%)	
Unsure	0 (0%)	
Other	2 (1%)	
Missing Data	1/209 (0.5%)	
Resistance Bands	79 (36.6%)	43 (58.1%)
TheraBands™	77 (96.3%)	
Long loop bands	5 (6.3%)	
Tubing/Tube bands	4 (5.1%)	
Mini/small circle bands	1 (1.3%)	
Unsure	1 (1.3%)	
Other	0 (0%)	
Cardio Machines	134 (62%)	50 (67.6%)
Treadmill	95 (71.4%)	
Stationary Exercise Bike	130 (97.7%)	
Stair Climber	8 (6%)	
Elliptical/Cross Trainer	21 (15.8%)	
Rowing Machine	35 (26.3%)	
Other	7 (5.3%)	
Missing Data	1/134 (0.7%)	
Multi Gym Apparatus/Machines with Weights	43 (19.9%)	22 (29.7%)
Unsure	0 (0%)	
Other	19 (8.8%)	13 (17.6%)
Missing Data	3/219 (1.4%)	

Note. *n*=219, *n* PR services = 74

Note. All questions were ‘tick all that apply’

5.4.5 Assessment of Patient Muscle Strength

Research Question 1: Do PR services assess patient muscle strength? If so, how is it assessed?

Half of participants (49.3%) stated their PR service did *not* assess patient muscle strength, and nearly half (47%) stated their PR service did (**Figure 11**). In terms of the number of PR services, this translated to 42 out of 74 (56.8%) PR services which assessed patient muscle strength.

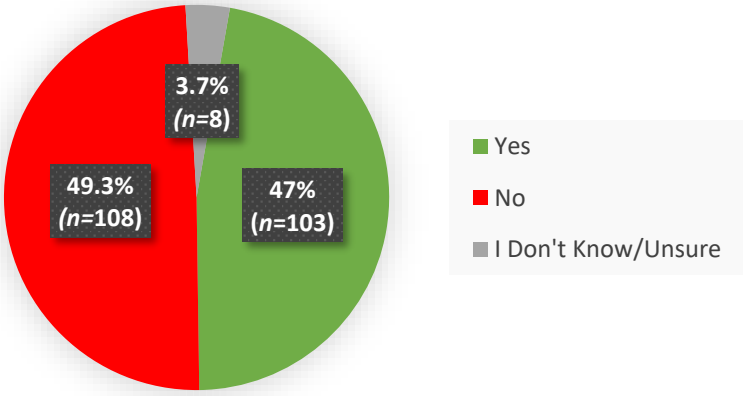

Figure 11. Strength assessment use in PR services, according to participants (N=219)

Of the participants who stated their PR service did assess patient muscle strength (*n*=103), a wide variety of SA methods were used. The most frequent assessment reported was a S2S test variation (*n*=32, 34%), which included the 5repS2S, 30secS2S, and 1minS2S. This was followed by 1-RM (*n*=29, 28.2%), m-RM (*n*=26, 25.2%), and then a dynamometer (*n*=17, 16.5%). The least used SA method was a strain gauge (*n*=6, 5.8%). These results are displayed in **Table 15**, along with the number of PR services using each SA. Due to the variation in SAs used, each method is discussed in turn below, outlining the duration (minutes), purpose of use, timepoint of conduction, and body area/muscle assessed. All questions, excluding duration,

were ‘tick all that apply’, allowing participants to select all applicable options. A detailed outline of these results are available in Appendix AD.

Table 15. Strength assessment methods used in PR services, according to participants (*n*=103)

Strength Assessment	***n* of participants (%)**	***n* of PR services (%)**
Sit to Stand Variation	35 (34%)	24 (57.1%)
Five-Repetition Sit to Stand (5repS2S)	22 (21.4%)	14 (33.3%)
1-minute Sit to Stand (1minS2S)	9 (8.7%)	7 (16.7%)
30-second Sit to Stand (30secS2S)	4 (3.9%)	3 (7.1%)
One-Repetition Maximum (1-RM)	29 (28.2%)	13 (31%)
Multiple-Repetition Maximum (m-RM)	26 (25.2%)	16 (38.1%)
Dynamometer	17 (16.5%)	8 (19%)
Strain Gauge	6 (5.8%)	2 (4.8%)
I don’t know/Unsure	3 (2.9%)	-
Other	4 (3.9%)	-

Note. n of participants = 103/219, *n* of PR services = 42/74
Note. question format was ‘tick all that apply’, with 15.5% (16/103) of participants selecting two strength assessment methods

5.4.5.1 Sit to Stand (S2S) Tests

The most used SA method reported by participants was a S2S test (*n*=35, 34%). Overall, the mean duration was 2.83 minutes (*SD* 2.32), with all participants reporting it was used for the purpose of an outcome measure, and 17.6% (*n*=6) stating it was used for exercise prescription. It was conducted at the start (100%) and end (91.2%) of the PR programme, and all participants stated it was used to assess lower body strength. However, there was variation in the type of S2S test used, each are summarised below.

Five-repetition Sit to Stand (5repS2S): The most used S2S variation was the 5repS2S (*n*=22, 21.4%). The mean duration was 3.2 minutes (*SD* 2.62), with all participants stating it was used for the purpose of an outcome measure, and 18.2% (*n*=4) stating it was used for

exercise prescription purposes. All participants stated it was conducted at the start of the PR programme, and 86.4% (*n*=19) stated it was conducted at the end. All participants reported it was used to assess lower body strength.

1-minute Sit to Stand (1minS2S): Nine participants (8.7%) reported the use of the 1minS2S. The mean duration was 2.13 minutes (*SD* 1.5), with all participants stating it was used for the purpose of an outcome measure, and one participant stating it was used for exercise prescription purposes. All participants stated it was conducted at the start and end of the PR programme, and was used to assess lower body strength.

30-second Sit to Stand (30secS2S): Four participants (3.9%) reported the use of the 30secS2S. The mean duration was 2.38 minutes (*SD* 2.1), with all participants stating it was used for the purpose of an outcome measure, and one participant stating it was used for exercise prescription purposes. All participants stated it was conducted at the start and end of the PR programme, and was used to assess lower body strength.

5.4.5.2 One-Repetition Maximum (1-RM)

In total, 28.2% (*n*=29) of participants stated 1-RM was used. The mean duration was 6.5 minutes (*SD* 3.4), with 85.7% (*n*=24) stating it was used for exercise prescription purposes, and 64.3% (*n*=18) stating use as an outcome measure. All participants said it was conducted at the start of the PR programme, and 60.7% (*n*=17) stated it was also conducted at the end. The 1-RM was primarily used to assess upper body strength (*n*=26, 92.9%), predominately the bicep muscles. Although, 42.9% (*n*=12) of participants stated it was used to assess lower body strength, specifically the quadriceps muscles.

5.4.5.3 Multiple-Repetition Maximum (m-RM)

In total, 25.2% (n=26) of participants stated m-RM was used. The mean duration was 6.4 minutes (*SD* 3.13), with nearly all participants (n=24, 96%) stating it was used for exercise prescription purposes, and half (*n*=13, 53%) stating use as an outcome measure. All participants reported it was conducted at the start of the PR programme, with 42.3% (*n*=11) stating it was also conducted at the end. Only three (11.5%) participants said it was used at another time point. All participants said the m-RM was used to assess upper body strength, predominately the bicep muscles, and half (*n*=13, 50%) said it was used to assess lower body strength, specifically the quadriceps muscles.

5.4.5.4 Dynamometer

In total, 16.5% (n=17) of participants reported a dynamometer SA. The mean duration was 4.24 minutes (*SD* 2.7), with all participants stating it was used as an outcome measure, and only three (17.6%) participants stating use for exercise prescription purposes. It was conducted both at the start (100%) and the end (94.1%) of the PR programme, and it is predominately used to assess upper body strength (*n*=15, 93.8%), specifically hand grip strength.

5.4.5.5 Strain Gauge

In total, 5.8% (*n*=6) of participants selected a strain gauge SA. The mean duration was 8.2 minutes (*SD* 4.26), with all participants stating it was used for the purpose of an outcome measure, and only one participant stating it was used for exercise prescription purposes. All participants stated it was conducted both at the start and end of the PR programme, and was exclusively used to assess lower body strength, specifically the quadricep muscles.

In summary, about half of PR services were reported to assess patient muscle strength, however a wide variety of SA methods were used. The most frequent assessments used were a S2S variation, 1-RM, and m-RM. 1-RM and m-RM tests were predominantly used to assess upper body strength, specifically bicep strength.

5.4.6 Prescription of Strength Training

Research Question 2: Do PR services include strength training in their exercise programme? If so, how is it prescribed?

Participants (*N*=219) were asked if ST was included in the PR exercise programme, and nearly all confirmed its inclusion. Specifically, 93.6% (*n*=205) reported yes, 0.9% (*n*=2) no, 1.8% (*n*=4) unsure, and 3.7% (*n*=8) was missing data.

5.4.6.1 Strength Training Prescription Variables

The following results, reporting the details of ST prescription, come from the participants who answered "yes" to the inclusion of ST (*n*=205). All questions were formatted as 'tick all that apply', allowing the selection of all applicable options. Full details of the ST prescription results are outlined in Appendix AE.

Number of Strength Training Exercises

PR exercise programmes are predominantly made up of strengthening exercises. Overall, an average of 10.4 (*SD* 3.5) individual exercises were included, of which 6.4 were ST based - equating to nearly two thirds (61.5%) of the exercise session.

Targeted Body Area

ST exercises were found to target both the lower (*n*=201, 99%) and upper body (*n*=197, 97%), as well as some targeting the trunk/core (*n*=71, 32%) (**Figure 12**).

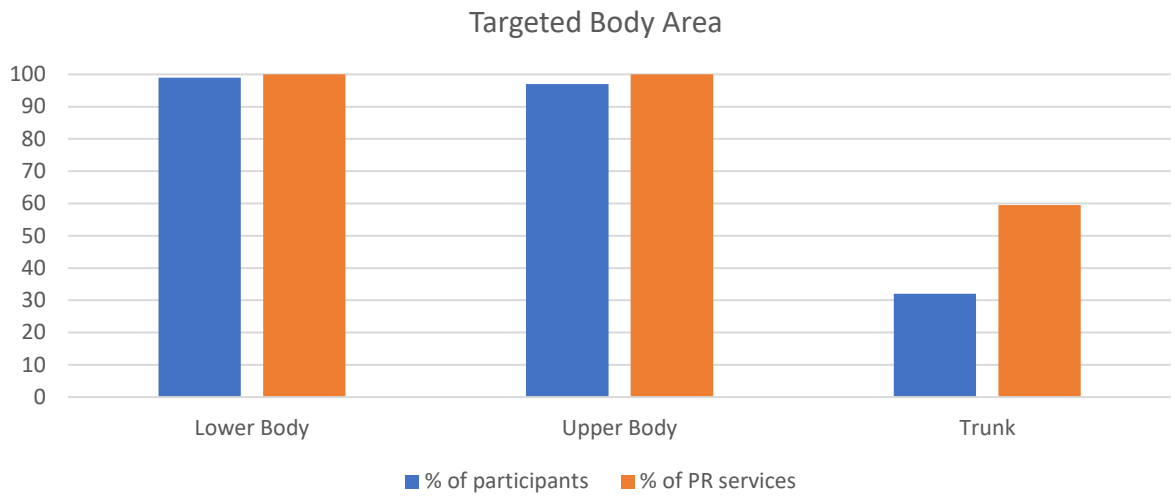

Figure 12. Targeted body area of strength training exercises, in reference to percentage (%) of participants (*n*=205) and PR services (*n*=74) (missing data: *n*=2, 1%)

Exercise Intensity

The most common method of prescribing exercise intensity for ST was a breathlessness scale (*n*=165, 81.7%). Of these participants (*n*=165), 76.2% (*n*=125) selected the modified Borg RPE scale 0-10, and 30.5% (*n*=50/165) selected the original Borg RPE scale 6-20. Other methods used to prescribe exercise intensity included 'to time' (*n*=73, 36.1%), heart rate (*n*=38, 18.8%), and a SA (*n*=33, 16.3%). These results are displayed in **Figure 13**. Of those who stated prescription using a SA (*n*=33), 40% (*n*=12) used 1-RM, 26.7% (*n*=8) m-RM, and 36.7% (*n*=11) predicted 1-RM.

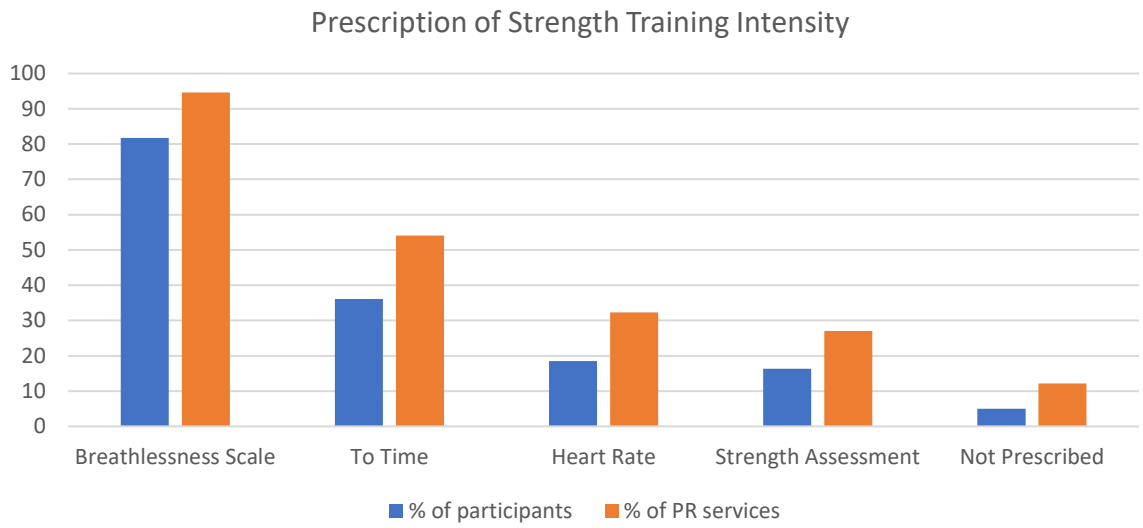

Figure 13. Methods of prescribing strength training intensity, in reference to percentage (%) of participants (*n*=205) and PR services (*n*=74) (missing data: *n*=3, 1.5%)

Load/Resistance

A main aspect of exercise intensity is the prescription of load/resistance. Participants were asked if a ST exercise used a load/resistance, how was it prescribed to patients. Results revealed large variation in the prescription methods used. Methods selected included, 70.4% (*n*=143) practitioner/staff selected, 59.1% (*n*=120) a Borg breathlessness scale, 36.9% (*n*=75) patient selected, 33% (*n*=67) 'to time', and 27.6% (*n*=56) a SA. These results are displayed in **Figure 14**. Of the participants who reported prescription using a Borg breathlessness scale (*n*=120), the modified Borg RPE scale 0-10 (*n*=78, 65.5%) was used more than the original Borg RPE scale 6-20 (*n*=47, 39.5%). Use of a SA was the least used method to prescribe load (*n*=56), of which 44.6% (*n*=25) used 1-RM, 37.5% (*n*=21) m-RM, and 7.9% (*n*=10) predicted 1-RM.

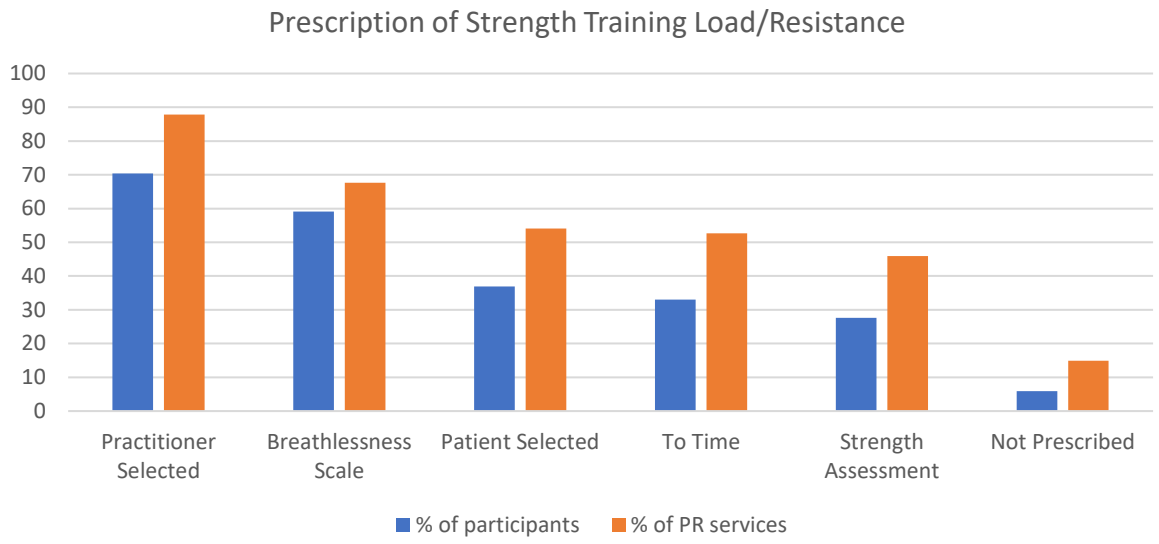

Figure 14. Methods of prescribing strength training load/resistance, in reference to percentage (%) of participants (*n*=205) and PR services (*n*=74) (missing data: *n*=2, 1%)

Exercise Volume

Participants were asked how ST exercise volume was prescribed to patients. The most common prescription methods used were exercise repetitions (*n*=161, 80.5%) and exercise sets (*n*=139, 69.5%). Other methods were also reported but these were less used, including 'to time' (*n*=85, 42.5%), patient reported (*n*=71, 35.5%). These results are displayed in **Figure 15**, To gain a better understanding of how these methods were used, participants were asked to provide further information about the parameters of these exercise volume prescriptions. The most frequent number of sets prescribed per exercise was 3 (*range* = 1-6), the most frequent number of repetitions in an exercise set was 10 (*range* = 5-50), and the most frequent time prescribed per exercise was 2 minutes (*range* = 0.5-10).

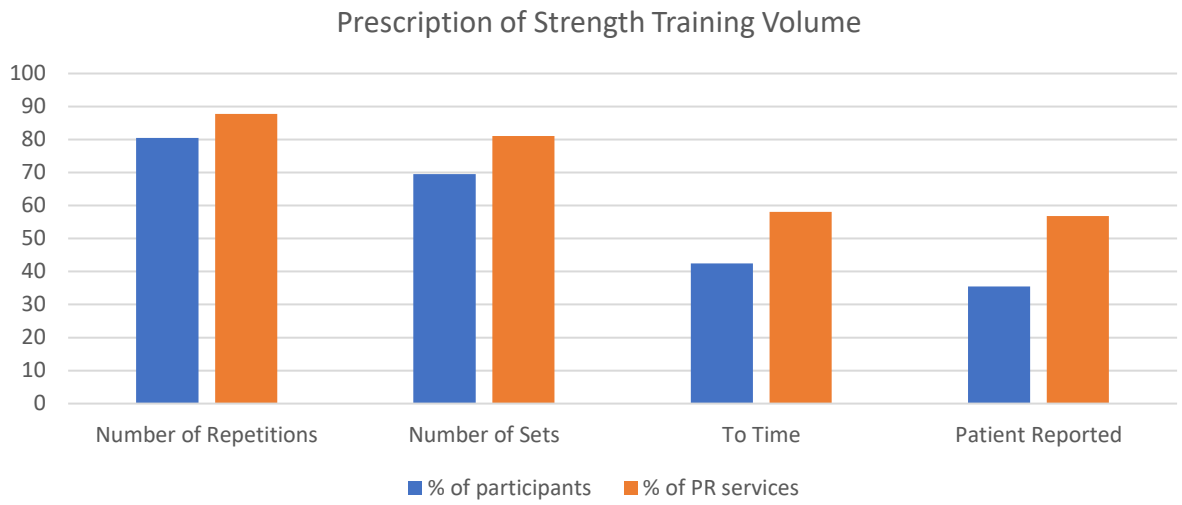

Figure 15. Methods of prescribing strength training volume, in reference to percentage (%) of participants (*n*=205) and PR services (*n*=74) (missing data: *n*=5, 2.4%)

Rest Periods

Participants were asked how ST rest periods/intervals were prescribed to patients. The following prescription methods were used: 57.2% (*n*=115) patient selected, 41.8% (*n*=84) practitioner/staff selected, and 39.8% (*n*=80) specified rest periods in line with the number of reps and sets. However, 14.4% (*n*=29) reported rest periods were not prescribed. These results are displayed in **Figure 16**.

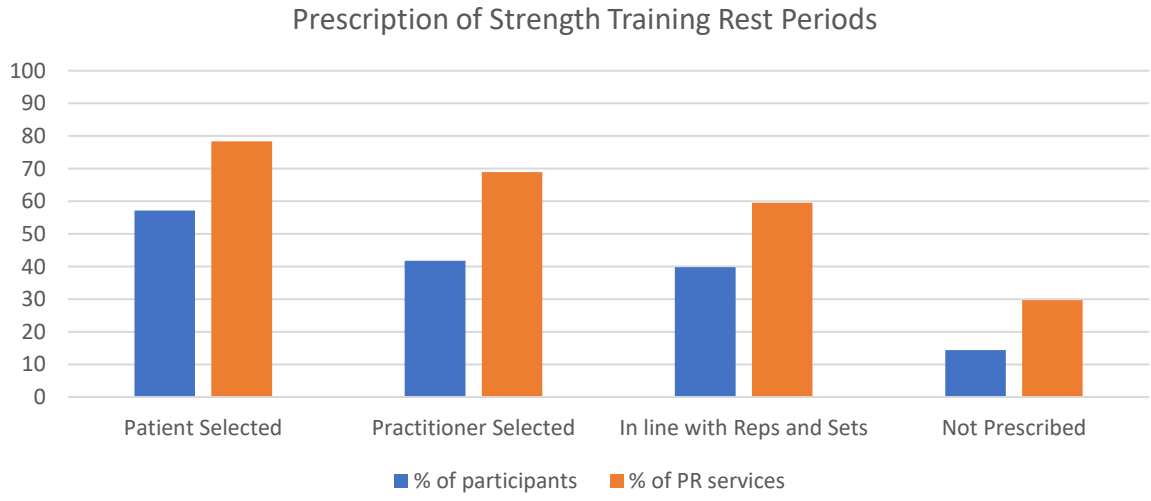

Figure 16. Methods of prescribing strength training rest periods, in reference to percentage (%) of participants (*n*=205) and PR services (*n*=74)

Exercise Progression

Participants were asked how exercise progression was prescribed to patients for ST. As shown in **Figure 17**, a variety of methods were used. Nearly all participants selected an increase in load/resistance (*n*=189, 95.5%), making it the most common method for ST progression. Other methods included an increase in the number of exercise repetitions (*n*=125, 63.1%), increase in number of exercise sets (*n*=93, 47%), increase in time performing the exercise (*n*=54, 27.3%), and a decrease in rest period duration (*n*=47, 23.7%). However, 5.9% (*n*=12) reported ST progression was not prescribed.

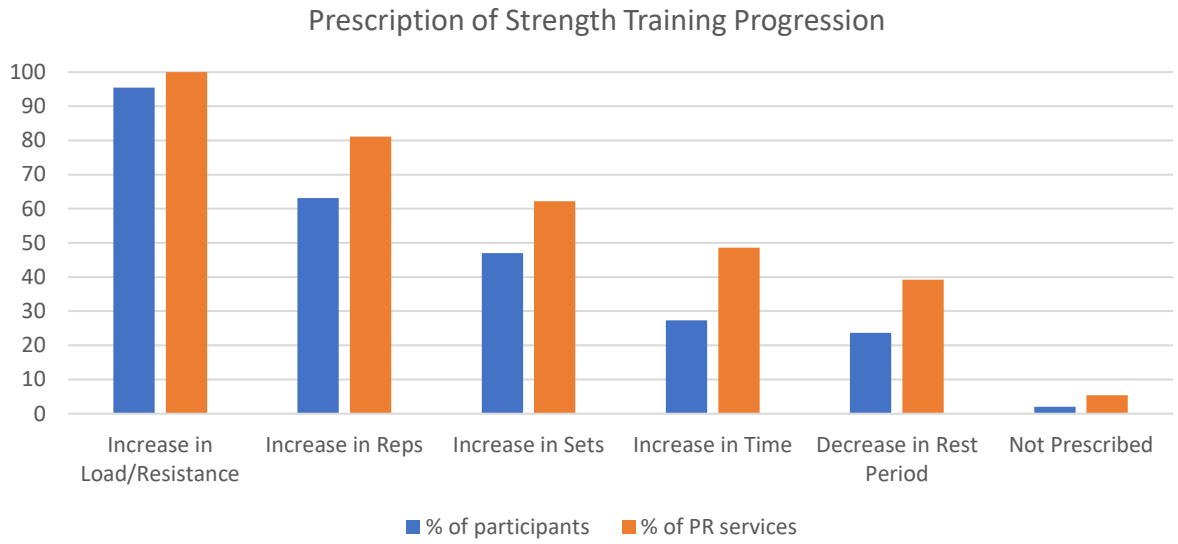

Figure 17. Methods of prescribing strength training progression, in reference to percentage (%) of participants (*n*=205) and PR services (*n*=74) (missing data: *n*=7, 3.4%)

In summary, nearly all participants reported that ST was included in PR exercise programmes. However, there is wide variation in how ST is prescribed, with no consensus or dominant strategy used across PR services.

5.4.6.2 Fulfilment of Strength Training Prescription Guidelines

Participants who reported ST was included in PR exercise programmes (*n*=205), were also asked if it met the ACSM prescription guidelines for healthy older adults, which has also been recommended for people with COPD (235). A description of the ACSM guidelines is provided in Chapter 2 (page 102). As illustrated in **Figure 18**, the vast majority (83.4%) of participants stated their PR service did *not* meet the full ACSM guidelines.

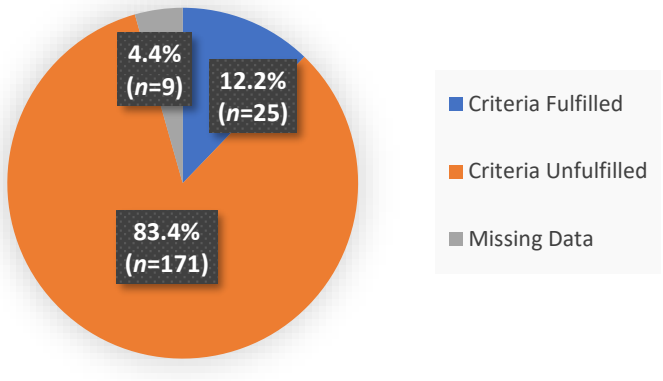

Figure 18. Percentage (%) of participants (n=205) who stated their PR service fulfilled/unfulfilled the ACSM guidelines for strength training prescription

As shown in **Table 16**, the criteria variables most prescribed were ST frequency, progression, and equipment - with over 80% of participants confirming prescription. Furthermore, over half of participants reported the prescription of exercise volume (≥1 sets of 10-15 repetitions). Whereas the least prescribed criteria variables were 8-10 strengthening exercises per session (42.9%) and exercise intensity (48.3%).

Table 16. Fulfilment of the ACSM strength training prescription criteria variables

	Prescribed ***n*** **(%)**	**Not Prescribed** ***n*** **(%)**
Exercise intensity (≥1 method):	99 (48.3%)	102 (49.8%)
40-50% 1-RM	16 (7.8%)	185 (90.2%)
60-70% 1-RM	29 (14.1%)	172 (83.9%)
5-6 Borg RPE (scale 0-10)	78 (38%)	123 (60%)
7-8 Borg RPE (scale 0-10)	13 (6.3%)	188 (91.7%)
8-10 ST exercises	88 (42.9%)	113 (55.1%)
≥1 sets	123 (60%)	78 (38%)
10-15 reps	115 (56.1%)	86 (41.9%)
≥2 ST frequency per week	168 (82%)	33 (16%)
Weight training and/or weight-bearing exercise programme	182 (88.8%)	19 (9.2%)
Weight/resistance equipment	177 (86.3%)	24 (11.7%)
Bodyweight exercises	139 (67.8%)	62 (30.2%)
Exercise progression	179 (87.3%)	22 (10.7%)

Note. n=196/205, missing data: n=9 (4.4%).
Note. Question was 'tick all that apply'.

5.4.6.3 Awareness of Strength Training Guidelines

As shown in **Table 17**, participants were aware of the recommendation for ST inclusion in PR, but only moderately aware of ACSM guidelines. On average, participants were 'very aware' of current guidelines published by leading respiratory organisations (e.g., by the BTS, ATS, and ERS) which recommend the inclusion of ST in PR exercise programmes. However, on average, participants were only 'moderately aware' of both ACSM ST guidelines for older adults and its recommendation for COPD.

Table 17. Awareness of strength training guidelines

	Current guidelines/statements published by leading respiratory organisations (e.g. BTS. ATS, and ERS) recommend the inclusion of strength training in pulmonary rehabilitation exercise programmes. How much were you aware of this?	**For COPD patients, the ATS and ERS recommend following the ACSM guidelines for strength training in healthy older adults.**	
		To what extent were you aware of these ACSM guidelines?	**To what extent were you aware of these ACSM guidelines being recommended for use with COPD patients?**
Median (*IQR*)	4 (*2*)	3 (*2*)	3 (*2*)
1 – Not at all aware	5 (2.3%)	29 (13.2%)	36 (16.4%)
2 – Slightly aware	13 (5.9%)	36 (16.4%)	37 (16.9%)
3 – Moderately aware	38 (17.4%)	63 (28.8%)	69 (31.5%)
4 – Very aware	76 (34.7%)	44 (20.1%)	35 (16.0%)
5 – Extremely aware	72 (32.9%)	33 (15.1%)	28 (12.8%)
Missing Data	15/219 (6.8%)	14/219 (6.4%)	14/219 (6.4%)

NOTE: n=219. BTS = British Thoracic Society, ATS = American Thoracic Society, ERS = European Respiratory Society, ACSM = American College of Sports Medicine.

5.4.7 Staff Training

Research question 3: Do PR practitioners have training for assessing muscle strength and delivering strength training?

5.4.7.1 Practitioner Training for Assessing Muscle Strength

Total Sample (*n*=219)

Of the total sample (*n*=219), over a third of participants (*n*=82, 37.4%) did *not* have training related to the assessment of muscle strength, whereas 61.7% (*n*=135) reported they did, and 0.9% (*n*=2) were unsure. Of the participants who had training (*n*=135), 53.3% (*n*=72) had only received training whilst working in PR, 22.2% (*n*=30) had only received training

outside of working in PR, and 24.5% (*n*=33) had received both. Additional information was collected regarding 'learning on the job' training. Of the participants (*n*=105) who received training while working in PR (either alone (*n*=72) or in combination with other opportunities (*n*=33))), results show training involved 'learning on the job' in some capacity, with 36.2% (*n*=38) reporting all of it was 'learning on the job', 44.8% (*n*=47) some of it, and 19% *(n*=20) none of it.

Participants who assess strength (*n*=103)

Staff training was also explored just among the participants who stated their PR service used a SA (*n*=103). As shown in **Figure 19**, nearly a third of participants (*n*=32, 31.1%) did *not* have training, despite working in a PR service which assessed strength. Exploration into the job roles and job duties of these participants was carried out. Of those who did *not* have training (*n*=32), the majority were physiotherapists (*n*=22, 68.8%), who had job duties leading and/or assisting in PR exercise sessions (*n*=27, 84.4%), and conducted patient assessments (*n*=22, 68.8%). Some even held a role of high responsibility, including site lead (*n*=14, 43.8%) and/or service manager (*n*=5, 15.6%).

Of the participants who reported they did have training related to the assessment of muscle strength (*n*=71, 68.9%, **Figure 19**), the circumstances in which this training was received was also collected. As shown in **Figure 20**, the majority of participants received training whilst working in PR. This training was received either solely working in PR (52.1%) or in combination with other training opportunities outside of working in PR (28.2%). However, a fifth of participants (19.7%) had only received training from outside/external opportunities, meaning no training was received while working in PR at any time.

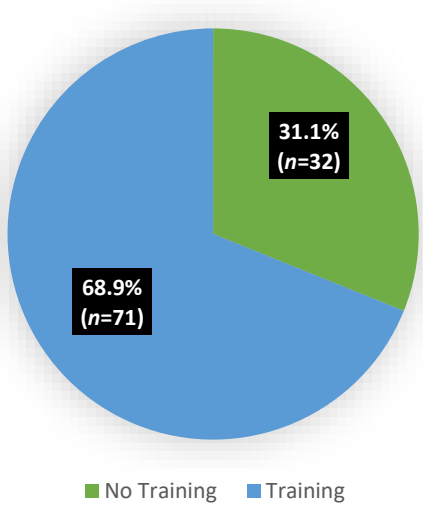

Figure 19. Participants (*n*=103) who stated their PR service does use a strength assessment, and the percentage (%) of these participants who have and have not received training related to the assessment of muscle strength

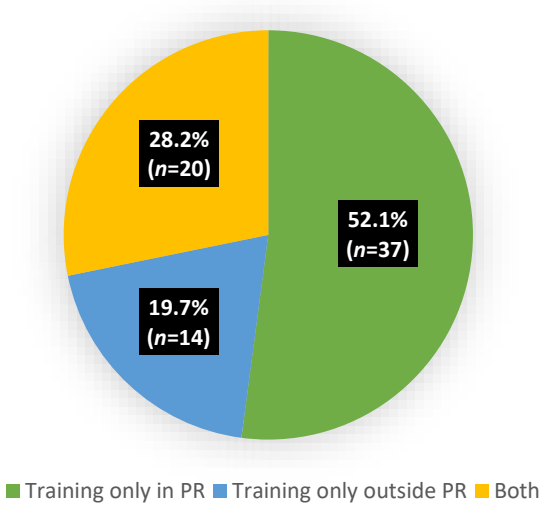

Figure 20. Participants who stated their PR service does use a strength assessment, and who have received staff training related to the assessment of muscle strength (*n*=71), with percentages (%) of training received while working in PR, outside of working in PR

5.4.7.2 Practitioner Training Opinions (Strength Assessment)

All participants were asked if themselves, and their colleagues, would benefit from training and/or additional training to support them in assessing patient muscle strength in PR (**Table 18**). On average, participants 'agree' that themselves and their colleagues would benefit from training. Participants were also asked to rate their confidence assessing patient muscle strength in PR. On average, participants 'somewhat agree' that they were confident (**Table 18**).

Table 18. Participant opinions on staff training for assessing patient muscle strength in PR

	I feel I would benefit from training/additional training to support me in assessing patient muscle strength in PR.	**I feel my colleagues would benefit from training/additional training to support them in assessing patient muscle strength in PR.**	**I am confident assessing a patient's muscle strength in PR.**
Median (*IQR*)	6 (*1*)	6 (*2*)	5 (*2*)
1 - Strongly Disagree	6 (2.7%)	3 (1.4%)	18 (8.2%)
2 - Disagree	11 (5%)	7 (3.2%)	14 (6.4%)
3 - Somewhat Disagree	5 (2.3%)	4 (1.8%)	18 (8.2%)
4 - Neither Agree nor Disagree	26 (11.9%)	25 (11.4%)	37 (16.9%)
5 - Somewhat Agree	44 (20.1%)	40 (18.3%)	63 (28.8%)
6 - Agree	73 (33.3%)	81 (37%)	49 (22.4%)
7 - Strongly Agree	54 (24.7%)	59 (26.95)	20 (9.1%)
Missing (%)	0/219 (0%)	0/219 (0%)	0/219 (0%)

Note. n=219.

5.4.7.3 Practitioner Training for Delivering Strength Training

As shown in **Figure 21**, of the total sample (n=219), nearly half of participants (45.2%) did *not* have training related to the delivery of ST in PR. Of the participants who had training (n=106), the majority received it while working in PR. As shown in **Figure 22**, this training was received either solely working in PR (53.8%) or in combination with other training opportunities outside of PR (21.7%). However, a quarter of participants (24.5%) had only received training from outside/external opportunities - no training was received while working in PR at any time. Additional information was collected regarding 'learning on the job' training. Of the participants (n=80) who had received training while working in PR, (either alone (n=57) or in combination with other opportunities (n=23))), results show training involved 'learning on the job' in some capacity, with 27.5% (n=22) reporting all of it being 'learning on the job', 51.2% (n=41) some of it, and 21.3% *(*n=17) none of it.

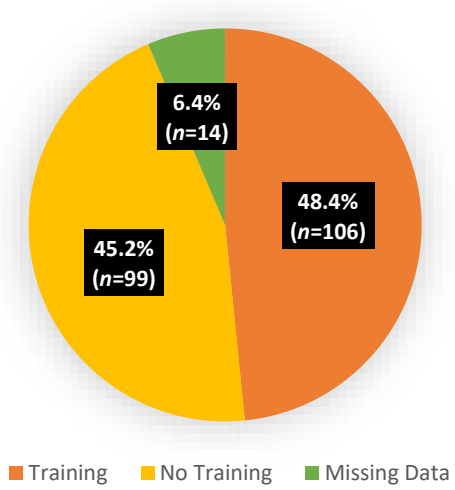

Figure 21. Percentage (%) of total participants (*n*=219) who have and have not received training related to the delivery of strength training

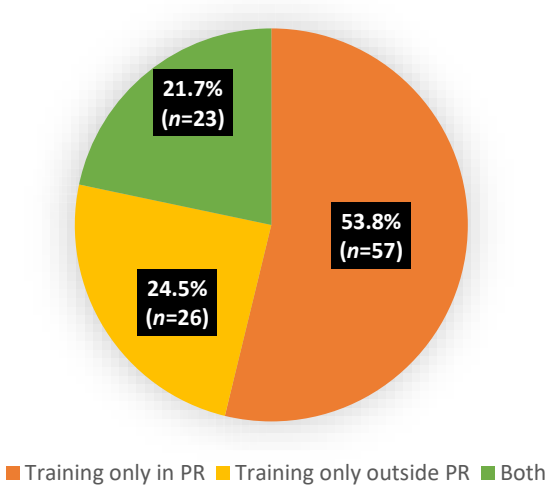

Figure 22. Participants who have received training related to the delivery of strength training (*n*=106), with percentages (%) of training received while working in PR, outside of working in PR, and both

5.4.7.4 Practitioner Training Opinions (Strength Training)

Participants were asked if themselves, and their colleagues, would benefit from training and/or additional training to support them in delivering ST in PR (**Table 19**). On average, participants 'agree' that themselves and their colleagues would benefit from training. Participants were also asked to rate their confidence delivering ST in PR. On average, participants 'somewhat agree' that they were confident (see **Table 19**).

Table 19. Participant opinions on staff training for delivering strength training

	I feel I would benefit from training/additional training to support me in delivering strength training in PR.	**I feel my colleagues would benefit from training/additional training to support them in delivering strength training in PR.**	**I am confident delivering strength training in PR.**
Median (*IQR*)	6 (*1*)	6 (*1*)	5 (*2*)
1 - Strongly Disagree	7 (3.2%)	4 (1.8%)	3 (1.4%)
2 - Disagree	10 (4.6%)	8 (3.7%)	11 (5%)
3 - Somewhat Disagree	6 (2.7%)	8 (3.7%)	12 (5.5%)
4 - Neither Agree nor Disagree	22 (10%)	27 (12.3%)	28 (12.8%)
5 - Somewhat Agree	52 (23.7%)	46 (21%)	55 (25.1%)
6 - Agree	68 (31.1%)	67 (30.6%)	66 (30.1%)
7 - Strongly Agree	36 (16.4%)	41 (18.7%)	25 (11.4%)
Missing (%)	18/219 (8.2%)	18/219 (8.2%)	19/219 (8.7%)

Note. n = 219.

In summary, despite the inclusion of SA and ST in PR programmes, a substantial portion of participants did not have related training. Of those which did, results showed that ‘learning on the job’ was a key method of training, with a large proportion receiving training whilst working in PR. The majority of participants felt they would benefit from training and/or additional training to support them in assessing patient muscle strength and delivering ST in PR.

5.4.8 Practitioner Attitudes

Research Question 4: What are the attitudes and opinions of PR practitioners towards strength assessment and strength training in PR?

5.4.8.1 Strength Assessment Attitudes

Overall, participants show positive attitudes and opinions towards the assessment of patient muscle strength in PR. **Table 20** presents the results of each SA attitude statement. On average, participants 'agree' that assessing patient muscle strength is important, safe, a useful outcome in PR, and should be standardised across all PR services. Additionally, on average, participants 'somewhat agree' that assessing patient muscle strength is easy.

Table 20. Attitudes towards strength assessment in PR

	Assessing patient muscle strength is important	**Assessing patient muscle strength is a useful outcome in PR**	**Assessing patient muscle strength is safe**	**Assessing patient muscle strength should be standardised across all PR services**	**Assessing patient muscle strength is easy**
Median (*IQR*)	6 (*2*)	6 (*1*)	6 (*2*)	6 (*2*)	5 (*2*)
1 - Strongly Disagree	1 (0.5%)	1 (0.5%)	1 (0.5%)	2 (0.9%)	4 (1.8%)
2 - Disagree	2 (0.9%)	4 (1.8%)	0 (0%)	4 (1.8%)	10 (4.6%)
3 - Somewhat Disagree	2 (0.9%)	7 (3.2%)	1 (0.5%)	9 (4.1%)	28 (12.8%)
4 - Neither Agree nor Disagree	20 (9.1%)	22 (10%)	35 (16%)	36 (16.4%)	60 (27.45)
5 - Somewhat Agree	31 (14.2%)	45 (20.5%)	32 (14.6%)	36 (16.4%)	54 (24.7%)
6 – Agree	98 (44.7%)	85 (38.8%)	93 (42.5%)	72 (32.9%)	51 (23.3%)
7 - Strongly Agree	64 (29.2%)	54 (24.7%)	55 (25.1%)	59 (26.9%)	11 (5%)
Missing Data	1/219 (0.5%)	1/219 (0.5%)	2/219 (0.9%)	1/219 (0.5%)	1/219 (0.5%)

Note. n=219.

5.4.8.2 Strength Training Attitudes

Overall, participants show positive attitudes and opinions towards ST in PR. **Table 21** presents results of each ST attitude statement. On average, participants 'strongly agree' that ST

is important and beneficial for patients. Furthermore, on average, participants 'agree' that ST is safe for patients, easy to deliver in PR, should be individually prescribed and should be standardised across all PR services.

Table 21. Attitudes towards strength training in PR

	Strength training is important for patients	**Strength training is beneficial for patients**	**Strength training is safe for patients**	**Strength training is easy to deliver in PR**	**Strength training should be individually prescribed to patients**	**Strength training should be standardised across all PR services**
Median (*IQR*)	7 (*1*)	7 (*1*)	6 (*1*)	6 (*1*)	6 (*1*)	6 (*2*)
1 - Strongly Disagree	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)	0 (0%)	1 (0.5%)
2 - Disagree	0 (0%)	0 (0%)	0 (0%)	3 (1.4%)	0 (0%)	6 (2.7%)
3 - Somewhat Disagree	1 (0.5%)	1 (0.5%)	2 (0.9%)	5 (2.3%)	0 (0%)	11 (5%)
4 - Neither Agree nor Disagree	4 (1.8%)	4 (1.8%)	12 (5.5%)	16 (7.3%)	13 (5.9%)	28 (12.8%)
5 - Somewhat Agree	8 (3.7%)	6 (2.7%)	17 (7.8%)	37 (16.9%)	14 (6.4%)	30 (13.7%)
6 - Agree	79 (36.15)	75 (34.2%)	99 (45.2%)	92 (42%)	86 (39.3%)	74 (33.8%)
7 - Strongly Agree	110 (50.2%)	115 (52.5%)	71 (32.4%)	48 (21.9%)	89 (40.6%)	52 (23.7%)
Missing Data	17/219 (7.8%)	18/219 (8.2%)	18/219 (8.2%)	17/219 (7.8%)	17/219 (7.8%)	17/219 (7.8%)

Note. n=219.

5.4.9 Barriers

Research Question 5: What barriers do practitioners face in PR concerning strength assessment and strength training?

5.4.9.1 Strength Assessment Barriers

On average, participants 'somewhat agree' that time is limited and exercise equipment is inadequate for assessing patient muscle strength in PR, as well as patient physical limitations making it difficult to assess patient muscle strength in PR. Results of these three perceived

barriers are presented in **Table 22**. Results of all SA barrier statements are available in Appendix AF.

Table 22. Perceived barriers to strength assessment and strength training in PR

	SA			ST
	Time is limited for assessing patient muscle strength	**Exercise equipment is inadequate for assessing patient muscle strength**	**Patients have physical limitations which makes it difficult to assess their muscle strength**	**Patients have physical limitations which makes it difficult for them to do strength training.**
Median (*IQR*)	5 (*2*)	5 (*2*)	5 (*1*)	5 (*1*)
1 - Strongly Disagree	9 (4.1%)	7 (3.2%)	4 (1.8%)	4 (1.8%)
2 - Disagree	18 (8.2%)	24 (11%)	15 (6.8%)	22 (10.0%)
3 - Somewhat Disagree	21 (9.6%)	9 (4.1%)	21 (9.6%)	22 (10.0%)
4 - Neither Agree nor Disagree	22 (10%)	38 (17.4%)	47 (21.5%)	46 (21.0%)
5 - Somewhat Agree	57 (26%)	39 (17.8%)	84 (38.4%)	61 (27.9%)
6 - Agree	64 (29.2%)	52 (23.7%)	35 (16%)	36 (16.4%)
7 - Strongly Agree	28 (12.8%)	50 (22.8%)	12 (5.5%)	7 (3.2%)
Missing Data	0/219 (0%)	0/219 (0%)	1/219 (0.5%)	21/219 (9.6%)

Results also indicate other potential barriers to assessing patient muscle strength in PR. Specifically, high staff workloads (*Mdn* 4 *IQR* 2), limited funding (*Mdn* 4 *IQR* 3), low staff numbers (*Mdn* 4 *IQR* 3), and a lack of training for both the practitioner (i.e. the participant) (*Mdn* 4 *IQR* 3) and their colleagues (*Mdn* 4 *IQR* 3). On average, participants 'neither agree nor disagree' with these SA barrier statements, showing mixed results and a split in level of agreement. As shown in **Figure 23-**, over a third of participants (36.5%-43.4%) agree to some

extent with these SA barrier statements when the agreement categories are combined (i.e. strongly agree, agree, and somewhat agree).

Factors found not to be perceived barriers to assessing patient muscle strength in PR were large class size, limited practitioner knowledge/understanding, and practitioner uncertainty of SA safety and benefit. On average, participants ‘disagree’ with these statements, indicating these factors are not perceived as SA barriers in PR. Full details are outlined in Appendix AF.

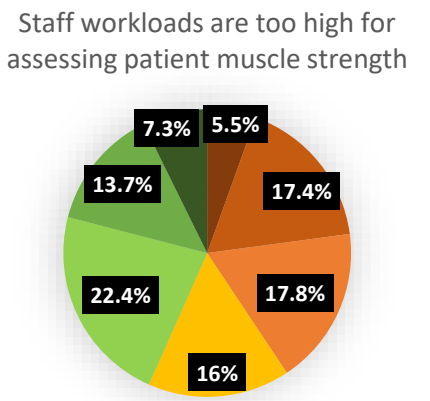

Figure 23. Level of agreement (%) towards high staff workloads as a barrier to assessing patient muscle strength in PR (*n*=219)

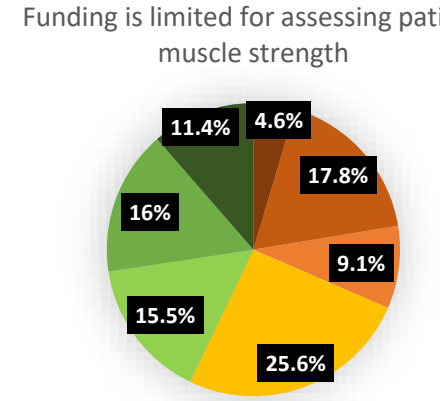

Figure 24. Levels of agreement (%) towards limited funding as a barrier to assessing patient muscle strength in PR (*n*=219)

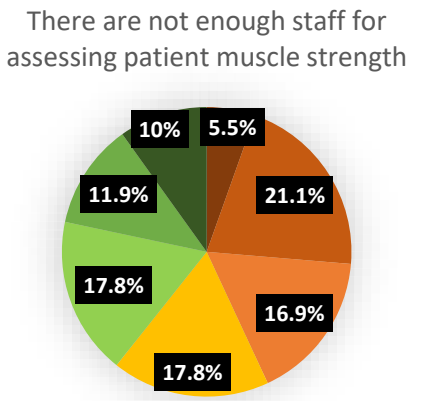

Figure 25. Levels of agreement (%) towards low staff numbers as a barrier to assessing patient muscle strength in PR (*n*=219)

Figure 26. Levels of agreement (%) towards a lack of participant training as a barrier to assessing patient muscle strength in PR (n=218/219

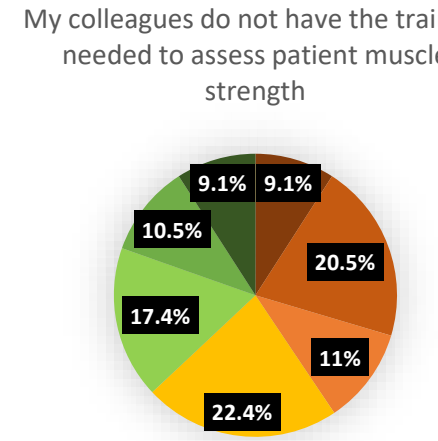

Figure 27. Levels of agreement (%) towards a lack of colleague training as a barrier to assessing patient muscle strength in PR (n=219*)*

5.4.9.2 Strength Training Barriers

On average, participants ‘somewhat agree’ patients have physical limitations, making it difficult for them to do ST. Results of this ST barrier statement are presented in **Table 22** (above). Results of all ST barrier statements are available in Appendix AG.

Results also indicate other potential barriers to delivering ST in PR. Specifically, inadequate exercise equipment (*Mdn* 4 *IQR* 3) and not enough equipment to go around all patients (*Mdn* 4 *IQR* 4). On average, participants ‘neither agree nor disagree’ with both barrier statements, showing mixed results and a split in level of agreement. As shown in **Figure 28** and **Figure 29**, over a third of participants (39.3% and 43.4 %, respectively) agree to some extent with both ST barrier statements when the agreement categories are combined (i.e. strongly agree, agree, and somewhat agree).

Factors found not to be perceived barriers to delivering ST in PR are outlined in Appendix AG. On average, participants either ‘disagreed’ or ‘somewhat disagreed’ with these barrier statements.

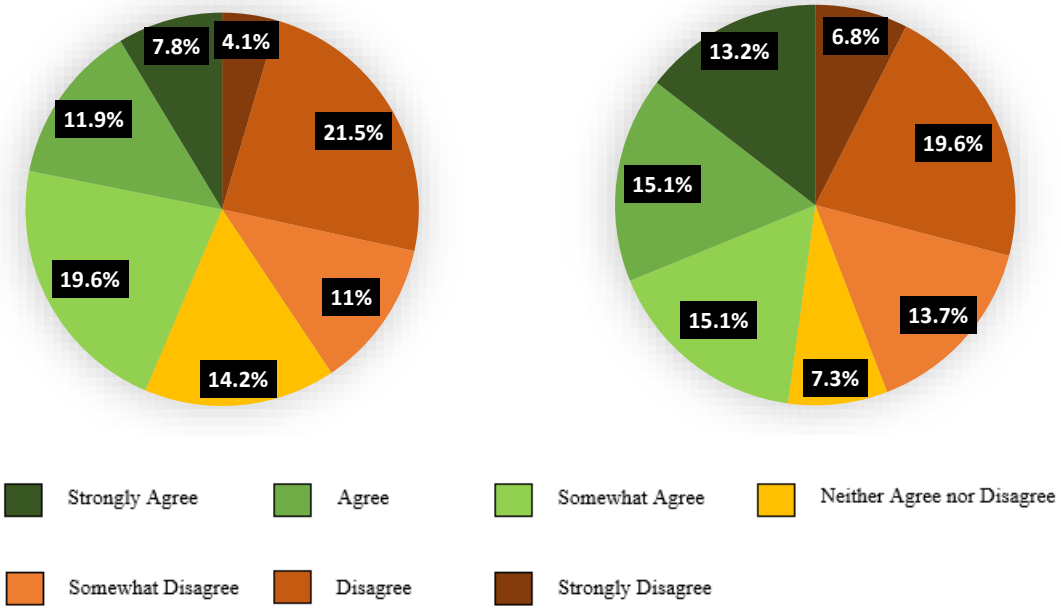

Figure 28. Levels of agreement (%) towards inadequate exercise equipment as a barrier to delivering strength training in PR (*n*=197/219)

Figure 29. Levels of agreement (%) towards 'not enough equipment to go around all patients' as a barrier to delivering strength training in PR (*n*=199/219)

5.4.9 Qualitative Insights

Throughout the survey a number of free-text questions were included, allowing participants the opportunity to provide further explanation and information. Qualitative data was gathered from 49 participants, which was predominately offered as additional 'end of survey' comments. These qualitative findings should be viewed with caution as they cannot be generalised to the whole sample. However, they provide some insight and context behind the main findings and themes which emerged from the quantitative results. These qualitative insights are particularly useful in relation to research question 5 (*What barriers do practitioners*

face in PR concerning SA and ST?), providing further insight into perceived barriers, specifically service resources, equipment, and staff training.

As reported on page 278, perceived barriers for SA in PR include service-related resources, such as time, funding, workloads, and staffing. Some participants (*n*=9) state the negative impact this can have on staff and service quality.

> *"Our service is limited by the need to rent a local hall that is limited in space and restricted by time pressures of other local groups accessing. The hall also needs to be hired to complete assessments so booking times are an issue. As therapists we are always being pushed to do more in less time with less resources rather than being supported to provide a robust service."*

> *"PR is historically underfunded, resourced and overcapacity in relation to patient referral. We strive for quality but without the resources we need, including training and upskilling of staff and career progression of experienced members of assist staff, retention is not possible."*

Furthermore, a significant barrier reported for both SA and ST in PR is inadequate and limited equipment (pages 278-282). However, as shown on page 256, the majority of participants reported the use of free weight equipment (e.g., dumbbells) in PR exercise sessions. Some participants (*n*=16) provide further context behind this finding, revealing it is not the absence of equipment as a whole, but the lack of adequate equipment across a range of weights and resistances. They state PR services, particularly those in community settings, have limited access and availability of suitable exercise equipment – they have dumbbells but they are restricted to low loads. Consequently, this limits ST prescription and progression, and makes certain SAs (e.g., 1-RM, m-RM) challenging to conduct as they require heavier weights.

> *"I think there is an attempt at strength assessment and exercise prescription in pulmonary rehabilitation but that if examined closely it would not strictly meet*

> *resistance training guidelines as mentioned in this survey. Most NHS centres I have worked at or visited have insufficient free weights or exercise equipment to deliver effective strength training. A group of 8 people sharing one set of free dumbbells does not allow for prescribed or progressive resistance training tailored to an individual's 1 rep max."*

> *"The assessment of muscle strength in order to prescribe strength training is difficult in the community setting due to the nature of equipment needed to carry out in depth strength assessments. Community PR services are limited by the amount of equipment they can store at venues or feasibly transport between sessions. Weight limits are 2.5kg in our setting which limits the level to which strength can be tested."*

Furthermore, it is suggested that PR guidance fails to provide clarity and consideration for the varying circumstances/settings and practical limitations faced by many services. Some participants (*n*=5) explain that it is their understanding that a 1-RM is considered the 'gold standard' of field SA tests and is recommended in clinical practice. However, there seems to be a lack of consideration within these recommendations for PR services which do not have the resources and equipment to achieve this. One participant explains that after seeing the NACAP audit report they attempted to include a 1-RM, but due to limited equipment they were unable to successful implement it. Similarly, another participant explains that they included a S2S assessment in the past, however as this was not an outcome measure recognised by PR accreditation guidelines, they stopped this assessment and now conduct a 1-RM. However, this 1-RM SA is conducted despite only having free weights of up to 5kg, which does question its efficiency and the true aims of its use (i.e. to fulfil the tick box for PR accreditation).

> *"There is a lack of specificity and clarity from the guidance about what strength training means. Practically doing a 1 rep max is the main limiting factor to inclusion, as well as evidence for standardised prescribing after this. Too much variation across services."*

> *"We included 1RM in our PR assessment sessions after the first report from NACAP audit, but not consistently completed due to limited free weights available & staff confidence. No longer completed."*

> *"Equipment is an issue in PR classes, we have free weights but only up to 5kg, which means some patients remain at this level unable to proceed. There are occasions when due to staff shortages/class numbers when patients are not reviewed and coast for a while. During the pandemic we trailed the use of a grip dynamometer at pre/post assessment but found it to an unreliable method. We also measured STS, but as this was not an outcome measure required for the accreditation process we are currently undertaking this has also been stopped. We currently use 1 rep max to determine the starting weight for resistance exercise."*

Another prominent theme throughout this study surrounds staff training. On pages 271-274, results shown that a large portion of participants do not have training related to SA and ST. Some participants (*n*=5) note that staff training is needed to assist the delivery and prescription of ST for patients. One participant provides valuable insight about their educational pathway, emphasising the importance of relevant staff training for a PR role as it is not necessarily provided within education and qualifications prior to working in PR.

> *"Prior to becoming a Physiotherapist I completed an undergraduate degree in Sports and Exercise Science as well as numerous individual coaching qualifications. It is this knowledge as well as participating in recreational sport which has given me the knowledge and confidence to deliver resistance training in pulmonary rehabilitation. My MSc (pre-registration) degree in Physiotherapy did not cover any principles of strength/endurance training or exercise prescription. When I qualified in 2011, I found that Physiotherapists were experts in clinical assessment and diagnosis, but in my experience poorly placed to actually prescribe and deliver strength/endurance training without additional qualifications… I would agree with the general themes of this survey that strength training is important and people would benefit from additional training in delivering effective strength training."*

Overall, these qualitative insights provide further clarity and context as to why participants may consider these factors as barriers to SA and ST within PR clinical practice.

5.5 Discussion

This discussion will follow a similar structure used to present the study results. Findings related to the assessment of patient muscle strength will be discussed first, following by those related to the prescription and delivery of ST. After which, barriers and influential factors will be discussed, which include practitioner attitudes and training, patient-related factors (i.e. physical limitations), and service-related factors (i.e. time and equipment). A summary of key study findings is presented in **Table 23**.

Table 23. Summary of key survey findings according to each research question

Research Question	Key Finding(s)
Research Question 1: Do PR services assess patient muscle strength? If so, how is it assessed?	• 47% of participants reported their PR service assessed patient muscle strength, equating to 56.8% of PR services represented in this study. Whereas 49.3% of participants reported their PR service did not. • Strength assessment methods varied. The most reported assessment was a sit to stand test, used predominately as an outcome measure. Followed by a 1-RM or m-RM test, primarily used for exercise prescription purposes and the assessment of bicep muscle strength.
Research Question 2: Do PR services include strength training in their exercise programme? If so, how is it prescribed?	• 93.6% of participants reported the inclusion of ST in PR exercise programmes. • However, ST prescriptions varied greatly overall, with no dominant strategy identified. The majority of participants (83.4%) reported the prescription of ST did not meet the ACSM guidelines for healthy older adults.
Research Question 3: Do PR practitioners have training for assessing muscle strength and delivering strength training?	• A substantial proportion of total participants did not have training related to the assessment of muscle strength (37.4%) and the delivery of ST (45.2%). • Staff training was predominately received while working in PR, with a primary method of training being 'learning on the job'. • Participants 'agree' themselves and their colleagues would benefit from training/additional training in the assessment of muscle strength and delivery of ST.
Research Question 4: What are the attitudes and opinions of PR practitioners towards strength assessment and strength training in PR?	• Overall, participants have positive attitudes and opinions towards SA and ST in PR
Research Question 5: What barriers do practitioners face in PR concerning strength assessment and strength training?	• Overall, participants perceive limited time, inadequate equipment, and patient physical limitations as barriers for the assessment of patient muscle strength in PR. Additional potential barriers include service-related factors (workloads, funding, and staff numbers) and staff training. • Overall, participants perceive patient physical limitations as a barrier for the delivery of ST in PR. Additional potential barriers include inadequate and limited equipment.

5.5.1 Assessment of Patient Muscle Strength

This study found 47% of participants reported their PR service assessed patient muscle strength, and 49.3% reported it did not. In terms of PR service numbers, 42 out of 74 (56.8%) measured patient muscle strength. These results are comparable to those report in the most recent 2020 NACAP PR audit (164), which found 55 out of 132 (41.7%) PR services measured muscle strength at assessment. Overall, there is still a substantial portion of PR services in England not assessing patient muscle strength, despite recommendations to do so (141).

Results revealed the methods used to assess patient muscle strength in PR varied. The most utilised SA method was a S2S test or a repetition maximum test (i.e., 1-RM or m-RM). Similar results were reported in the 2020 NACAP PR audit (164), however the present study revealed the use of different S2S variations. The 5repS2S was primarily used, but some participants reported the use of the 30secS2S and 1minS2S. However, it can be questioned if a S2S test is actually a measure of muscle strength, as the different variations are not well-differentiated in terms of their use and what they measure. S2S tests have been used to examine and evaluate a variety of outcomes, such as functional status (515), balance (516), lower body power (517), frailty (518), and differentiation between fallers and non-fallers (518, 519). A literature review conducted by Vaidya et al. (288) concluded that S2S tests appear to be appropriate methods for assessing functional status in COPD and evaluating lower limb activity, as well as considered to be an alternative to other frequently used tests, such as the 6MWT. Research has shown 5repS2S (283, 291), 30secS2S (62, 291, 310), and 1minS2S (271, 290, 310) significantly correlate with lower limb muscle strength to varying degrees. Therefore, S2S tests could be considered an indirect or surrogate assessment of strength. However, S2S tests also significantly correlate with the 6MWT (281, 286, 289-291), further supporting its use as a measure of functional capacity. It is important to note that although the present study

reports the 5repS2S as the most used S2S variation in PR, there is actually limited research investigating its use in COPD populations, with the 1minS2S more widely used (288). There are multiple factors and influences involved in the performance of a S2S test, which questions if it provides insight into a specific outcome or if it is an overall assessment (230). A S2S test does involve an element of strength but also involves balance and motor coordination, as well as impacted by patient physical limitations, such as musculoskeletal, cardiorespiratory, and shortness of breath - which are all common in COPD (228). Key advantages of a S2S test include the need for minimal equipment and time – this study reports a duration of about 3 minutes. Therefore, it is not surprising that many PR services use a S2S test as a SA due to these practical benefits, especially as this study found perceived SA barriers included limited time and inadequate equipment.

The other SA methods commonly used were 1-RM and m-RM tests, utilised as an outcome measure but primarily for exercise prescription purposes. Results revealed that these SAs were predominantly used to measure bicep muscle strength. However, the literature clearly emphasises the importance, relevance, and priority of lower limb strength in COPD, specifically the quadriceps (33). Lower body strength is significantly reduced in COPD patients, with upper body strength shown to be better preserved in comparison (143). This questions the suitability of a bicep SA in COPD and PR, especially as research has shown mixed results regarding the responsiveness of upper body strength after ST, with some studies showing significant improvements and others reporting no change (181). Furthermore, it is not clear how only individually prescribing load for a bicep curl exercise translates to the prescription of other strengthening exercises. Lower limb 1-RM and m-RM tests are more challenging within clinical practice, particularly in settings of low resource, as they require heavy and specialised weighted exercise equipment. Many research studies utilise weighted

apparatus to assess muscle strength, such as leg press and leg extension machines (234). But results of this study and previous surveys (164) show PR services rarely have access to such equipment – supporting the perceived SA barrier of inadequate equipment. Therefore, a 1-RM or m-RM bicep muscle SA is likely more feasible and accessible because it is an isolated muscle exercise that can be conducted with a lighter load.

The least used SAs were reported to be a dynamometer and strain gauge. A dynamometer was predominantly used to assess hand grip strength (HGS), however there is debate regarding its usefulness and relevance within PR. Within COPD populations, HGS has been associated with relevant patient outcomes, including fatigue (520), frailty (521), disease severity (522), HRQoL (274, 277), and mortality and morbidity (277). Research has also shown moderate correlations with quadriceps muscle strength (238, 271), indicating a decrease in leg strength is associated with a decrease in HGS. However, it is recommended that HGS should be used conservatively as a SA, limiting its use to the evaluation of hand, finger, and forearm strength - rather than an indicator of overall body strength (228, 231). HGS is not frequently assessed or reported as an outcome measure during interventions for COPD (315), but rather in cross-sectional and large population based studies. A key reason being its lack of sensitivity to short-term changes in muscle strength and responsiveness to ST exercise programmes (269). Consequently, it can be argued that HGS is an unsuitable SA in PR programmes, which typically only last 7-8 weeks. Instead, due to its association with important patient outcomes, it is considered more appropriate in clinical consultations for indicating muscle weakness, such as a marker for sarcopenia and frailty (276), evaluating disease prognosis, and directing treatment strategies (277).

Lastly, the use of a strain gauge has been proposed in published reviews as a feasible SA in clinical practice, shown to provide reliable and reproducible results (93). However, the true practicality of such an assessment is argued otherwise. Strain gauge assessments require time and specialised equipment, which is not commercially available - meaning custom built apparatus is needed (234). Therefore, feasibility in PR is unlikely, which is probably why only two PR services reported utility. In summary, the results of this study show the types of SA used in PR varies, with choice of assessment dependent on the circumstances and resources available to each service.

5.5.2 Prescription of Strength Training

This study found nearly all (93.6%) participants reported the inclusion of ST in PR exercise programmes, fulfilling the recommendation outlined in UK PR guidelines (33, 36, 141, 151, 154). Similar results were found in previous surveys (164, 166, 385), but the extent of ST inclusion has not yet been reported. The current study revealed ST to be a core component of PR exercise, accounting for nearly two thirds (61.5%) of the exercises included. However, investigation into the prescription of ST revealed wide variation, with no dominant strategy used across PR services.

Results show nearly all participants reported their PR service used free weights, with all specifying dumbbells, and half specifying ankle weights. There was also noteworthy use of resistance bands (TherBands ™), which research has demonstrated to be effective, as well as being practical, low cost, portable, and easy to use (335, 345, 364-370). One meta-analysis showed resistance bands to be an effective alternative to conventional ST using weighted machines (360). Equipment alternatives like this could provide a solution to limited equipment access, especially considering this study showed minimal use of machine weights in PR

programmes. Research in this area has increased over recent years, but further robust research is needed, particularly with a focus on feasibility and prescription in COPD populations and PR settings (371). Although there is widespread use of dumbbells, data was not collected on the range and quantity of weights available. Considering inadequate and limited equipment were potential barriers within PR, further detail of these specifics would be useful to investigate in the future. Qualitative insights provide some context and explanation about equipment use and the challenges faced in clinical practice. Some participants stated that although they have use of dumbbells for ST, the weight ranges available are low. This means SAs that require heavy loads (e.g., 1-RM and m-RM) and exercise progression are limited to the weights available. Participants specified a maximum of 2.5-5kg, which for many patients is not enough for effective exercise prescription and progression. Equipment is a barrier to SA and ST in PR, therefore future research should continue to investigate alternative equipment and prescription strategies, with a particular focus on feasibility within PR settings.

The use of a SA to individually prescribe exercise intensity and load/resistance was the least used method, likely a consequence of PR barriers, such as limited time and equipment. The most reported prescription method was the use of a Borg breathlessness scale with frequency comparable with previous survey findings (164). However, its suitability for ST prescription is questionable and unclear. In the literature, these scales are predominately discussed and recommended in relation to AT and cardiorespiratory fitness, making it an appropriate tool for this modality, but not necessarily ST (31, 53, 235, 523). In fact, UK PR guidelines do not mention the use of Borg breathlessness scales for exercise prescription at all (33, 36, 141, 151, 154), and it is not a ST prescription strategy reported in COPD research (181, 227, 317, 318, 320, 511). ST is said to evoke less dyspnoea during exercise (524), making it easier and more tolerable compared to AT (525, 526). Consequently, this questions the

relevance of a breathlessness scale for effective and reliable ST prescription, especially for individualised load/resistance. Research is needed to future investigate the role and effectiveness of breathlessness scales for the prescription of ST.

This study also provides insight into the prescription of ST volume. The primary method of prescription was the use of exercise sets and repetitions, with average parameters reported at 3 sets of 10 repetitions per exercise, which are within the range recommended in some PR guidelines (235, 394). Alternatively, a commonly reported prescription method was the conduction of exercise 'to time', used for the prescription of exercise volume, intensity, load/resistance, and progression. Using time and exercise duration is practical if time is limited within PR, as allocating time to each exercise helps keep to a strict schedule. However, its suitability and effectiveness for individually prescribing and progressing ST is questionable, as exercise volume could be susceptible to variance from one session to the next depending on speed and effort level. Exercising to time likely makes ST easier for practitioners to delivery and explain to patients, and as an initial strategy could help inactive and deconditioned patients commence and increase activity. However, it is typically used for AT or interval training (e.g. HIIT) (235), which benefit cardiorespiratory and metabolic function (182, 527). The use of 'time' to prescribe and progress ST exercises is not a method recognised or reported in COPD research studies or PR guidelines (33, 53).

A key implication of this study is the need for improved guidance and recommendations for ST prescription in PR. The only formal and comprehensive criteria available are those outlined for healthy older adults by the ACSM (235). However, as shown in this study, the majority of participants reported the prescription of ST did not fulfil this criteria. A key limitation is the lack of specificity to COPD patients and PR programmes. The prescription

variables predominately met (>80%) were ST frequency (≥2 times per week), ST progression, and a focus on weight training or weight-bearing exercises. Fulfilment of these criteria is likely more attainable due to recommendations being broad and non-specific. Alternatively, the two criteria argued as being the most difficult to fulfil are the prescription of ST intensity and number of ST exercises. The ACSM guidelines recommend that ST intensity be prescribed using %1RM, but if this is not possible then Borg RPE scales can be used. As already discussed, SAs like 1-RM or m-RM are not commonly used, likely due to limited equipment and time. Whereas Borg RPE scales are likely easier to use. The ACSM guidelines for older adults recommend a moderate score of 5-6 or above on the modified Borg RPE scale, however within COPD populations a score of 4-6 is considered a more suitable target for training intensity (53, 225). Although both Borg RPE scale recommendations are comparable, COPD patients often have a lower tolerance to high exercise intensities due to their respiratory limitations, and as a result Borg RPE targets are lower to compensate for this (235). This could explain why the ACSM prescription criteria for ST intensity was not fulfilled.

Lastly, the ACSM guidelines recommend the inclusion of 8-10 strengthening exercises. This is not feasible or practical within most PR programmes due to time constraints. Exercise sessions combine ST with AT, so time has to be allocated to each modality, meaning the prescription of 8-10 strengthening exercises is not possible within the one-hour duration of a typical PR exercise session. Despite the ACSM guidelines being the only comprehensive criteria of ST prescription recommended for COPD, this study showed participants were only moderately aware of them. Similar results have been reported in other studies (456, 528, 529). A reason for this lack of awareness could be that American published guidelines are not used or referenced by healthcare organisations in the UK. However, even clinicians based in the US show low familiarity with American based guidelines (e.g. ATS), especially when compared to

familiarity with GOLD guidelines (456). This shows the importance of educational initiatives for HCPs about guidelines and recommendations, to increase awareness, familiarity, and use.

Overall, there is a need for clearer COPD-specific guidelines for ST prescription, with explicit consideration for the structure, setting, and circumstances of PR programmes in England. Literature acknowledges the lack of an optimal ST prescription strategy for COPD, with recommendations for future research to work towards its development. However even if an optimal strategy was determined, implementation and feasibility in all PR services is unlikely due to variation in resources and settings. Therefore, future research should also work towards developing optimal prescription strategies within a variety of settings and using a variety of equipment.

5.5.3 Barriers and Influential Factors

Results indicate that practitioner attitudes are likely facilitators of SA and ST in PR. Overall, participants agree that assessing patient muscle strength is important, safe, useful, and should be standardised across PR services. Similar findings were found in response to ST, with participants agreeing it is important, beneficial, safe, and easy to deliver, as well as ST being individually prescribed and standardised across PR services. Practitioner attitudes and agreement have previously been reported as important factors for the diagnosis and management of COPD (456, 528, 530). One study found adherence to COPD guidelines for spirometry testing was predicted by clinician agreement with the recommendations, along with self-efficacy and resource availability (456). This emphasises that positive practitioner attitudes likely facilitate and aid adherence to recommendations within healthcare services. However, the implementation and use of SA and ST in PR is not determined solely by this - there are

other barriers and influential factors at play. This study identified staff training, patient physical limitations, and service-related factors as barriers.

A substantial portion of participants did not have training related to the assessment of muscle strength and delivery of ST. Of the total sample, 37.4% of participants had not received or completed training related to the assessment of muscle strength. This lack of training is understandable to some extent, as if a PR service did not assess strength it negates the need. However, of these participants over a third stated their service did assess strength, with all participants involved in assessments or having roles of responsibility in PR programmes, such as site leads. Furthermore, considering ST is a core component of PR, nearly half of all participants (45.9%) do not have training related to its delivery. The BTS guidelines and quality standards for PR in the UK state services should "*evidence that professionals providing pulmonary rehabilitation are adequately trained/experienced in prescribing and supervising exercise training*" (141) (p. 14). Comparable standards are also reported in ATS guidelines stating, "*relevant expertise is required to deliver resistance training*" (394) (p. 13). Evidently, this quality measure is not being met, as nearly half of practitioners who are leading, assisting, and supervising PR exercise programmes are not adequately trained. Limited staff training and knowledge/understanding is a common barrier named within PR, COPD, and similar settings. Specifically, the use of behaviour change interventions in UK PR (402), exercise training for COPD (395), self-management of COPD (455), referral and promotion of PR (464, 467), and provision of UK cardiac rehabilitation (405). Of these studies, the authors and HCPs themselves, conclude there is a need training, suggesting bespoke and formal training interventions as a solution to this barrier.

Additional study results show that the majority of participants received training while working in their current PR job or anytime working in PR. This emphasises the responsibility of PR services to offer and provide training to meet these quality standards. Qualitative insights touch on this, with one participant stating that the prescription and delivery of ST is not widely covered in previous education, and as such many PR staff require additional training and experience. It is essential that the training provided and received is relevant and high quality - not only to benefit current staff, but future staff as well. Results show 'learning on the job' is a key method of training and knowledge exchange. Such training is beneficial by providing opportunities of first hand and practical experience in the clinical working environment, as well as direct contact and face time with patients (471). However, it may not be the most suitable method to fully learn, understand, and reflect, especially regarding the underlying fundamentals of a topic. Furthermore, 'learning on the job' training is heavily reliant on the knowledge, understanding, and previous training of other staff and colleagues – as essentially it is learning by copying (471). This is not to say that learning from a colleague is unsuitable, but it is ensuring that this training is relevant, adequate, and high quality. If not, it can lead to challenges and issues of standardisation in clinical practice. One study (396) explored the attitudes, opinions, and concerns of HCPs for the establishment and delivery of rural PR in Australia. It reported that HCPs were using the 6MWT in different ways, indicating varied levels of understanding. This demonstrates that just because an assessment is conducted within a working clinical setting, it does not mean staff are doing or using it correctly. 'Learning on the job' does not guarantee correct and adequate teaching as clinical practice may vary from colleague to colleague and thus service to service. Regardless of which training method is used, either formal or informal, it needs to be the 'right' training, which is high quality and relevant to the patient population and clinical setting (i.e., PR).

There are some contradictions in the study findings related to staff training. Staff training is indicated as a potential SA barrier in PR. However, this does not seem to translate to low knowledge or confidence, with participants somewhat agreeing they are confident assessing strength and somewhat disagreeing knowledge and understanding is a barrier. Furthermore, although nearly half of participants do not having training related to the delivery of ST, a lack of training and knowledge/understanding was not a perceived barrier. However, the majority of participants felt they would benefit from training and/or additional training to support them in assessing patient muscle strength and delivering ST in PR. It could be that practical training is needed, rather than education to improve knowledge. However, objective measures are needed to ascertain this, as self-evaluation of understanding and skill may not accurately represent reality. Further investigation is needed to explore this paradox, pinpointing the specific training components which require focus and attention.

Another perceived barrier reported are the physical limitations of patients, both when assessing strength and performing ST exercises. COPD patients are commonly of older age (10, 12) and have multiple comorbidities (16) – all of which need consideration when conducting assessments and prescribing exercise. Even though ST is shown to be safe and well tolerated by COPD patients (181-183), previous research has reported physical limitations and comorbidities as barriers to PR, exercise, and ST (364, 446, 457). Consideration is also needed when choosing and performing a SA, as some methods may not be possible if patients are severely deconditioned or have limited mobility. Chronic conditions and physical limitations are not a justification for the absence of ST, but instead emphasises the importance of individualised exercise for the patient. Aside from COPD, ST is recommended for a variety of health conditions (235) and is shown be effective and safe within other comorbid populations, such as cardiovascular disease (531), hypertension (532, 533), arthritis and musculoskeletal

conditions (534), and diabetes (235). Effective exercise prescription should still be implemented and aimed for but accommodated for a variety of physical abilities and limitations.

Lastly, service-related factors were identified as barriers to SA and ST use in PR. Specifically, limited time and inadequate equipment were reported as barriers for SA, as well as additional challenges including high workloads, limited funding, and low staffing. Regarding the delivery of ST, potential resource barriers identified were inadequate and limited equipment. Service-related barriers, such as time, funding, and resources (e.g., workloads, staffing, and space) are commonly reported in studies based in clinical practice, patient care, and the conduction of interventions (395, 396, 403, 405, 454, 455). No studies have been identified investigating barriers to SA use in PR, however comparable literature is available reporting similar findings related to the implementation of COPD-related devices, such as a spirometer (456) and handheld fan (398). It must be noted that these studies were conducted in different countries and thus different healthcare systems, yet similar barriers are reported regardless. Limited and restricted time is often reported as a main barrier of healthcare services and clinical practice - and PR is no exception. PR programmes are comprehensive, and include many components that are each considered important and essential in their own right, for example AT and walking tests (141, 394). Therefore, the use and allocation of time has to be efficient. There is only so much time allocated for patient assessments, so a SA has to be time-sensitive and easy to use. The same goes for ST. As shown in this study, and previous research and guidelines (2, 164, 394), PR programmes are about 7-weeks in length, with two sessions per week, which each include one hour of exercise. Therefore, ST prescription protocols should aim to produce meaningful improvements within this specific timeframe. Many studies have been conducted investigating the effectiveness of exercise training programmes for COPD, and

have shown significant improvements in muscle strength (181, 226, 227). However, the prescription and delivery protocols used in some studies do not mirror the reality of PR, with some lasting 12 weeks in duration and only including ST as the exercise modality.

Another key service-related barrier is inadequate and limited equipment. Similar findings were reported in other studies, specifying access to equipment as a significant barrier (398, 456). Access and availability of equipment for SA and ST in PR could be influenced by the setting and environment in which programmes take place. This study reports a variety of venues and settings, including church and community halls, leisure centres and gyms, and hospitals. Meaning all settings may not have access to the ideal equipment needed, for example a commercial or hospital gym will likely have exercise equipment whereas a community hall may not. If money were no object, all PR services could achieve and fulfil optimal practice recommendations, but this is not the reality of UK healthcare. The choice and implementation of a SA, and the prescription of ST, needs to account for these barriers and challenges in PR clinical practice. It is vital that future research investigates best practice within the parameters of real-world clinical settings and the resources they have available to them. Furthermore, PR guidelines should acknowledge the heterogeneity and variability, providing guidance and advice for different settings and equipment.

5.5.4 Strengths and Limitations

The strengths of this study include the detailed exploration of SA and ST use in PR. This research contributes to knowledge and understanding by providing further insight and a level of detail which has not been previously collected or reported. Secondly, it has explicitly identified barriers faced within PR services, directly in relation to SA and ST. To the researcher’s knowledge this study has not be conducted before and provides clear direction and

focus for future research and clinical practice. Lastly, data was collected directly from the practitioners involved in PR delivery. They are the frontline staff working in this setting and service day-to-day, therefore their involvement and opinion is crucial to improve understanding.

Unfortunately, the sample size target of 291 participants was not reached. It is possible that this target was an overestimated representation of staff working in PR. A simple calculation was conducted with the assumption that exclusive practitioners worked at each PR site, but it is possible that the same staff work across all PR sites in their service. Attaining this sample size target was also challenging due to a number of difficulties during recruitment, with research sites and PR services reporting low staff numbers, staff sickness, staff redeployment due to Covid-19, and high workloads and limited time. The recruitment period was extended by two months, but due to limited resources and time could not remain open.

Furthermore, there is potential for response bias within this survey study, which could impact the true representation of PR and staff in England. Firstly, the majority of participants were female (82.2%) with a physiotherapist job role (61.6%), meaning data was limited and lacked representation from male participants and other roles within PR, such as nurses and healthcare/therapy assistants. The addition of more data from these groups may have impacted or changed the results presented. However, it is also plausible that female physiotherapists make up the majority of staff working in PR. Secondly, it is possible that voluntary response and non-response bias may be present. Trusts/organisations, PR services, and PR practitioners who volunteered to take part may have been more invested and interested in the research topic, especially considering there was no financial or tangible incentive to participate. This may have resulted in the study over-reporting one aspect or over-representing one perspective, as the

study sample could have specific opinions or varying responses compared to PR services and PR practitioners who did not take part (418).

The survey was fairly long in length and duration (20-25 minutes), which could have contributed to recruitment difficulties and the incomplete survey responses received. Some participants did provide feedback supporting this conclusion, with a couple stating the survey was “repetitive.” As the study was investigating both SA and ST in PR, question format and wording were similar, but this was necessary so data could be collected on each topic independently. Furthermore, data were collected only by participant self-reporting, and was not corroborated by other external checks, therefore accuracy of actual PR provision and practices may be limited. Participants were required to answer most questions retrospectively and recall PR practices before the Covid-19 pandemic, with surveys completed 1.5-2 years after the start of the pandemic. As such, the data was likely subject to recall bias. Some contradictions were observed among participants working in the same PR services. Specifically, 12 participants gave contradicting answers regarding the use of a SA, with some reporting strength was assessed and others reported it was not. This could be explained by some PR sites in their service using a SA and others not, or participants not being aware of SA use in their service if patient muscle strength is not assessed at the sites they work at. Lastly, ACSM guidelines published in 2014 were used as a reference criteria for ST prescription (235), but an updated edition has been published since (375). At the time of this study, difficulties were experienced accessing this updated book, and so was not used. Since then, limited access was made available, confirming guidelines for ST prescription in healthy adults remain consistent.

5.5.5 Study Implications and Future Research Recommendations

This study has a number of implications for PR clinical practice and future research. Results reveal large variation in the assessment of patient muscle strength and prescription of ST across PR services in England. This emphasises and supports the need for clearer and more specific guidelines for use in COPD and PR. PR guidance published within the UK considerably lack advice and recommendations, with insufficient detail and little acknowledgement for PR variation. Future research should still focus on determining optimal methods and strategies, but focus should not be placed solely on the gold-standard, but also on favourable strategies for the variety of settings, equipment, and resources used. Development and investigation should strongly consider the barriers and influential factors experienced within real-world PR, with a particular emphasis on feasibility. In the meantime, resources should be developed to help guide best practice, so services are able to replicate and integrate current methodologies and protocols into clinical practice. Involving PR stakeholders in future research and resource development would be beneficial as it would account for service practice and perceived barriers and facilitators.

Although this study shows variation in ST prescription, such as the use of Borg breathlessness scales, it cannot conclude on their effectiveness. Research is needed to investigate and determine if such methods have a positive impact on PR outcomes, particularly muscle strength, and how they compare to traditional prescription methods (e.g., %1-RM or m-RM). Lastly, this study found a substantial portion of staff did not have training related to the assessment of patient muscle strength or delivery of ST. Of those who did have training, results cannot ascertain the true relevance or quality. Future research should focus on the quality and effectiveness of staff training, especially understanding and application, as well as identifying the specific aspects of training that require attention. Other healthcare areas and

services (e.g., cardiac and oncology rehabilitation), which assess strength or aim to improve muscle strength, would likely find these study results useful, allowing for comparison and evaluation of clinical practices. These descriptive results provide an overview of barriers faced in PR, however exploration and identification of barriers and influential factors specific to PR services which do and do not used a SA and prescribe ST would be beneficial.

5.6 Conclusion

This a novel study which provides helpful insight into the use of SA and ST in PR services in England, as well as the influential factors and related barriers faced by practitioners within clinical practice. ST is included in the majority of PR programmes, whereas SA is low. There is large variation in the methods used to assess patient muscle strength and prescribe ST. Key factors identified as barriers are service-related factors, particularly time and equipment, staff training, and the physical limitations of patients. There is a need for clearer guidance on the use of SA and ST in PR, with consideration for variability, feasibility, and barriers within clinical practice.

Chapter 6. Statistical analysis of survey data on strength assessment and strength training in pulmonary rehabilitation services in England: exploratory factor analysis and binary logistic regression

6.1 Chapter Overview

This chapter further explored the descriptive data collected and reported in Chapter 5, with the aim of identifying specific factors which impact SA use and ST prescription in PR services in England. Subsequent statistical analyses were conducted, specifically exploratory factor analysis and binary logistic regression. Results found service-related barriers, colleague-related barriers, and practitioner confidence were predictors of SA non-use. Despite analyses conducted to explore predictors of ST prescription, non-significant and inconclusive results were found. This chapter provides further insight into factors which impact the assessment of patient muscle strength in PR, supporting findings previously reported in this thesis.

6.2 Introduction

In Chapter 5, descriptive findings were reported on the use of SA and ST in PR services in England. Results showed the assessment of patient muscle strength was low, with half (47%) of participants reporting their PR service did assess strength and half (49.3%) reporting it did not. On the other hand, the inclusion of ST in PR exercise programmes was high, with nearly all participants (93.6%) reporting its inclusion. However, methods regarding its delivery and prescription varied. Previous thesis chapters have discussed the limitations of PR guidelines for the prescription of ST, arguing vague and limited guidance, especially in the UK. The only

comprehensive criteria referenced is the ACSM guidelines for healthy older adults, which has also been recommended for COPD (235). These guidelines address the key exercise prescription variables of ST, which include frequency, intensity, volume, mode, and progression. Descriptive findings in Chapter 5 (page 269) reported that a substantial portion of participants (83.4%) stated the ACSM ST guidelines were not fulfilled in PR exercise programmes. This emphasises the increasing need to improve guidance and recommendations for the prescription and delivery of ST in PR. However, there are a number of influential factors and barriers faced by practitioners related to the use of SA and ST in clinical practice.

In Chapter 5, practitioners are reported to have positive attitudes and high confidence, yet a substantial portion do not have training related to SA or ST. Furthermore, barriers identified included factors related to service provision, such as limited time, limited and inadequate equipment, high workloads, limited funding, and insufficient staff numbers. Other barriers included patient physical limitations and a lack of staff training (both participating practitioners and colleagues). These descriptive findings provide valuable insight into SA and ST use, as well as the challenges faced by the practitioners who deliver PR. It provides an overview of PR practices and indicates targeted areas for future improvement. However, further exploration into this data would provide a clearer picture about the impact of specific factors and barriers, and could help identify potential predictors which influence PR services to assess muscle strength and prescribe ST, and services which do not. Therefore, this chapter will outline and present subsequent statistical analyses of the survey data collected and reported in Chapter 5. Specifically, it aims to explore and identify predictors of SA use and ST prescription.

6.2.1 Research Questions

- What factors predict whether or not PR services assess patient muscle strength?

- What factors predict whether or not PR services prescribe strength training?

6.3 Methodology

Data were collected from a cross-sectional questionnaire-based online survey. Full details of the study methodology and descriptive findings are outlined in Chapter 5, along with the survey questions presented in Appendix Z. Participants were HCPs who had a job role either running, managing, or assisting in PR exercise programmes and who had worked in PR conducting standard face-to-face exercise programmes before the Covid-19 pandemic (i.e., before March 2020).

A representative sample size was initially calculated (see Chapter 5, page 244), which determined a target sample of 291 participants to be appropriate. As subsequent statistical analyses were going to be conducted with the survey data, specifically exploratory factor analysis (EFA) and binary logistic regressions, it was also important to consider sample size in reference to these. As the study was exploratory in nature, an *a priori* power calculation was not possible, as no previous relevant findings were available to determine the sample size required. One alternative is using 'rule of thumb' guidelines, which suggest a minimal criterion of 10 events per variable (EPV) for performing a binary logistic regression analysis (535-537). However, within the present study, the total number of independent/predictor variables was not yet known because this would be influenced by the results of the EFA. Nevertheless, with consideration for the potential number of predictor variables which could be included, 10 variables was deemed a reasonable number for estimation. From this, a sample size of 100 participants per outcome group is needed to meet the criterion of 10 EPV, totally a minimum sample size of 200 participants. In relation to EFA, a 'rule of thumb' recommendation states 300 participants (538-540) is considered 'good' and 200 participants is considered 'fair' (541).

Overall, with consideration for the previous representative estimate and ‘rule of thumb’ guidelines a sample size of about 300 (291 specifically) participants was aimed for.

6.4 Analysis

Analysis was conducted using IBM SPSS Statistics (version 27). EFA and binary logistic regression were conducted to answer research questions 1 and 2.

6.4.1 Exploratory Factor Analysis

EFA was conducted to collapse data items into smaller subsets of measurement variables, such as composite/sum scores, so the data could then be included in the subsequent relevant binary logistic regressions. Five independent analyses were conducted. The following two EFAs were conducted to assist the answering of research question 1: the 5-items of SA attitudes (see page 277); and the 17-items of SA barriers (see page 278 and Appendix AF). The following three EFA were conducted to assist the answering of research question 2: the 5-items of ST attitudes (see page 277); the 18-items of ST barriers (see page 282 and Appendix AG); and the 3-items of ST guideline awareness (see page 270). Internal reliability, using Cronbach’s alpha (α), was conducted to ensure internal consistency within emergent factors for each EFA. The chosen method for dealing with missing data was pairwise deletion, which minimises data loss and allows utilisation of as much data as possible.

The sample size within each EFA varied between 196 and 219 (using pairwise deletion). An outline of the sample size within each EFA, and across included items, is presented in corresponding results tables. Although the sample sizes did not reach the proposed 300 target, a sample of 200 is still considered ‘fair’ (541). During each EFA, additional tests of sampling adequacy were conducted. Firstly, using the Kaiser-Meyer-Olkin (KMO) measure, with a

minimum acceptable value of ≥0.5 (542). Secondly, examining the average communality value among factor items. An average communality value of between 0.5 and 0.6 is deemed acceptable for sample sizes of around 200 participants (543).

Principal axis factor analysis was conducted with an oblique rotation (direct oblimin). Principal axis factor analysis was chosen as the extraction method because the primary aims of analysis were to explore the data and reduce it down to composite/sum scores for further analysis (538). An oblique rotation method was chosen because factors were likely to be related and not completely independent of one another (538). This was evident from correlations between included items, showing the underlying processes and constructs measured were related to some extent. Note, for analyses which extract a one factor solution, there are no substantial differences between rotation methods, as rotation of the factor loadings is not possible. Factorability of items within each EFA was determined through examination of correlations and communalities. Correlations between items were explored to ascertain if relationships were within the recommended range of ≥.3 and ≤.9 (538), as well as conduction of the Bartlett's Test of Sphericity to determine if correlations had adequate strength overall (i.e. they were not too small). A significant result of the Bartlett's Test of Sphericity is desirable. Moreover, the communality of each item was examined to confirm shared common variance with other items, with a cut-off point of enquiry set at a value of ≥.3 (544). Once factorability was confirmed, the EFA was conducted and factor membership of items was examined. The cut off point for factor loadings was set at a score of ≥.4 (545), with such scores considered stable (546).

6.4.2 Binary Logistic Regression

6.4.2.1 Assessment of Patient Muscle Strength

A binary logistic regression was conducted to answer research question 1, exploring if any variables predicted whether or not patient muscle strength was assessed in PR services. The binary outcome variable was if a SA was used or not used. Variables were included, as predictors, if they could be theorised as having an impact on SA use. The predictor variables included were number of ST exercises, number of PR sites, SA practitioner training, and SA confidence. In addition, any composite/sum variables constructed from the relevant EFAs were included as well.

Initially, data related to equipment types used in PR services were going to be included as predictor variables, but due to the following reasons were excluded from the final analysis. An assumption of binary logistic regression is exclusive categories (i.e., a case can only be a member of one group within each variable). As the original data was 'tick all that apply' it resulted in multiple response variables. This meant each equipment type had to be entered into the logistic regression as its own dichotomous variable (i.e., yes/no), resulting in five additional categorical variables. This caused substantial issues with the assumptions of a binary logistic regression. Field (538) recommends the contingency table of all categorical variables should have expected frequency cell counts of more than 1, with no more than 20% having less than 5. In this case, the majority of cell counts were less than one, with many completely blank - indicating no data points were present for some category combinations. Therefore, this would have resulted in the analysis having very low test power. Before making a final decision to exclude these variables, a preliminary analysis was run to check the occurrence of any significance - which revealed none. With all this considered, it was decided to exclude equipment types as predictor variables in this binary logistic regression.

6.4.2.2 Prescription of Strength Training

A separate binary logistic regression was conducted to answer research question 2, exploring if any variables predicted whether or not ST was prescribed in PR services. The ACSM ST guidelines for healthy older adults was used as the criteria of reference, which has also been recommended for COPD (235). Specifically, these guidelines state ST prescription should include the following: an exercise intensity of 40-50% 1-RM (increasing to 60-70% 1RM with experience) or 5-6 on the modified Borg RPE scale; an exercise volume of 8-10 exercises, with ≥1 sets of 10-15 repetitions per exercise; a frequency of ≥2 times per week; progression of strength exercises; and the use of weighted equipment and/or weight-bearing exercises. Initially, the binary outcome variable was whether this criteria was fulfilled or not, according to participants. However, the sample quantity in each outcome group was not sufficient. As reported in Chapter 5 (see page 269), the descriptive results showed that only 12.2% (*n*=25/205) fulfilled this criterion. On the chance that this initial criterion was too restrictive, the prescription of 8-10 exercises was removed, with the justification being that it could be unrealistic for PR services. PR exercise sessions typically last 1 hour and involve both ST and AT (394). Due to this time limit, including 8-10 strengthening exercises alongside cardio-based exercise would be challenging and unlikely. Based on this modified criteria the sample quantity increased slightly in the outcome group that fulfilled the criteria. Specifically, 25.4% (*n*=52/205) fulfilled this modified criteria, 70.2% (*n*=149/205) did not, and 4.4% (*n*=9/205) was missing data. Although the binary outcome groups are not evenly weighted in terms of cases/participants, the binary logistic regression was still conducted - justified by the exploratory nature of the study and its analyses.

As stated, the binary outcome variable was the fulfilment or unfulfillment of this modified ST prescription criteria. Variables were included, as predictors, if they could be

theorised as having an impact on ST prescription in PR. The predictor variables included were number of PR sites, duration of exercise session, PR programme length, ST practitioner training, ST confidence, and SA use. In addition, any composite/sum variables constructed from the relevant EFAs were included as well. Initially, data related to equipment types used in PR services were going to be included, but in the final analysis it was excluded for the same reasons as stated above for the SA binary logistic regression.

6.5 Results

6.5.1 Assessment of Patient Muscle Strength

Research Question 1: What factors predict whether or not PR services assess patient muscle strength?

EFA was conducted for the purpose of reducing the quantity of data into a manageable number of variables. This then allowed for data to be included and explored as predictor variables in the subsequent binary logistic regression. To answer research question 1, EFA was performed to collapse the 5-items of SA attitudes and the 17-items of SA barriers into new variables. After which, they were entered as predictor variables into the subsequent binary logistic regression, which explored if factors predicted whether or not PR services assessed patient muscle strength.

6.5.1.1 Exploratory Factor Analysis: Strength Assessment Attitude

The 5-items of SA attitudes were included exclusively in this EFA (see **Table 24**). Details and descriptive results of these items can be found in Chapter 5 (page 249 and 277). Sampling adequacy was confirmed by the overall KMO measure (KMO = 0.74) and the KMO measure of each item included (KMO = 0.69-0.87), as well as the average communality value

(.52) being within the acceptable range. Preliminary examination of factorability was conducted. As shown in **Table 24**, all correlations were within the recommended range of ≥.3 and ≤.9, except the item '*assessing patient muscle strength is easy',* which was observed to have correlations ≤.3 with three other variables, providing evidence for potential removal. Examination of the Bartlett's Test of Sphericity was found to be significant [$\chi 2(10) = 355.78$, $p<.001$]. Secondly, the communality of each item was examined, which revealed four out of five items were above the minimum value of ≥.3. However, the item '*assessing patient muscle strength is easy'* did not meet this criterion (communality of .16), providing further evidence for possible removal. To examine the suitability of this item being included, an initial analysis was run with all items. Results revealed this item had a borderline acceptable factor loading score of .397. However, once all evidence was collated it was decided to remove this item from the analysis on the basis of 1) low correlations with three of the four other items, 2) low communality value, and 3) borderline factor loading score. Further justification for this decision included a slight increase in factor internal consistency once removed ($\alpha = .77$ to $\alpha = .79$).

Table 24. Correlation matrix of the 5-items of strength assessment attitudes

	Assessing patient muscle strength is important	Muscle strength is a useful outcome measure in PR	Assessing patient muscle strength is safe	Assessing patient muscle strength should be standardised across all PR services	Assessing patient muscle strength is easy
Assessing patient muscle strength is important	-				
Muscle strength is a useful outcome measure in PR	.745**	-			
Assessing patient muscle strength is safe	.457**	.481**	-		
Assessing patient muscle strength should be standardised across all PR services	.479**	.487**	.295**	-	
Assessing patient muscle strength is easy	.235**	.241**	.441**	.276**	-

Note. ** correlation is significant at the <0.01 level

Following the removal of the item '*assessing patient muscle strength is easy'*, factorability of the remaining four items was re-examined. The Bartlett's Test of Sphericity was still significant [$\chi2(6) = 302.89$, $p<.001$], and the communalities of each item were within reasonable range (≥.3). As shown in **Table 25**, the item '*assessing patient muscle strength is safe'* did have a borderline communality value of .29 but was retained within the analysis as no additional evidence was present to warrant exclusion. Given these overall indicators, factor

analysis was deemed suitable with the four remaining items. Results of the EFA revealed a one factor solution, which had an eigenvalue of ≥1 and explained 62.5% of the variance in the data. Inspection of the scree plot supported extraction of one factor (see Appendix AH). The factor loading matrix is presented in **Table 25**, showing all four items had a primary factor loading of ≥.4. Moreover, internal consistency was acceptable (α = .79), with no substantial increases in the alpha achieved by eliminating additional items. A composite score was created for this one factor solution, based on the mean of the four items. The descriptive label of 'Strength Assessment (SA) Attitude' was assigned to this new variable. Scores could range between 1 and 7, with higher scores indicating greater agreement (i.e., a positive attitude) towards SA use in PR, and lower scores indicating greater disagreement (i.e., a negative attitude).

Descriptives of this new variable show, on average, that participants had a positive attitude towards SA use in PR (*M* = 5.7, *SD* = .92).

Table 25. Summary of EFA results for strength assessment attitudes

	Factor Loading	Communality	Item Sample Size
Assessing patient muscle strength is important	.88	.72	218
Muscle strength is a useful outcome measure in PR	.85	.77	218
Assessing patient muscle strength is safe	.56	.29	217
Assessing patient muscle strength should be standardised across all PR services.	.54	.31	218
No. of items	4		
Eigenvalue	2.5		
% of variance	62.5		
α	.79		
Average communality	.52		

Note. Extraction Method was Principal Axis Factoring. Rotation Method was Oblique (Direct Oblimin).

6.5.1.2 Exploratory Factor Analysis: Strength Assessment Barriers

The 17-items of SA barriers were included exclusively in this EFA. Details and descriptive results of these items can be found in Chapter 5 (see page 278 and Appendix AF). Sampling adequacy was confirmed by the overall KMO measure (KMO = 0.85) and the KMO measure of each item included (KMO = 0.78-0.94), as well as the average communality value (.67) being within the acceptable range. Preliminary examination of factorability was conducted. Correlation analysis revealed all relationships between items were ≤.9, and examination of the Bartlett's Test of Sphericity was found to be significant [$\chi 2(136) = 2575.19$, p=0.000]. However, there were a large number of correlations ≤.3 (56 in total). These are shown in the correlation matrix presented in Appendix AI. On closer inspection these low correlations

were between items which were unlikely to be grouped into the same factors. Although all items are presented as barriers to assessing patient muscle strength, they cover a wide range of aspects within PR. As this analysis was exploratory, all variables were kept in the analysis at this point, unless further evidence was presented to exclude specific items. The communality of each item was examined, showing all were above the cut-off value of ≥.3. At this stage, factor analysis was deemed suitable with all 17 items. Results of an initial EFA revealed a four factor solution. All factors had an eigenvalue of ≥1 and explained 72.6% of the variance in the data, in total. All items met the ≥.4 minimum criteria of a primary factor loading, except the item '*exercise equipment is inadequate for assessing patient muscle strength'*, which loaded onto two factors (.353 on Service Barriers and .364 on Colleague Barriers). Consequently, this item was removed from the analysis as it failed to meet the minimum loading criteria and had no clear membership to one particular factor.

Following the removal of the item '*exercise equipment is inadequate for assessing patient muscle strength'*, factorability of the remaining 16 items was re-examined and confirmed. The Bartlett's Test of Sphericity was significant [$\chi 2(120) = 2477.4$, $p = 0.000$], and the communality of each item was ≥.3 (see **Table 26**). Results of the final EFA remained a four factor solution. All factors had an eigenvalue of ≥1 and explained 41.5%, 15.5%, 10.2%, and 7.6% of the variance in the data, respectively (74.8% in total). Inspection of the scree plot supported this extraction, with the 'levelling off' of eigenvalues after four factors (see Appendix AJ). The factor loading matrix is presented in **Table 26**, showing all items had a primary factor loading of ≥.4. As shown, two items did have secondary factor loadings. Specifically, items '*I am uncertain about the safety of assessing patient muscle strength*' and '*I am uncertain about the benefit of assessing patient muscle strength'* both loaded highest on Factor 4 (Practitioner Barriers), but also had a loading on Factor 3 (Patient Barriers). However,

after further inspection, these items had stronger loadings and pattern fit with Factor 4 (Practitioner Barriers) and so remained.

Table 26. Summary of EFA results for strength assessment barriers

	Factor 1	Factor 2	Factor 3	Factor 4	Commu-nality	Item Sample Size
	SA Colleague Barriers	SA Service Barriers	SA Patient Barriers	SA Practitioner Barriers		
My colleagues do not have the knowledge and understanding needed to assess patient muscle strength.	**.975**				.887	219
My colleagues do not have the training needed to assess patient muscle strength.	**.834**				.770	
My colleagues are uncertain about the safety of assessing patient muscle strength.	**.802**				.759	217
My colleagues are uncertain about the benefit of assessing patient muscle strength.	**.763**				.696	219
There are not enough staff for assessing patient muscle strength.		**.968**			.902	219
Staff workloads are too high for assessing patient muscle strength.		**.950**			.877	219
Time is limited for assessing patient muscle strength.		**.739**			.515	219
Class sizes are too large for assessing patient muscle strength.		**.720**			.668	219
Funding is limited for assessing patient muscle strength.		**.572**			.453	219
Patients have psychological limitations which makes it			**.776**		.694	218

difficult to assess their muscle strength.						
Patients have physical limitations which makes it difficult to assess their muscle strength.			**.693**		.474	218
It is difficult to get patients to comply with the directions/instructions when assessing their muscle strength.			**.545**		.504	218
I do not have the knowledge and understanding needed to assess patient muscle strength.				**-.895**	.871	219
I do not have the training needed to assess patient muscle strength.				**-.809**	.688	218
I am uncertain about the safety of assessing patient muscle strength.			.369	**-.497**	.519	215
I am uncertain about the benefit of assessing patient muscle strength.			.335	**-.462**	.477	218
No. of items	4	5	3	4		
Eigenvalues	6.646	2.483	1.627	1.210		
% of variance	41.535	15.519	10.172	7.562		
α	.93	.90	.78	.83		

Note. Extraction Method was Principal Axis Factoring. Rotation Method was Oblique (Direct Oblimin); Factor loadings >.4 are in bold; Average communality = .672

Factor labels were assigned based on the overarching topic of each. Factor 1 was labelled ‘SA Colleague Barriers’, Factor 2 ‘SA Service Barriers’, Factor 3 ‘SA Patient Barriers’, and Factor 4 ‘SA Practitioner Barriers’. Internal consistency (α) for each factor was examined, with all revealed to be acceptable and ranging from .78 to .93 (see **Table 26**). No substantial increases in the alpha could have been achieved by eliminating additional items.

Composite scores were created for each factor, based on the mean of the items included in each. Scores could range between 1 and 7, with higher scores indicating agreement towards the barriers faced when assessing patient muscle strength in PR, and lower scores indicating disagreement.

Descriptives of these four new variables show, on average, participants were fairly neutral in agreement towards SA Service Barriers ($M = 4.11$, $SD = 1.43$) and SA Patient Barriers ($M = 3.89$, $SD = 1.12$), with a slight lean into the disagreement end of the scale for Colleague Barriers ($M = 3.56$, $SD = 1.51$) and Practitioner Barriers ($M = 3.24$, $SD = 1.35$).

6.5.1.3 Binary Logistic Regression: Assessment of Patient Muscle Strength

A binary logistic regression was conducted to examine whether any factors were associated with the likelihood of a PR service assessing patient muscle strength. Hereafter, this outcome variable will be referred to as 'SA Use'. Nine predictor variables were included in the analysis: 1) number of ST exercises, 2) number of PR sites, 3) SA Practitioner Training, 4) SA Confidence, as well as the four new variables constructed from the related EFAs, 5) SA Service Barrier, 6) SA Patient Barrier, 7) SA Practitioner Barrier, 8) SA Colleague Barrier, and 9) SA Attitude. Of the total study sample (N=219), 179 participants were included in this analysis.

Of these predictor variables, SA Practitioner Training and SA Confidence were categorical. SA Practitioner Training was formatted as a dichotomous variable: participants without SA training (No = 0) and participants with SA training (Yes = 1). Initially this variable was expanded to include specific training categories. As reported in Chapter 5 (see page 271) these categories were: no training, training only received in PR, training only received outside PR, and both. However, this failed to meet the preliminary analysis assumption that all expected

cell frequencies for categorical variables should be ≥1, with no more than 20% <5 (538). Additionally, no significant results were produced in a preliminary analysis. Consequently, it was decided to simplify the variable to only two categories. Similarly, the variable SA Confidence was also collapsed in the final analysis model. As reported in Chapter 5 (see page 273), this variable originally had seven categories corresponding to varying levels of agreement. However, the presence of multiple categories also resulted in the failure to meet the preliminary analysis assumption of cell frequency. As a result, similar agreement categories were collapsed together to form three new recoded categories: 'Agree' [3], 'Neither Agree nor Disagree' [2], and 'Disagree' [1]. As there were three categories a categorical comparison group was assigned. The most common group (i.e., the one with the most data points) was selected, which was the category 'Agree' [3].

Preliminary checks were carried out by testing for multicollinearity and reviewing the contingency table of all categorical variables included. Both assumptions were met, with results revealing collinearity statistics were appropriate (Tolerance = >0.1, VIF = <10), and all expected cell frequencies were within the parameters recommended. As this analysis was exploratory, the method of model building used was force entry, whereby all variables were put into the model at the same time, as there was no theoretical reasoning for giving preference to certain variables. The model was statistically significant [$\chi^2(10) = 82.398$, $p = .000$.], suggesting that it could distinguish between cases with 'SA Use' and those without. The model 'explained' between 36.9% (Cox & Snell R square) and 49.2% (Nagelkerke R square) of the variance in the dependent variable, and correctly classified 79.9% of cases. In addition, the Hosmer and Lemeshow test indicated the model had adequate fit with a non-significant result [$\chi^2(8) = 5.481$, $p = .705$]. As shown in **Table 27**, SA Service Barrier, SA Colleague Barrier, and

SA Confidence ‘Disagree’ [1] significantly contributed to the model, whereas the other variables did not.

Table 27. Binary logistic regression coefficients of the model predicting ‘SA Use’

	β	SE	Wald’s χ^2	*df*	*p*	*OR*	95% CI *OR*	
							Lower	Higher
SA Practitioner Training	.576	.443	1.688	1	.194	1.779	.746	4.243
SA Confidence			7.186	2	.028			
SA Confidence - Disagree [1]	**-1.83**	.683	7.172	1	**.007****	**.161**	.042	.613
SA Confidence - Neither Agree nor Disagree [2]	-.491	.529	.861	1	.353	.612	.217	1.726
Number of PR sites	.074	.074	1.010	1	.315	1.077	.932	1.244
Number of ST exercises	.029	.086	.112	1	.738	1.029	.869	1.219
SA Attitude	.333	.275	1.471	1	.225	1.395	.814	2.390
SA Service Barrier	**-.546**	.165	10.914	1	**.001****	**.579**	.419	.801
SA Patient Barrier	-.205	.204	1.008	1	.315	.815	.546	1.215
SA Practitioner Barrier	-.099	.240	.169	1	.681	.906	.566	1.451
SA Colleague Barrier	**-.435**	.187	5.438	1	**.020***	**.647**	.449	.933
Constant	2.678	2.349	1.300	1	.254	14.555		

Note. * $p < .05$, ** $p < .01$; ‘SA Confidence’ categorical comparison group was ‘Agree’ (3).

As all significant variables had an odds ratio (OR) of less than 1, the inverse of this value was computed to aid interpretation and reporting, allowing for more meaningful results. Initially, the target group of the outcome variable (‘SA Use’) indicated a SA was used (Y = 1). However, the computed inverse swaps the target group, so it is now SA *not* used (Y = 0). Therefore, all results will be interpreted as predicting group membership of cases where a SA is *not* used. The multiplicative inverse is calculated by dividing 1 by the odds ratio [1/OR].

Results suggest that for every one unit increase in SA Service Barrier the predictive odds of a SA *not* used increased by 1.7 [1/.579 = 1.727]. In other words, for every one unit increase in SA Service Barrier, participants were 1.7 times more likely to work in a PR service which did *not* use a SA. Similarly, for every one unit increase in SA Colleague Barrier the predictive odds of a SA *not* used increased by 1.5 [1/.647 = 1.546]. Meaning, for every one unit increase in SA Colleague Barrier, participants were 1.5 times more likely to work in a PR service which did *not* use a SA. Furthermore, results suggest participants who disagreed they were confident assessing patient muscle strength were 6.2 [1/.161 = 6.211] times more likely to work in a PR service which did *not* use a SA than participants who agreed they were confident. Overall, an increase in SA Service Barrier and SA Colleague Barrier were associated with an increased likelihood of participants working in a PR service which did *not* use a SA, and participants who disagreed they were confident assessing patient muscle strength were more likely to work in a PR service which did *not* use a SA compared to those who agreed. Following the analysis, an inspection of the residuals was conducted, revealing all cases had acceptable values. This concluded there were no outliers or cases with substantial influence.

6.5.2 Prescription of Strength Training

Research Questions 2: What factors predict whether or not PR services prescribe strength training?

EFA was conducted for the purpose of reducing the quantity of data into a manageable number of variables. This then allowed for data to be included and explored as predictor variables in the subsequent binary logistic regression. To answer research question 2, EFA was performed to collapse the 5-items of ST attitudes, the 18-items of ST barriers, and the 3-items of ST awareness into new variables. After which, they were entered as predictor variables into

the subsequent binary logistic regression, which explored if factors predicted whether or not PR services prescribed ST (according to the ACSM guidelines for healthy older adults).

6.5.2.1 Exploratory Factor Analysis: Strength Training Attitude

The 6-items of ST attitudes were included exclusively in this EFA (see **Table 28**). Details and descriptive results of these items can be found in Chapter 5 (see page 277). Sampling adequacy was confirmed by the overall KMO measure (KMO = 0.79) and the KMO measure of each item included (KMO = 0.71-0.94), as well as the average communality value (.67). being within the acceptable range. Preliminary examination of factorability was conducted. As shown in **Table 28**, all correlations were within the recommended range of ≥.3 and ≤.9, except the item '*strength training should be standardised across PR services'* which was observed to have correlations ≤.3 with all other variables, providing evidence for potential removal. Examination of the Bartlett's Test of Sphericity was found to be significant [$\chi 2(15) = 704.544$, $p<.001$]. Secondly, the communality of each item was examined, which showed four out of the six items were above the minimum value of ≥.3. However, items '*strength training is easy to deliver in PR'* and '*strength training should be standardised across PR services*' were below this cut-off value, with communalities of .231 and .051, respectively. This evidence suggests the potential removal of both items, with even further support for the exclusion of '*strength training should be standardised across PR services*'. To examine the suitability of both items being included, an initial analysis was run with all items. Results revealed the item '*strength training is easy to deliver in PR*' had an acceptable factor loading of .480, whereas the item '*strength training should be standardised across PR services*' did not, with a factor loading of 0.227. Collation of evidence led to the removal of item '*strength training should be standardised across PR services'* from the analysis on the basis of 1) low correlations with all other items, 2) low communality value, and 3) a factor loading of ≤.4.

Further justification for this decision included an increase in factor internal consistency once removed (α = .76 to α = .84).

Table 28. Correlation matrix of the 6-items of strength training attitudes

	Strength training is important for patients	Strength training is beneficial for patients	Strength training is safe for patients	Strength training is easy to deliver in PR	Strength training should be individually prescribed to patients	Strength training should be standardised across PR services.
Strength training is important for patients	-					
Strength training is beneficial for patients	.936**	-				
Strength training is safe for patients	.594**	.607**	-			
Strength training is easy to deliver in PR	.391**	.396**	.446**	-		
Strength training should be individually prescribed to patients	.678**	.693**	.465**	.367**	-	
Strength training should be standardised across PR services.	.172**	.210**	.082	.166**	.245**	-

Note. ** correlation is significant at the <0.01 level

Following the removal of the item '*strength training should be standardised across PR services'*, factorability of the remaining 5 items was re-examined and confirmed. The Bartlett's Test of Sphericity was still significant [$\chi 2(10) = 688.482$, $p<.001$], and the communality of

each item was within reasonable range (≥.3). As shown in **Table 29**, the item '*strength training is easy to deliver in PR'* did have a communality of .226 but was retained within the analysis as no additional evidence was present to warrant exclusion. Given these overall indicators, factor analysis was deemed suitable with these 5 items. Results of the final EFA revealed a one factor solution, which had an eigenvalue of ≥1 and explained 59.5% of the variance in the data. Inspection of the scree plot supported extraction of one factor (see Appendix AK). The factor loading matrix is presented in **Table 29**, showing all 5 items had a primary factor loading of ≥.4. Moreover, internal consistency was acceptable (α = .84), with no substantial increases in the alpha achieved by eliminating additional items. A composite score was created for this one factor solution, based on the mean of the 5 items, with the descriptive label of 'Strength Training (ST) Attitude' assigned to this new variable. Scores could range between 1 and 7, with higher scores indicating greater agreement (i.e., a positive attitude) towards ST in PR, and lower scores indicating greater disagreement (i.e., a negative attitude).

Descriptives of this new variable show, on average, that participants had a positive attitude towards ST in PR (*M* = 6.2 *SD* = .67).

Table 29. Summary of EFA results for strength training attitude

	Factor Loading	Communality	Item Sample Size
Strength training is important for patients	.936	.879	202
Strength training is beneficial for patients	.952	.906	201
Strength training is safe for patients	.664	.441	201
Strength training is easy to deliver in PR	.475	.226	202
Strength training should be individually prescribed to patients	.726	.527	202
No. of items	5		
Eigenvalue	3.286		
% of variance	59.506		
α	.84		
Average communality	.596		

Note. Extraction Method was Principal Axis Factoring. Rotation Method was Oblique (Direct Oblimin).

6.5.2.2 Exploratory Factor Analysis: Strength Training Barriers

The 18-items of ST barriers were included exclusively in this EFA. Details and descriptive results of these items can be found in Chapter 5 (see page 282 and Appendix AG). Sampling adequacy was confirmed by the overall KMO measure (KMO = 0.87) and the KMO measure of each item included (KMO = 0.76-0.95), as well as the average communality value (.68) being within the acceptable range. Preliminary examination of factorability was conducted. Correlation analysis revealed all relationships were ≤.9, and examination of the Bartlett's Test of Sphericity was found to be significant [$\chi 2(153) = 2765.193$, $p=0.000$]. However, there were a large number of correlations ≤.3 (48 in total). These are shown in the correlation matrix presented in Appendix AL. On closer inspection these low correlations were between items which were unlikely to be grouped into the same factors. Although all items are

presented as barriers to delivering ST, they cover a wide range of aspects within PR. As this analysis was exploratory, all variables were kept in the analysis at this point, unless further evidence was presented to exclude specific items. The communality of each item was examined, showing all were above the cut-off value of ≥.3. At this stage, factor analysis was deemed suitable with these 18 items. Results of an initial EFA revealed a four factor solution. All factors had an eigenvalue of ≥1 and explained 73.77% of the variance in the data, in total. All items met the ≥.4 minimum criteria of a primary factor loading, except the item '*there is not enough equipment to go around all patients'*, with a loading of .374 onto Factor 1 (Service Barriers). As a result, this item was eliminated from the analysis as it failed to meet the minimum loading criteria. Further justification for this decision included a slight increase in factor internal consistency once removed (α = .88 to α = .90).

Following the removal of the item '*there is not enough equipment to go around all patients'*, factorability of the remaining 17 items was re-examined and confirmed. The Bartlett's Test of Sphericity was still significant [$\chi 2(136) = 2599.780$, $p = 0.000$] and the communality of each item was ≥.3 (see **Table 30**). Results of the final EFA remained a four factor solution. All factors had an eigenvalue of ≥1 and explained 43.75%, 13.56%, 9.54%, and 8.49% of the variance in the data, respectively (75.34% in total). Inspection of the scree plot supported this extraction, with the 'levelling off' of eigenvalues after four factors (see Appendix AM). The factor loading matrix is presented in **Table 30**, showing all items had a primary factor loading of ≥.4.

Table 30. Summary of EFA results for strength training barriers

	Factor 1	Factor 2	Factor 3	Factor 4	Commu-nalities	Item Sample Size
	ST Service Barriers	ST Colleague Barriers	ST Practitioner Barriers	ST Patient Barriers		
There are not enough staff for delivering strength training.	**.964**				.909	199
Staff workloads are too high for delivering strength training.	**.924**				.860	199
Class sizes are too large for delivering strength training.	**.830**				.718	196
Time is limited for delivering strength training.	**.783**				.675	199
Funding is limited for delivering strength training.	**.728**				.576	199
Exercise equipment is inadequate for delivering strength training.	**.453**				.409	197
My colleagues do not have the knowledge and understanding to deliver strength training to patients.		**-.915**			.874	197
My colleagues do not have the training needed to deliver strength training to patients.		**-.888**			.838	197
My colleagues are uncertain about the safety of strength training for patients.		**-.845**			.751	198
My colleagues are uncertain about the benefit of strength training to patients.		**-.809**			.703	197
I do not have the knowledge and understanding to deliver strength training to patients.			**.924**		.877	199
I do not have the training needed to deliver strength training to patients.			**.759**		.714	199

I am uncertain about the benefit of strength training for patients.			**.576**		.372	196
I am uncertain about the safety of strength training for patients.			**.559**		.518	199
Patients have psychological limitations which makes it difficult for them to do strength training.				**.846**	.707	198
Patients have physical limitations which makes it difficult for them to do strength training.				**.814**	.607	198
It is difficult to get patients to comply with the directions/instructions for strength training.				**.573**	.514	199
No. of items	6	4	4	3		
Eigenvalues	7.437	2.305	1.622	1.444		
% of variance	43.75	13.56	9.54	8.49		
α	.918	.939	.837	.803		

Note. Extraction Method was Principal Axis Factoring. Rotation Method was Oblique (Direct Oblimin); Factor loadings >.4 are in bold; Average communality = .68

Factor labels were assigned based on suitability and relevance to the overarching topic of each. Factor 1 was labelled ‘ST Service Barriers’, Factor 2 ‘ST Colleague Barriers’, Factor 3 ‘ST Practitioner Barriers’, and Factor 4 ‘ST Patient Barriers’. Internal consistency (α) for each factor was examined, with all revealed to be acceptable, ranging from .803 to .939 (see **Table 30**). No substantial increases in the alpha could have been achieved by eliminating additional items. Composite scores were created for each factor, based on the mean of the items included in each. Scores could range between 1 and 7, with higher scores indicating agreement towards the barriers faced when delivering ST in PR, and lower scores indicating disagreement.

Descriptives of these four new variables show, on average, that participants were fairly neutral in agreement towards ST Patient Barriers (*M* = 3.9, *SD* = 1.27). Whereas ST Service Barriers (*M* = 3.45, *SD* = 1.37), ST Colleague Barriers (*M* = 3.04, *SD* = 1.41), and ST Practitioner Barriers (*M* = 2.68, *SD* = 1.14) leaned towards the disagreement end of the scale.

6.5.2.3 Exploratory Factor Analysis: Awareness of Strength Training Guidelines

The 3-items of ST awareness were included exclusively in this EFA (see **Table 31**). Details and descriptive results of these items can be found in Chapter 5 (see page 270). Sampling adequacy was confirmed by the overall KMO measure (KMO = 0.63) and the KMO measure of each item included (KMO = 0.58-0.92), as well as the average communality value (.69) being within the acceptable range. Preliminary examination of factorability was conducted. As shown in **Table 31**, all correlations were within the recommended range of ≥.3 and ≤.9, and examination of the Bartlett's Test of Sphericity was found to be significant [$\chi 2(3) = 371.897$, $p<.001$]. Secondly, the communality of each item was examined, which revealed two out of three items were above the recommended value of ≥.3. However, the item '*awareness of the recommendation to include strength training in PR'* had a borderline communality of .29 (see **Table 31**), which could suggest potential removal from the analysis. To examine the suitability of this item still being included, an initial analysis was run with all items.

Table 31. Results of the correlation matrix of the 3-items for awareness of strength training guidelines

	Awareness of the recommendation to include strength training in PR	Awareness of ACSM strength training guidelines for older adults	Awareness of ACSM strength training guidelines for older adults in COPD
Awareness of the recommendation to include strength training in PR	-		
Awareness of ACSM strength training guidelines for older adults	.501**	-	
Awareness of ACSM strength training guidelines for older adults in COPD	.514**	.886**	-

Note. ** correlation is significant at the <0.01 level

Results of the EFA, revealed a one factor solution, which had an eigenvalue of ≥1 and explained 76.21% of the variance in the data. Inspection of the scree plot supported extraction of one factor (see Appendix AN). The factor loading matrix is presented in **Table 32**, showing all three items had a primary factor loading of ≥.4. As a result, the decision to retain the item '*awareness of the recommendation to include strength training in PR*' was made, as no additional evidence was present to warrant exclusion. Internal consistency (α) was found to be acceptable at .84. The alpha level could have been increased to .93 by removing the item '*awareness of the recommendation to include strength training in PR*', but considering internal consistency was already high and the communality value borderline, this item was retained. A composite score was created for this one factor solution, based on the mean of the three items. The descriptive label of 'Strength Training (ST) Guideline Awareness' was deemed suitable

and was assigned. Scores could range between 1 and 5, with higher scores indicating high awareness of ST guidelines, and lower scores indicating low awareness.

Descriptives of this new variable show, on average, that participants had moderate awareness of ST guidelines (M = 3.32, SD = 1.03).

Table 32. Summary of EFA results for awareness of strength training guidelines

	Factor Loading	**Communality**	**Item Sample Size**
Awareness of the recommendation to include strength training in PR	.539	.290	204
Awareness of ACSM strength training guidelines for older adults	.932	.868	205
Awareness of ACSM strength training guidelines for older adults in COPD	.951	.904	205
No. of items	3		
Eigenvalue	2.286		
% of variance	76.207		
α	.84		
Average communality	.69		

Note. Extraction Method was Principal Axis Factoring. Rotation Method was Oblique (Direct Oblimin).

6.5.2.4 Binary Logistic Regression: Prescription of Strength Training

A binary logistic regression was conducted to examine whether any factors were associated with the likelihood of a PR service fulfilling the modified ACSM ST prescription criteria or not. Hereafter, this outcome variable will be referred to as 'ST Criteria Fulfilment'. Twelve predictor variables were included in the analysis: 1) number of PR sites, 2) duration of exercise session, 3) PR programme length, 4) ST Practitioner Training, 5) ST Confidence, 6)

SA Use, as well as the new variables constructed from the related EFAs, 7) ST Service Barrier, 8) ST Patient Barrier, 9) ST Practitioner Barrier, 10) ST Colleague Barrier, 11) ST Attitude, and 12) ST Guideline Awareness. Of the total study sample (N = 219), 158 participants were included in this analysis. Of these variables, ST Practitioner Training, ST Confidence, and SA Use were categorical. As described in the SA binary logistic regression above (page 321), the same decisions were made to format ST Practitioner Training into a dichotomous variable (0 = No Training, 1 = Training) and collapse ST Confidence from seven categories to three categories (1 = Disagree, 2 = Neither Agree nor Disagree, 3 = Agree). As there were three categories a categorical comparison group was assigned - 'Agree' [3]. The variable 'SA Use' originally had three categories: SA used, SA not used, and I don't know/Unsure. However, the category 'I don't know/Unsure' only contained eight participants, which resulted in the failure to meet the preliminary analysis assumption of expected cell frequencies. Consequently, it was decided to simplify the variable into only two categories, by excluding 'I don't know/Unsure'.

Preliminary checks were carried out by testing for multicollinearity and reviewing the contingency table of all categorical variables included. Results revealed collinearity statistics were appropriate (Tolerance = >0.1, VIF = <10), however expected cell frequencies did not meet the assumptions aforementioned, with 50% of expected cell frequencies falling below 5. Despite actions taken to rectify the low cell frequencies (e.g., collapsing and removing variable categories), low test power was still suggested. Nevertheless, in response to this, it was decided to accept this loss of power and still run the analysis. As this analysis was exploratory, the method of model building used was force entry, whereby all variables were put into the model at the same time, as there was no theoretical reasoning for giving preference to certain variables. Results revealed that the model was not statistically significant [$\chi^2(13) = 15.994$, p = .249], suggesting it could not distinguish between cases which fulfilled the ST prescription

criteria and those which did not. However, the Hosmer and Lemeshow test indicated the model had adequate fit with a non-significant result [$\chi^2(8) = 6.678$, $p = .572$] and correctly classified 76.6% of cases. However, none of the variables were found to significantly contribute to the model. See Appendix AO for full table of results.

6.6 Discussion

This chapter aimed to explore and identify predictors of SA use and ST prescription. Analysis identified service-related barriers, colleague-related barriers, and practitioner confidence as predictors of SA use in PR. Specifically, an increase in SA Service Barriers and SA Colleague Barriers were associated with an increased likelihood of participants working in a PR service which did *not* use a SA, and participants who disagreed they were confident assessing patient muscle strength were more likely to work in a PR service which did *not* use a SA compared to those who agreed. In other words, participants were more likely to work in a PR service which did *not* assess patient muscle strength if they perceived service and colleague related barriers to be higher and had lower confidence assessing muscle strength.

EFA was conducted for the purpose of reducing relevant data to a manageable number of variables, so it could be included as predictors in subsequent binary logistic regressions. Service-related barriers encompassed a number of factors likely to influence the provision of PR, and thus the inclusion and use of SA. It included limited time, limited funding, high workloads, large class sizes, and low staff numbers. At an organisational level, the presence of such barriers can make any change or adjustment to clinical practice challenging, especially the implementation of another component. This would likely stretch these resources, unless more resources were provided, such as more time and funding. Organisational and environmental factors like these are commonly reported as barriers in COPD and PR research

(395, 396, 398, 403, 405, 454-456). Unfortunately, causation cannot be determined from this present study, due to its cross-sectional nature. However, these findings have allowed specific areas of influence to be identified. In this case, it has emphasised the importance of the environment in which SA is implemented and used. Not all SA methods are suitable or appropriate for use in clinical practice, with variations in cost, time, equipment, and technical skill required (230). The resources available to a PR service need careful consideration before selecting a SA and introducing it into clinical practice and the existing infrastructure of the programme.

One factor likely to highly influence and impact SA use is the availability and access of equipment, including both the specific devices/apparatus needed (e.g., HHD) and/or necessary exercise equipment (e.g., weights). Equipment has been reported as a barrier in previous COPD studies, which simply demonstrates that in order to conduct an assessment and fulfil recommendations the actual assessment device needs to be available (398, 456). Most SA methods require equipment of some kind, varying in cost and space required (230). PR settings and venue types will play a significant role in the access and availability of equipment, for example a commercial or hospital gym will likely have exercise and assessment equipment whereas a community hall may not. Despite descriptive findings in Chapter 3 identifying inadequate equipment as a perceived barrier for SA in PR, this item was not included in the binary logistic regression. The item was removed from the EFA and thus not included in the SA service barrier variable. A reason for this exclusion could be that equipment is slightly different compared to other service-related barriers (e.g., time, workloads etc). Equipment is a tangible and objective occurrence – it is either available or it is not. Whereas the other service-related barriers are more subjective and susceptible to fluctuation. Therefore, equipment related

survey items did not fit into the emergent factors of the EFA. Further research is needed to explore the specific impact of equipment on SA and ST use in PR.

Colleague-related barriers included a number of competency factors, such as knowledge and understanding, relevant training, and uncertainty of safety and benefit. A SA was more likely not to be used if this group of barriers were perceived to be higher. This finding is understandable to some extent, as if a PR service or practitioner does not assess muscle strength, then training and understanding may not be needed. It is important to note that these are participant perceptions of their colleagues understanding and training - it is not an objective measure. Secondly, this is an overall finding related to colleagues as a collective group, so perceptions of competency may be high for some and low for others, resulting in an average answer provided. Nevertheless, this strongly highlights that if SA was introduced into a PR service, a key factor of focus is the collective training of staff, ensuring all practitioners have the knowledge, understanding, and skills to successfully assess strength in PR clinical practice. A lack of training and knowledge have been reported as barriers in previous research in COPD, PR, and similar clinical settings (395, 402, 405, 455, 464, 467).

The last predictor associated with SA use was practitioner confidence. Participants who disagreed they were confident assessing muscle strength were more likely to work in a PR service which did not use a SA. This result is understandable, as confidence could be lower simply because the PR service or practitioner does not conduct the assessment. If it is not part of their job role then confidence may be lower (399). Confidence can also be described as self-efficacy, which refers to an individual's belief in their ability to perform a behaviour – in this case performing a SA. Studies have found confidence and self-efficacy of HCPs were predictors of spirometry use (456), prescription of inhaled corticosteroids for COPD patients

(529), promotion of PR (464), and general provision of COPD management (547). Meaning inadequate confidence may limit adherence and utility of assessments and treatments for COPD. Therefore, opportunities for experience, practice, and training will likely impact practitioner confidence positivity, as the more you learn and do, the more confident you become in your own competency and skill. In one study, Australian HCPs (n = 33) participated in an educational training programme for the management of chronic lung disease, which included training components on the delivery and prescription of exercise programmes, and performance of assessments (e.g. spirometry and 6MWT) (548). Confidence, as well as knowledge, significantly increased following completion of the training programme, and was maintained at 3 and 12 month follow-ups. It also led to the establishment of effective PR programmes – showing the training benefited both staff competence and practice application. There are studies examining the implementation and training relating to general COPD management guidelines (549, 550), but none specifically examined the impact of training on the assessment of muscle strength and/or the prescription and delivery of ST in PR. Again, causation cannot be established from the present study - specifically it cannot confirm that practitioner confidence (and training and knowledge) determines SA use in PR. Instead, this highlights important areas of focus, for example ensuring adequate training and opportunities are offered and provided to PR practitioners.

Lastly, discussion is warrant regarding the identification of predictor variables for ST prescription, specifically fulfilment of the ACSM criteria (235). The binary logistic regression produced insignificant results. A key reason for this outcome was a small sample size, leading to the analysis being underpowered. However, it also shows the lack of PR services meeting the ACSM prescription guidelines for ST. Even when this criteria was modified to closer reflect the reality of PR (i.e. removal of 8-10 strength exercises), fulfilment was still low. Possible

reasons for this are the lack of specificity for COPD and PR, as they were ultimately designed for older adults. Furthermore, there is limited reference to American published guidelines by UK healthcare organisations (36, 141, 151, 154, 394), which could hinder practitioner awareness. This study showed participants were only moderately aware of them. Similar results have been reported in other studies, with low familiarity and awareness reported as barriers to COPD guideline implementation (456, 528, 529). In one study of 500 US primary care providers, participants were less familiar with American guidelines (ATS/ERS and American College of Physicians) than global guidelines (GOLD) (456). In the present study, although the results of the ST analysis were insignificant, it further supports the need for clearer and more specific guidance for ST prescription in PR, particularly within the UK. However, publication of clinical guidelines is only the first step towards an actual change in service and practitioner behaviour, therefore strategies to disseminate, promote, and implement guidelines must be utilised (548, 551). Passive dissemination is shown to be largely ineffective, with recommended strategies being multifaceted and actively engaging HCPs throughout the process (552).

6.6.1 Strengths and Limitations

The strengths of this subsequent analysis include further exploration of barriers and influential factors of SA use in PR. Using the data collected from the survey reported in Chapter 5, three predictors of SA non-use were identified. These predictors are service-related barriers (e.g., limited time), colleague-related barriers (e.g., lack of knowledge, understanding, and relevant training), and practitioner confidence. These results support the descriptive findings previously reported in Chapter 5 and the qualitative findings reported in Chapter 3.

Unfortunately, the sample size target of 291 participants was not achieved, which did result in analyses being underpowered to varying extents. As described in Chapter 5 (page 301), a number of difficulties were experienced during recruitment, which resulted in a smaller sample of 219 participants. For EFA, a sample of 300 is considered 'good' (541), and as such was deemed a realistic target within the parameters of this study and healthcare area. Unfortunately, this sample target was not reached, with cases ranging from 196-219 in each analysis. EFA guidelines consider 200 participants to be 'fair' (541), but smaller samples can lead to low test power. To explore the impact of a smaller sample, additional checks of sampling adequacy were conducted and reported, specifically using KMO and the average communality value among included factor items. Small sample size also impacted the binary logistic regressions. The regression analysis of SA use nearly met the proposed criterion of 10 EPV. Of the total study sample (*N*=219), 179 participants were included in this analysis, equating to 8.9 EPV (89 subjects in the smaller outcome group ÷ 10 regression coefficients = 8.9 EPV). Test power could have been improved with a larger sample size, but nonetheless significant results were still produced. The regression analysis of ST prescription, specifically fulfilment of the ACSM ST criteria, had an insufficient sample size. This analysis was severely underpowered, contributing to the lack of significant results. Of the total study sample (*N* = 219), 158 participants were included in this analysis, however this only equated to 3.3 EPV (39 subjects in the smaller outcome group ÷ 12 regression coefficients = 3.3 EPV).

A second study limitation was the format of some survey questions. In hindsight questions related specifically to equipment use, and the types of equipment used, could have been formatted more appropriately for use as predictor variables in the binary logistic regressions. As previously explained in the study methodology (page 311), data related to equipment type failed to meet the assumptions of a binary logistic regression, as it did not have

exclusive categories and as such produced many categorical groups with insufficient frequency cell counts (538). It can be theorised that access and availability of equipment can impact and influence the assessment of muscle strength and prescription of ST in PR, and has previously been identified in this thesis as an important factor and barrier. Therefore, future research should investigate the impact of equipment access and availability within PR, with a specific focus on SA use and ST prescription and delivery.

6.6.2 Study Implications and Future Research Recommendations

This study further supports and highlights targeted areas of consideration and improvement for the assessment of patient muscle strength in PR. Specifically, the influence of service and organisational factors and how they determine the type of SA used and how it is implemented into clinical practice. Additionally, it emphasises the importance of adequate and relevant training of staff as a collective group. If a SA is used, all PR practitioners should have the competence and skills to conduct the assessment, as well as have the confidence in themselves and their colleagues. Future research should focus on the feasibility of assessing muscle strength in PR, investigating specifically how each of these identified factors impact use and non-use. Specific focus should be placed on the use, access, and availability of equipment within PR settings, as well as relevant training offered and completed by practitioners. Lastly, as this study produced inconclusive results regarding predictors of ST prescription in PR, further investigation is warranted to identify and isolate specific factors and barriers.

6.7 Conclusion

Subsequent statistical analyses explored predictors of SA use and ST prescription in PR services in England. Service-related barriers, colleague-related barriers, and practitioner

confidence were found to predict SA non-use. Unfortunately, non-significant and inconclusive results were found when exploring predictors of ST prescription, warranting further investigation in this area. This study provides further insight into factors which can impact the assessment of patient muscle strength in PR. Future research should focus on the feasibility of SA use and how it is implemented into PR services, with consideration for available resources and training for practitioners.

Chapter 7. Discussion and Conclusion

7.1 Summary of Findings

This thesis aimed to explore and understand the use of SA and ST in PR clinical practice, and identify influential factors which help, hinder, and impact use. The chapters included in this thesis are summarised in **Table 33**, and a brief overview of findings is outlined here.

Firstly, Chapter 2 presented a comprehensive narrative review of key literature on SA and ST in COPD and PR. Muscle weakness is an important consequence of COPD, with quadriceps muscle strength recognised as an important systemic marker for the condition. Therefore, assessing and treating muscle weakness is argued as being of paramount importance in the comprehensive management of this disease. This review found muscle strength is assessed in COPD research, but there is heterogeneity in the methods used. Whereas there is minimal use in PR research specifically. Furthermore, ST is shown to be an effective strategy to target muscle weakness in COPD. However, there are wide variations in the prescription parameters used, as well as a lack of sufficient description in published studies - making replication and application in clinical practice difficult. PR guidelines strongly recommend SA and ST in PR, but guidance is limited, vague, and inconsistent – particularly in the UK. Consequently, the absence of adequate guidelines and recommendations may cause difficulties when services are implementing and using SA and ST. This is evidenced to some degree by previously published PR surveys, however insufficient data is collected, preventing a clear picture of provision. Overall, this questioned how PR services are assessing muscle strength and prescribing ST, and what influences are present in real world practice.

The findings of the practitioner interviews (Chapter 3) indicated that PR practitioners recognise the importance of ST, and the benefits SA can offer to staff and patients. However, there is some uncertainty regarding the usefulness and relevance of SA within the parameters of current clinical practices. An important aspect of PR is the physical, psychological, and educational support provided by staff, which should be considered and utilised when conducting a SA and delivering ST, as patients can demonstrate limitations in their understanding and physical ability. Barriers to SA use in PR were service and environmental factors, such as limited time, high workloads and demands, and limited equipment; as well as the need for further staff training related to the assessment of strength and the prescription and delivery of ST in PR. The findings of the patient interviews (Chapter 4) compliment the practitioner interviews, by outlining patient perspectives and experiences of SA, ST, and exercise in PR. Patients show some misunderstandings and misconceptions about ST, however it is apparent that daily function and the performance of daily activities is an important outcome. Mixed views towards SA are evidenced, with some patients recognising the benefits and others questioning the relevance. Staff support is an important facilitator of exercise, as well as PR offering important psychosocial benefits, particularly peer support. However, challenges to exercise continuation and adherence after PR are evidenced, particularly difficulties with independent exercise once structure, support, and supervision are removed.

In Chapter 5, the PR survey study found nearly all practitioners (93.6%) reported the inclusion of ST in PR programmes, whereas only 47% reported SA use. A key finding of this study showed large variation in the methods used to assess patient muscle strength and prescribe ST. Additionally, it found that a substantial proportion of PR practitioners did not have training relevant to SA (37.4%) or ST (45.2%), but they did demonstrate positive attitudes and opinions towards use in PR. Perceived barriers to SA and ST in PR were a lack of staff

training, physical limitations of patients, and service-related factors, such as limited time and equipment. Lastly, Chapter 6 further explored the descriptive data collected from the survey study, and found service-related barriers (e.g., limited time), colleague-related barriers (e.g., limited understanding and training), and practitioner confidence were predictors of SA non-use. In other words, practitioners were more likely to work in a PR service which did *not* assess patient muscle strength if they perceived service and colleague related barriers to be higher and had lower confidence assessing muscle strength.

Table 33. Summary of thesis chapters/studies

Chapter	Aim(s)	Key Findings	Contributions to literature/knowledge
Narrative Literature Review (Chapter 2)	To present a comprehensive review that summarises and discusses the most relevant literature related to SA and ST in COPD and PR.	There is wide variation in how muscle strength is assessed and how ST is prescribed in research studies. Despite PR guidelines recommending SA and ST, there is markedly limited guidance for application in PR clinical practice. Previous surveys have collected data on SA and ST in PR, but detail was limited, preventing a clear picture of provision.	A review of SA and ST in PR guidelines and published PR surveys has not been conducted before.
Practitioner Interviews (Chapter 3)	To explore practitioner perspectives and experiences of SA and ST in PR. Specifically, to explore the use of SA and ST in a PR programme, the impact it has on the practitioners and their patients, and factors which help and hinder use in PR.	Practitioners expressed positive views and opinions of SA and ST in PR, recognising the importance and benefits it offers services and patients. However, a number of factors were identified as hinderances, including uncertainty of SA in current practices, need for staff training, physical and psychological limitations of patients, and service-related factors (e.g., limited time and equipment).	This is the first qualitative study to explore practitioner perspectives and experiences of SA and ST in a PR setting. Practitioners showed acceptability towards SA and ST in PR; however improvements in implementation and use is needed for successful application in clinical practice e.g. appropriate resources and training.
Patient Interviews (Chapter 4)	To explore patient perspectives and experiences of SA, ST, and exercise in PR. Additionally, the impact of this on the patients, and the identification of factors which	Patients demonstrate some misunderstanding and misconceptions about ST. But an important outcome of ST is daily function and activities. Patients have mixed views about SA in PR, with some recognising its benefits and others questioning its relevance. Staff support is a key facilitator for exercise during PR, as well as the psychosocial benefits, with emphasis	This is the first qualitative study to explore patient perspectives and experiences of SA and ST in a PR setting. It suggests more focus is needed on patient understanding when conducting a SA and prescribing and delivering ST. Appropriate education and messaging is needed throughout PR

	help and hinder the use of SA and ST in PR.	placed on peer support. Patients express difficulty adhering and continuing exercise after PR, with barriers contributing to this being the loss of support, supervision, and structure.	programmes. Furthermore, it suggests that patients may rely on the PR structure, staff, and peers for support, motivation, and accountability. Consideration is needed for how PR services and staff can support patients during programmes so they can exercise independently once completed.
National PR Survey (Chapter 5)	To investigate SA and ST use in PR services in England, as well as practitioner training, attitudes, and perceived barriers.	Results showed 47% of participants reported their PR service assessed strength, and 93.8% reported the inclusion of ST. However, methods of assessment and prescription varied greatly overall. A substantial proportion of participants did not have training related to SA (37.4%) and ST (45.2%), and overall participants agreed additional training would be beneficial. Positive attitudes towards SA and ST were found, however a number of perceived barriers were reported, including service-related factors (e.g. time and equipment), patient physical limitations, and staff training.	This study outlines details of SA and ST use which has not been previously investigated or reported. It also highlights the need for clearer ST and SA guidance in PR, with consideration for variability, feasibility, and barriers within clinical practice.
Statistical Analysis of National PR Survey Data (Chapter 6)	This study conducted subsequent statistical analyses (EFA and binary logistic regression) on the survey descriptive data, aiming to explore and identify factors which predict SA use and ST prescription in PR.	Service-related barriers (time, workloads, funding, class size, staff numbers), colleague-related barriers (knowledge/understanding, relevant training, uncertainty of safety and benefits), and practitioner confidence were predictors of SA non-use. Despite analyses conducted to explore predictors of ST prescription, non-significant and inconclusive results were found.	This study provides further insight into factors which could impact the assessment of patient muscle strength in PR, such as service resources and staff training.

7.2 Key Findings and Implications for Discussion

This section will discuss the key findings and implications evidenced across the chapters within this thesis, as well as recommendations for future research and clinical practice. These include PR guidance, feasibility in clinical practice, staff training, and patient understanding, education, and support.

7.2.1 PR Guidance

This thesis demonstrates variance in PR clinical practices, showing the methods used to assess muscle strength and prescribe ST are diverse, with no dominant strategy observed. The survey study in particular demonstrates this across PR services in England. One determinant could be the lack of guidance and informative resources. As discussed in Chapter 2, PR guidelines support and recommend the inclusion of SA and ST (33, 36, 141, 151, 154), however, there is markedly limited information outlining how to successfully achieve this in real world practice. Basic overarching recommendations are provided, but no further guidance is offered within the text or through signposts to other resources. If this information is not available to PR services and practitioners, then it is not surprising that methods and approaches widely vary. This is further evidenced through discrepancies between research, guideline recommendations, and real-world application.

The survey study found different SA methods were used across services in England, with the most utilised being a S2S variation (5repS2S, 30secS2S, 1minS2S) or a bicep 1/m-RM test. A bicep m-RM was also used by the PR service participating in the interview studies. However, it is not clear if a S2S test is actually a measure of muscle strength, but instead may be more appropriate for assessing functional status (288). Moreover, the relevance and suitability of a bicep SA is questioned, due to the emphasis and importance placed on

quadriceps muscle strength in COPD populations. It is also unclear how only individually prescribing load for a bicep curl exercise translates to the prescription of other strengthening exercises. Future research should investigate the validity, effectiveness, and relevance of these methods for assessing muscle strength in PR. Overall, there is a noticeable lack of cohesion between published guidelines, recommendations, and clinical practice.

This is the same for guidance regarding ST prescription in COPD and PR. ST is an effective intervention for improving muscle strength for COPD patients (181, 317-320), and consequently all PR guidelines recommend individually prescribed and progressive ST (36, 141, 151, 154, 394). As reported in the survey study, ST accounts for nearly two thirds (61.5%) of the exercises included. However, prescription practices are diverse, as well as the appropriateness of some methods being questioned. An example is the use of a Borg breathlessness scale to prescribe ST intensity/load, which is a common method reported in the survey study and previous PR audits (164). However, it is not clear exactly how this method effectively prescribes ST intensity, as it is not a prescription strategy used in COPD research (181, 227, 317-320) or one recommended in UK PR guidelines (33, 36, 141, 151, 154). Future investigation is needed to evaluate its effectiveness for the prescription of ST. One suggestion is assessing and comparing changes in muscle strength after a PR programme which prescribes ST using the modified Borg RPE breathlessness scale compared to prescription using the m-RM/1-RM method.

Furthermore, the only comprehensive ST criteria referenced for COPD are the ACSM prescription guidelines for healthy older adults (235). Although they provide some general guidance, they are not COPD-specific. Statements published by respiratory organisations in the US and Canada reference these ACSM guidelines (53, 225, 387), however guidance published

within the UK does not (33, 36, 141, 151, 154). This is evidenced by the survey study (Chapter 5) reporting only moderate practitioner awareness and limited fulfilment of the ACSM guidelines by PR services. Future research should focus on determining a ST prescription protocol for COPD specifically, providing PR services and practitioners with a starting point for flexible and individualised programming. One suggestion is the use of a menu-driven template or tool, which has also been a suggestion in a recent ATS workshop report for identifying relevant needs of patients when choosing the method of PR (142). It would outline ST exercises of varying difficulties and progressions, which also accounts for different equipment types. In

Example ST Exercise Menu (Quadriceps)

7. Leg press (e.g., using weighted resistance machines)
6. Weighted squat (e.g., with dumbbells/weights)
5. Bodyweight squat (if the patient is able, this can be advanced by increasing squat depth)
4. Assisted bodyweight squat (holding onto an object for stabilisation e.g., a table, chair, walking frame)
3. Sit to stand (unassisted)
2. Assisted sit to stand (assisted using arms or a walking frame)
1. Leg extensions with resistance band (if unable to stand)

Prescription protocol

Intensity/load:
- If weights are used, prescribe starting load using 1-RM or m-RM method
- If weights are not used, prescribe intensity and the starting point on the menu by assessing the patient's ability to complete up to 10 repetitions and using the modified Borg RPE breathlessness scale (target of 4-6/10).

Volume: 3 sets of 10 repetitions

Rest periods: rest periods between sets should be individualised (i.e., until patients have regained a comfortable Borg RPE breathlessness score)

Progression: Once 10 repetitions can be completed, add additional resistance/weight (e.g., 0.5-1kg or a higher band resistance), or advance up the menu tool.

Explanation of relevance to patients: This exercise is important because… it works the leg muscles you use to stand up from a chair and sit down. It works a lot of muscles in your lower body, but a main muscle group it works are the muscles at the front on your legs/thighs (i.e., your quadriceps).

, an example of a ST exercise menu for the quadriceps is presented. This would provide PR services and practitioners a standardised starting point for prescribing and programming ST exercises. These exercise menus would consider variance in available equipment and would also allow for the exercises to be individualised and progressive for patients, which is an essential factor outlined by PR guidelines and standards (e.g., BTS and PRSAS) (36, 141, 151, 154, 394).

Example ST Exercise Menu (Quadriceps)

7. Leg press (e.g., using weighted resistance machines)
6. Weighted squat (e.g., with dumbbells/weights)
5. Bodyweight squat (if the patient is able, this can be advanced by increasing squat depth)
4. Assisted bodyweight squat (holding onto an object for stabilisation e.g., a table, chair, walking frame)
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Intensity/load:
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Explanation of relevance to patients: This exercise is important because… it works the leg muscles you use to stand up from a chair and sit down. It works a lot of muscles in your lower body, but a main muscle group it works are the muscles at the front on your legs/thighs (i.e., your quadriceps).

Figure 30. Example ST exercise menu for the quadriceps

Despite limited guidance, ST is still a core component of PR programmes and the prevalence of SA is slowly increasing (164, 166, 385). This thesis shows that PR guidelines need to catchup with current practices, with the development of clearer and more specific

guidance and resources. It highlights the need for PR guidelines to account for variance in service and programme circumstances and consider the feasibility of recommendations in real-world practice. Presently, the BTS (53) and PRSAS (154) guidance is not sufficient enough to meet this need. These guidelines are based on the best available evidence, which is important to ensure safe and effective practice, and is considered crucial to the integrity of PR programmes (142). However, the process of appraising and scoring evidence to identify the 'gold standard' or 'best practice' could be counterproductive and unrealistic for many services - as what is considered 'gold standard' and 'best practice' in one PR setting, may not be feasible or attainable in another (e.g., a high vs low resource PR service). An element of standardisation in PR is required to ensure high quality care, however dictating the level of quality based on one standardised method or template is not suitable for the variation observed across services. Instead, guidance and recommendations should consider the context in which they are being applied and acknowledge the variance in PR services, reporting best practice for a variety of settings (e.g., availability of different equipment). If services have the ability and capacity to meet the 'gold standards' then they should aim to do so, however for many services this may be unattainable and could be setting them up for failure. Guidance for practice cannot truly follow a 'one size fits all' template, due to service and patient differences.

Overall, evidence should inform practice, but there should also be a cyclical relationship whereby practice informs research, helping to evolve interventions and guidance to reflect the reality and feasibility of ST and SA in a PR context. Research provides direction and evidence for practice, but if recommendations are based on findings and methods which are unsuitable for clinical practice then it questions how useful the evidence is if it cannot be applied. PR is already a successful evidence-based intervention but there is room for improvement and refinement (553), particularly regarding ST and SA. PR would benefit from

clearer guidance for ST and SA, if not, practices and methods will continue to vary, with questionable relevance and effectiveness. Guidelines should outline recommendations for SA and ST but follow this up with specific details and examples of how this can be successfully achieved and fulfilled. Future research should still focus on determining optimal methods and strategies, but focus should not be placed solely on the gold-standards, but also on favourable strategies which complement the varying settings, resources, and equipment used. It is unlikely that all PR services can meet optimal or 'gold-standard' recommendations, therefore best practice advice for differing circumstances should also be provided.

7.2.2 Feasibility in Clinical Practice

Another explanation for the variance in SA use and ST prescription is feasibility in PR clinical practice, specifically the influence of service, organisational, and environmental factors. Previous literature has primarily investigated and discussed SA methods and ST interventions in terms of effectiveness, validity, and reliability (181, 200, 227, 228, 230-232, 317, 320, 554), however more attention is needed regarding feasibility in real-world practice. This thesis provides a clearer understanding of SA and ST use in PR, in particular the practical challenges and barriers faced, which can negatively impact application. These include service-related factors, such as limited time, high staff workloads and demands, and limited equipment access and availability. Barriers like these are commonly reported in COPD and PR research (395, 396, 398, 403, 405, 454-456).

A key determinant of feasibility is having the capacity and the necessary resources. The presence of service-related barriers can make any change to clinical practice challenging, especially the implementation of another component. One simple solution is to allow for more time, but this would likely rely on additional funding – which might not be possible for many

services. Instead, ways to efficiently use and allocate time is needed. PR programmes are comprehensive and include many components that are each considered important and essential in their own right (33, 141). Therefore, it is vital to consider how SA and ST fits into the existing infrastructure of PR. It is important to consider how long it takes to conduct a SA, as some are more time-consuming than others (230). A SA should be time-sensitive and easy to use, as well as compatible with other assessments conducted (e.g., walking test). Similarly, the prescription and delivery of ST must be realistic and within the timeframes of PR programmes. Time must be shared alongside AT within each exercise session, with prescription protocols producing meaningful results across the programme duration (e.g. 7-weeks) (2, 33, 164). Importantly, the need to fulfil PR guideline recommendations should not compromise the quality of supervision, support, and assessment (142). This could be one challenge faced by PR services attempting to comply with PRSAS standards and other PR guidelines. If standardised recommendations are provided with no flexibility or consideration for different service context and circumstances, then many may be compromising on the quality of ST and SA to meet said standards and attain the accreditation label of a high-quality service. This is evidenced to some degree in the qualitative insights obtained from the survey data, with one participant divulging that they use a 1-RM SA despite having insufficent equipment to appropriately assess and prescribe (see page 283). This could be cause for concern, as services may use the PRSAS standards as a simple tick box exercise in order to attain accreditation and categorisation as a service of quality. When in reality, the true feasibility of the requirements being asked of them are unattainable and as such ineffective and low-quality methods may be used in an attempt to meet them.

Another factor influencing the feasibility of SA and ST is equipment access and availability. A possible determinant is the venue in which PR programmes are located. As

shown in this thesis and previous literature (164), PR can take place in a variety of settings, meaning equipment is dependent on site location. However, this results in differences and inconsistencies in the types of equipment used across services. A variety of equipment is used in PR, including free-weight dumbbells, resistance bands, and weighted machines. However, when access to ST equipment is reported, it does not necessarily mean adequate quality and quantity. As shown in the survey study, nearly all practitioners reported the use of dumbbells, but a perceived barrier was limited and inadequate equipment. Qualitative insights from the survey provided some context to this discrepancy, stating the barrier is not necessarily the complete absence of equipment, but rather not having enough equipment across a range of weights and resistances. Consequently, this restricts the prescription and progression of ST, and how muscle strength is assessed. This could explain why Borg breathlessness scales, S2S tests, and 1-RM and m-RM bicep tests are predominately used in practice. They are easier and more feasible to implement and use, as a S2S test requires minimal equipment and time, and a bicep 1/m-RM only requires lighter loads. Unfortunately, the survey study did not collect data on the range and quantity of weight equipment available within services. Considering equipment was identified as a barrier, the collection of these specific details would be useful in the future, as well as further investigation into how equipment impacts SA and ST use.

This thesis highlights that consideration is needed for the feasibility of SA and ST in PR, and how it fits into its existing structure and the resources available. It is not just about *if* SA and ST are included, but what, how, and why it is done. Specifically, service-related factors (time, workloads, and equipment) are identified as barriers, which are key determinants of feasibility. The choice and implementation of SA, and the prescription of ST, need to account for these challenges in clinical practice. It is vital that future research investigates best practice within the parameters of real-world clinical settings and the resources they have available to

them, for example the conduction of feasibilities trials to test different SA methods, exploration of new techniques to assess strength with minimal equipment (e.g., using resistance bands), and the development of ST prescription protocols using varying or limited resources. In particular, PR guidance should acknowledge the variability in settings, resources, and circumstances of services, for example providing guidance and recommendations for the prescription of ST using different equipment types e.g., weighted machines, free weights, resistance bands, and bodyweight (see **Figure 30**). If feasibility and service variation is not considered, then many services may struggle to meet recommendations and standards which are beyond their capability.

7.2.3 Staff Training

A key finding within this thesis is the importance of appropriate staff training for the assessment of patient muscle strength and prescription and delivery of ST. It is strongly emphasised by practitioners and patients that staff have an important and influential supportive role during PR. Throughout, staff provide physical, psychological, and educational support, all of which are important when prescribing and delivering exercise, particularly ST, and when conducting assessments and tests, such as a SA. Therefore, practitioners should have the relevant training and necessary skills to successfully support patients. However, the survey study found relevant training is not being provided. A third of practitioners reported they do not have training relevant to SA, and nearly half reported a lack of training for the delivery of ST. ST is a core component of PR, and as such the BTS guidelines and quality standards for PR in the UK state services should "*evidence that professionals providing pulmonary rehabilitation are adequately trained/experienced in prescribing and supervising exercise training*" (141) (pg. 14). Comparable standards are also reported in ATS guidelines stating, "*relevant expertise is required to deliver resistance training*" (53) (pg. 13). Evidently, this

quality standard is not being met. Practitioners agreed that training would be beneficial for themselves and their colleagues to support them in assessing patient muscle strength and delivering ST in PR, with a lack of training identified as a potential barrier.

Findings also revealed that, according to practitioners, training is predominately 'learning on the job'. This ultimately means PR services are responsible for ensuring staff are appropriately trained in SA and ST, as they do not always have related training or education prior to working in PR. Regardless of which training method is utilised, it needs to be the 'right' training, which is high quality and relevant to the patient population and clinical setting. Practitioners should have the understanding and skills to program, prescribe, and deliver ST, and if a SA is implemented and used, practitioners should also have the understanding and skills to conduct this assessment correctly. This thesis strongly highlights that a key area for improvement is the collective training of staff. If SA and ST are included in the PR programme, and is part of staff job roles, practitioners should have the knowledge, understanding, and skills to conduct it correctly and effectively, as well as having the confidence in themselves and their colleagues. Practitioners have an essential supportive role for exercise and education in PR, therefore relevant training will also positively impact and benefit patients through education, guidance, and appropriate messaging throughout PR. This could subsequently help prepare patients to self-manage their condition and continue exercise/ST after completion.

In America, the AACVPR has a certificate scheme for the PR professional (142, 555), which acknowledges the specialist skills required to deliver effective and patient centred PR. This certification includes a requirement to complete an educational programme, which currently comprises of 12 modules describing the fundamentals of PR. Within the UK, a scheme like this, or mandatory basic training, does not currently exist and is not part of the

PRSAS accreditation. Literature states that a future focus of PR should be the training needs of practitioners (142, 553), and as this thesis shows this is particularly true for ST and SA. Therefore, consideration of a certificate scheme or mandatory PR training, which includes a module for ST and SA, may be a reasonable suggestion.

In terms of credible PR training offered in the UK, the BTS offers two short 2-day virtual courses related to PR (556): 1) BTS fundamentals of pulmonary rehabilitation (557) and 2) BTS advanced course in pulmonary rehabilitation (558) (see Appendix AP). The 'fundamentals' course is aimed at a multi-disciplinary audience involved in the delivery and management of PR, as well as an introduction for new members of staff. The course is designed in line with the ERS/ATS statements (53) and the PRSAS standards of practice (154). The learning objectives focus on the understanding of PR evidence and the basic principles of exercise training, the evaluation of functional status and prescription of appropriate exercise training, and analysis of service outcomes (557). However, content related to ST and SA appears minimal. The 2024 session programme (see Appendix AQ) outlined a 30-minute allocation for 'the fundamental of resistance exercise prescription', which seems an insufficient amount of time, especially when compared to the longer 50 minutes allocation for 'the fundamentals of aerobic exercise prescription'. The prescription and delivery of ST involves a multitude of variables and considerations (235), meaning the level of detail necessary to cover such information is not possible within this timeframe. Furthermore, any indication that this course covers the use of SA is absent. As appropriately titled, this course covers the fundamentals of PR and likely does not have the scope to provide a high-level of detail for each specific component of a PR programme, such as ST and SA. The content is introductory and is aimed at multiple disciplines, indicating that information is targeted at a basic level to accommodate a variety of HCPs. Additionally, the 'advanced' course offered, does not appear

to address ST or SA either. The learning objectives of the 2023 programme (see Appendix AP) focus on the understanding of alternative PR models, strategies to augment the benefits of PR (e.g., oxygen therapy, balance retraining, and intermittent exercise), post-COVID-19 assessment and rehabilitation, and how to effectively deliver formal education session remotely. It is highly likely that the content and focus is adjusted annually based on current relevance to research and practice.

These BTS courses provide basic training for PR practitioners, and are delivered online, with a combination of pre-course recorded content and live presentations. This is likely appealing to many services providers as a starting point and a formal opportunity for staff training, as well as the benefit to time and travel expenses. However, these courses only run once per year and at a significant cost (£110 - £130 per person) (557, 558), meaning accessibility and availability may be a limiting factor. Consequently, services may appoint one member of staff to complete the training, relying on them to train and inform other colleagues in the team. This could call into question the quality and accuracy of the relayed information. Overall, these courses cover the general components of PR, but training courses and content related specifically to ST and SA are absent. ST and SA are important components of a PR programme and as such specific and relevant training should be easily accessible and available to staff. Despite these existing courses being available, this thesis reports practitioners are still lacking training for ST and SA in PR. This highlights a need for training which focuses on these specific PR components, with consideration for both the type and level of information provided, and how it is delivered and accessed. Future research should focus on the development and evaluation of ST and SA training resources and interventions for PR services and staff.

One suggestion is the development of an e-learning training resource, which is high-quality, relevant, and accessible. This would give PR practitioners a dedicated space to increase their knowledge, understanding, and competence of SA and ST, both generally and within the context of PR. The NHS provides an online platform called e-Learning for Healthcare (559) (see: https://www.e-lfh.org.uk/), which delivers a wide range of programmes to support the health and care workforce. Presently, there is not yet learning content related to PR or the prescription and delivery of ST in older adults or patient populations (e.g., COPD). This would be a low-cost opportunity to develop initial content that is easily accessible to PR staff across England.

In terms of the content, it should be comprehensive and detailed, providing varying levels of depth depending on an individual's knowledge and requirements. The basic overarching fundamentals are essential (e.g., what is ST? what is SA?), but further information should also be provided (e.g., how to prescribe and programme ST? how to assess strength?). Additionally, it should consider patient variations and limitations (e.g., co-morbidities and understanding), varying service circumstances (e.g., available equipment), as well as provide recommendations and advice for application in PR clinical practice. The training and resource content should be supported by current evidence (e.g., BTS guidelines and PRSAS standards) and research, with information updated as new evidence and recommendations emerge. For the delivery, it should be available and accessible to all PR services and practitioners at minimal cost. Using an online or e-learning platform would make this achievable and would enable the material to be accessed at any time (e.g., as a knowledge refresher or for use in practice). Further resource development may include the introduction of additional resources (e.g., ST and SA example videos, an integrated 1-RM calculator etc.) and opportunities to test an

individual's knowledge (i.e., quizzes and certificates of completion). If needed and if there is a demand, this online training resource could be supplemented with live training presentations and practical workshops.

Actionable next steps are presented in ***Figure 31***, which displays an example protocol for a small, contained project that focuses on the initial development and pilot of this online educational and training resource. Funding will be required for the conduction of this study, and for the creation, development, and setup of the online resource. The involvement of field experts would also be required to ensure accurate and appropriate information, and for the development and delivery of this resource on the chosen online platform.

Staff Training Resource Example Protocol

AIM: To develop, evaluate, and refine an SA and ST online training resource for PR practitioners in England

STAGE 1: DEVELOP

Initial creation and development of the online training resource and its content.

- Consult with and gain input from industry and field experts
- Draw on available, relevant, and current evidence (e.g., guidelines and research)
- Consider feasibility and application in clinical practice (e.g., recommendations, suggestions, and advice)
- Consider variations in PR service circumstances
- Present information for varying levels of knowledge and experience (e.g., fundamentals to advanced)
- Provide opportunities for self-assessment (e.g., quizzes and tests of user knowledge)

STAGE 2: PILOT AND EVALUATE

Pilot and evaluate the online training resource with participating PR services and PR practitioners in England

- Data collected using pre-post questionnaires (before and after completion/use of online training resource)
- Possible outcomes to assess:
  - Knowledge/understanding
  - Competence
  - Confidence
  - Satisfaction
  - Acceptability
  - Helpfulness/usefulness
  - Experiences using the training resource

STAGE 3: REFINE

Amend and refine the training resource in accordance with the pilot and evaluation findings.

Figure 31. An example protocol for the development of an online staff training resource

7.2.4 Patient Understanding, Education, and Support

This thesis highlights the importance of patients having the necessary understanding about SA and ST, with a particular emphasis on education and support as a means of facilitation. Findings demonstrate that patients can have misunderstandings and misconceptions, for example a lack of comprehension about why they need to build muscle strength when their lungs are the main problem, the association that ST is gym-based and primarily performed by

younger fitter cohorts, and the presence of gender differences and stereotypes (i.e. ST is for men). Similar findings have been reported in previous studies with COPD patients and older adults demonstrating misconceptions and limited awareness of benefits (42, 49), inaccurate knowledge (69), negative beliefs (44), and gender differences (216, 397, 445). Such findings could evidence generational and cultural differences, potentially due to patients being of an older demographic. However, limited education and experience could also contribute to the formation and preservation of misconceptions and misunderstandings, for example a SA could be perceived as meaningless without the accompaniment of appropriate explanation. This questions if participant reservations about SA in PR is a result of limited understanding, as relevance may not be directly obvious.

When sufficient explanation and information is provided it can lead to increased patient engagement (404) and motivation to heed advice, undertake tests, and be assessed (400, 492). Therefore, if a SA is used or implemented into clinical practice it is important to explain why it is being used and how it benefits both the patient and the service. This could be included in the pre-assessment session before the SA is conducted, making sure explanations are relevant and easy to understand. It is also important to consider and address this when delivering ST to patients. Conscious effort should be made to dispel myths and correct misconceptions, as well as promote ST and the benefits it can offer to all adults regardless of age, gender, and health status. Education in PR is important for ensuring patients have realistic attitudes, perspectives, and perceptions of exercise, ST, and SA. This can be achieved by ensuring relevant educational content and positive messaging throughout, whether this be via informative handouts and resources (e.g. from the NHS (560) and Chartered Society of Physiotherapy (561)), formal educational sessions, or even the smaller nuanced moments of staff support. These findings

emphasise the importance of patient education and understanding, not just for the acquisition of knowledge, but also the impact it has on attitudes, perceptions, and behaviour.

However, it is not just about a lack of understanding, but also about what is important to patients, and using this to inform exercise, education, and support. A key finding in this thesis is the importance of daily function and activity for patients, particularly the role of muscle strength and the positive impact of ST on improvement. Practitioners recognise and observe this, and patients often describe the performance of daily activities as an indicator of strength improvement (215, 219-221, 461, 465, 475). Such importance may be placed on daily function because the inability to perform daily activities can result in the loss of independence and increased need for care (490). With this in mind, ST would ideally be programmed and prescribed to reflect this. When ST is delivered and explained during PR, benefits and relevance to daily function and activities should be drawn upon, with emphasis on meaningful and functional strength. One example is explaining to patients how a squat or a bicep curl exercise translates to daily movements and why it is beneficial, for instance it will help standing up from a chair or lifting heavy shopping. This has been included in the example of the ST exercise menu presented in **Figure 30**. Consequently, this could lead to increased patient understanding and awareness of benefits, helping to facilitate ST and exercise adherence during and after PR (215, 221). If an individual believes an action or behaviour will decrease the seriousness of a health condition they are more likely to engage or 'buy into it' – in this instance ST and exercise (491).

This thesis also highlights that the support received from staff and peers is an integral component of PR programmes. Staff have an important and influential role in providing physical, psychological, and educational support. Practitioners are praised for this, particularly

their supervision, assistance, and guidance during exercise sessions (215, 216, 218-221, 397, 461, 475). The presence of HCPs instils a sense of safety, reassurance, and comfort (218, 461), and is reported to be a key facilitator for exercise performance, attendance, and adherence (215, 221). Additionally, due to the group format, patients are given the opportunity to connect with peers, providing and receiving social support that contributes positively to their PR experience and improved psychological wellbeing. These social benefits are reported to motivate, encourage, and sustain regular programme attendance (215-217) (220, 221) (461). As staff and peer support is shown to be an important facilitator for exercise during PR and exercise programmes, it is not surprising that many patients experience difficulty continuing exercise once this structured and supportive environment stops (218, 220, 221, 397, 461, 494, 495, 497). This is evidenced in this thesis and previous studies (215, 218, 505) with patients particularly struggling with the transition from group to independent exercise.

Interventions to overcome this have been conducted by developing supervised exercise programmes after PR (215, 217, 497, 506), however benefits are short lived (213). It can be argued that offering and providing exercise maintenance programmes is unsustainable and only a partial solution, as they are primarily reliant and dependent on external support from others. PR is a short-term healthcare intervention, which aims to *"promote the long-term adherence to health-enhancing behaviours*" (53) (p. e14), which includes self-management and exercise adherence. Therefore, it is important to acknowledge and utilise the supportive role of HCPs and staff to facilitate this - but not to the extent of dependency. A related term is 'collaborative self-management', which aims to promote self-efficacy through increased patient knowledge and skills, while participating with a HCP to optimally manage their condition (53, 562). This further highlights the importance of patient education related to ST and exercise for increasing knowledge and understanding, as well as patient confidence, self-efficacy, and autonomous

ability. Patients should leave PR equipped with the necessary tools to successfully continue and adhere to exercise and ST long-term – without having to rely solely on the support, supervision, and presence of others. Therefore, appropriate strategies during and after a PR programme should be implemented and utilised with this aim in mind, if not, a continued cycle of deterioration and PR referral may ensue. Future research should develop and evaluate approaches which focus on independent exercise outside of PR. One example could be the use of behaviour change strategies, such as goal setting, action planning (implementation intentions), and self-monitoring. This could be introduced at the start of a PR programme and conducted throughout its duration, coupled with staff coaching and support where they can discuss barriers and facilitators, and troubleshoot ideas. Collaborative self-management strategies, such as action plans, are shown to be beneficial for the prevention, early recognition, and treatment of COPD exacerbations, as well as reported to reduce healthcare use, recovery time, and reduce costs (53).

7.3 Contributions to Knowledge

To the best of the researcher's knowledge, the review of PR guidelines and surveys, and all three studies in this thesis have not been conducted prior. This thesis contributes new knowledge and understanding about SA and ST in PR, specifically from the viewpoint of practitioners and patients. Both qualitative studies were the first to explore practitioner and patient perspectives and experiences of SA and ST. Moreover, the survey study provided a level of detail about the assessment of muscle strength and prescription and delivery of ST that has not been collected or reported before. This thesis explored and identified factors and areas of influence, including limited PR guidance, service-related barriers (e.g. time and equipment), a need for relevant staff training, and limited patient understanding. The findings will help the

development of future research studies and interventions for SA and ST in COPD and PR, as well as highlights considerations for improvements in clinical practice.

These findings could help PR services reflect on current practices, as well as services looking to introduce a SA in the future. Other rehabilitation programmes (e.g., cardiac and oncology rehabilitation) and healthcare areas that assess patient muscle strength, or those that might benefit from it, may find these findings relevant and insightful, allowing for comparison and evaluation of their own clinical practices.

7.4 Conclusion

The work completed in this thesis has explored SA and ST in PR, and has identified areas of influence that can be targeted to aid implementation, delivery, and use in clinical practice. Importantly, this research has involved essential stakeholders within PR, drawing on the perspectives and experiences of practitioners and patients. The assessment of patient muscle strength and the inclusion of ST is recommended in PR guidelines, but guidance is vague and inconsistent. This thesis provides a more detailed picture of use and shows many services report fulfilling this criteria, however provision and practices vary. No clear or consistent approach is observed, with the suitability of some assessment and prescription methods being uncertain. If SA and ST are recommended, then sufficient guidance for best practice is needed to direct PR services. Settings, resources, and equipment can differ, emphasising the need for PR guidance and recommendations to acknowledge and consider this, as well as future research to investigate effective strategies realistic to the parameters and variance of PR clinical practice. Additional considerations for implementation and use include the impact on staff, patients, and current practices, ensuring staff have relevant training, and ensuring appropriate education and messaging is provided throughout PR for patients. Overall, this thesis highlights that successful

implementation and use of SA and ST in PR clinical practice is multifaceted; influenced and dependent on factors related to services, practitioners, and patients. PR is a successful and effective treatment option, but this thesis highlights areas to better it even further. This exploration has increased understanding, which will be useful to relevant stakeholders, and provides a springboard for future research and developments in clinical practice.

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Appendix

Appendix A

Timeline of PhD and Covid-19 Pandemic Restrictions

Date	Action/Information
21st Oct 2019	PhD started
28th Oct 2019 to 15th Nov 2019	Introductions and observations of PR and PROVIDE CIC. PROVIDE had three PR sites (Maldon, Braintree, and Chelmsford). I visited and observed each of these. I also attended a few home visits and COPD clinics that the service carried out. These provided an introduction and basic understanding of PR and how it was organised and delivered within this service. PhD planning occurred throughout this time and afterwards.
13th Feb 2020	NHS/HRA ethics was submitted for the face-to-face practitioner interviews and patient interviews
23rd March 2020	1st UK national lockdown University of Essex closed and entered 'advanced protection'. Advanced protection = where essential services only are delivered on campus, and research is predominantly delivered and engaged with remotely.
1st April 2020	NHS/HRA ethical approval obtained, however an amendment had to be submitted altering the recruitment and data collection methods to comply with government restrictions.
14th May 2020	NHS/HRA amendment submitted (with Covid-19 changes)
28th May 2020	NHS/HRA amendment approved (with Covid-19 changes)
4th June 2020	University of Essex ethics subcommittee approval obtained
16th June 2020	PROVIDE R&D clinical excellence group approval obtained
23rd June 2020 to 10th August 2020	Practitioner interview and patient interview recruitment and data collection carried out
August – Feb 2020	• Interview transcription • Practitioner interview data analysis • Preparing for PhD confirmation board • Literature search and review • Planning and modifying PhD project plan
5th Nov 2020	2nd UK national lockdown
4th Jan 2021	3rd UK national lockdown
Feb/March 2021	The decision to change the PhD project was made, as the University of Essex research labs were still closed, and local PR services were still not running standard programmes. It was not known when the research labs would re-open or when face to face PR would start again, as restrictions were still in place. The original PhD plan (along with modifications) were abandoned, and a new plan was constructed (online survey), which still linked and utilised the two qualitative interview studies already carried out.

April to August 2021	• Planning and designing the survey • Preliminary contact made, and scoping emails, sent to NHS Trusts/non-NHS organisations with PR services (May – July 2021) • Planning of appropriate ethical protocol for this study. It was unclear how ethical approval should be submitted and obtained for this study. Multiple meetings were had with the REO at the University of Essex, and direct correspondence was needed with the HRA, to determine the most suitable course of action.
15th April 2021	University of Essex moved from 'advanced protection' to 'enhanced protection'. Enhanced protection = with many functions delivered remotely, and other, limited services available safely on campus. Research is delivered and engaged with remotely where possible, and only essential lab work on site following approved risk assessments.
19th July 2021	England removed the vast majority of Covid-19 restrictions, including social distancing
27th July 2021	University of Essex moved from 'enhanced protection' to 'sustained protection' Sustained protection = providing measures that enable more elements of on-campus activity to resume than within Enhanced Protection and envisaged to be required over an extended time period. Research is delivered and engaged with remotely where appropriate, and lab work on site following approved risk assessments.
7th Sept 2021	HRA ethics submitted for national survey study
7th Oct 2021	HRA ethical approval obtained for national survey study
16th Oct 2021	University of Essex ethics subcommittee approval obtained
25th Oct 2021 to 6th May 2022	• Individual research site R&D approval obtained • Subsequent ethical amendments submitted to include more participating research sites (24th Nov 2021, 16th Dec 2021, 21st Jan 2022, 15th Feb 2022, 9th Mar 2022) • Participant recruitment • Data collection
May 2022 to Oct 2022	• Patient interview analysis • Survey data analysis
Oct 2022 – Oct 2023	Studies/chapters and thesis write up

Appendix B

Literature review search terms and keywords (EBSCO database)

EBSCOhost

Friday, May 05, 2023 8:27:06 AM

#	Query	Limiters/Expanders	Last Run Via	Results
S1	(“chronic obstructive pulmonary disease” OR COPD or emphysema* OR “chronic* bronchiti*” OR “obstructive lung disease*” OR “chronic obstructive air* disease*” OR COAD) OR (obstruct* AND (pulmonary OR lung* OR airway* OR airflow* OR respirat* OR bronch*))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - APA PsycArticles;APA PsycInfo;CINAHL Ultimate;E-Journals;MEDLINE Ultimate;SPORTDiscus with Full Text	395,889
S2	“pulmonary rehab*” OR PR OR “respirat* rehab*” OR “respirat* therapy” OR “breathlessness rehab*” OR “COPD rehab*” OR “exercise therapy” OR “exercise rehab*”	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - APA PsycArticles;APA PsycInfo;CINAHL Ultimate;E-Journals;MEDLINE Ultimate;SPORTDiscus with Full Text	146,486
	OR limb* OR extremit* OR upper OR lower) N3 strength*) OR (“musc* strength” OR “musc* weak*” OR sarcopenia OR “musc* function*” OR “musc* disfunction*” OR “musc* force*”)		PsycInfo;CINAHL Ultimate;E-Journals;MEDLINE Ultimate;SPORTDiscus with Full Text	
S5	S1 AND S2 AND (S3 OR S4)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - APA PsycArticles;APA PsycInfo;CINAHL Ultimate;E-Journals;MEDLINE Ultimate;SPORTDiscus with Full Text	616

Appendix C

International guidelines and standards for strength assessment

	NCPR Ireland guidance for setting up PR (2020) (373)	ATS/ERS statement (2013): key concepts and advances in PR (53)	ACCP/AACVPR evidence based clinical guidelines for PR (2007) (374)	ACCP/AACVPR guidelines for PR programmes (2020, 5th ed) (225)	ACSM guidelines for exercise testing and prescription (2014, 9th ed.) (235) NB: Not specific to PR	ACSM guidelines for exercise testing and prescription (2018, 10th ed.) (375) NB: Not specific to PR and limited access	CTS clinical practice guidelines (148)	CTS quality indicators for PR programmes in Canada (147)	Australian and New Zealand PR guidelines (149)
Inclusion of SA in PR	Yes. "The following need to be completed as a minimum… and where possible a measure of quadriceps muscle strength is highly recommended. After this other outcomes may be chosen for individual patient needs and specific research purposes."	Yes. Mentions use of SA for the purpose of prescribing exercise intensity for ST.	No.	Yes. "Resistance exercise testing and training serve many important purposes in today's PR program, including: for documentation of pre resistive and post resistive testing results for documentation of patient improvements in muscular strength and endurance for outcomes assessment."	Yes. Mentions use of a SA (1-RM%) for the purpose of prescribing ST intensity. ST prescription of healthy adults/older adults recommended for COPD.	Yes. Mentions use of a SA (1-RM%) for prescribing ST intensity.	No.	Yes. **"QI6:** A direct or indirect 1-RM test is conducted to assess muscle function and to develop the muscle strengthening exercise prescription." **"QI13:** At a minimum, the following health outcomes are measured before and after the program: Aerobic exercise endurance, muscle function, health status."	No.
SA as outcome measure	Yes.	No.	No.	Yes.	No.	No.	No.	Yes.	No.
SA for exercise prescription	Yes.	Yes.	No.	Yes.	Yes.	Yes.	No.	Yes.	No.

Type of SA	Yes. Indirect/ predicted 1-RM for exercise prescription.	Yes. 1-RM and m-RM for prescription of exercise intensity.	No.	Yes. 1-RM and m-RM (i.e.3-RM to 8-RM) for determining initial workload, and other muscular outcome tests (e.g. TUG, 30secS2S, 5S2S, handgrip dynamometer test).	Yes. 1-RM% for prescription of ST intensity. A conservative approach to assessing maximal muscle strength should be considered in patients at high risk for or with, pulmonary health conditions. For these groups, assessment of 10- to 15-RM that approximates training recommendations may be prudent.	Yes. Mentions 1-RM% for prescribing ST intensity. Also, mentions other physical function tests to assess upper and lower muscular strength and endurance in individuals with chronic lung disease e.g. TUG, 30secS2S, 5S2S, 30 sec arm curl test, 6min pegboard test, handgrip HHD.	No.	Yes. Indirect 1-RM (i.e. m-RM).	No.
SA instructions or signpost	Yes. Many patients will not be able to perform a1-RM test, therefore, this will be calculated using the Oddvar Holten Diagram and formula which is used with pregnant women and athletes alike (563).	Yes. Initial loads equivalent to either 60 to 70% 1-RM or one that evokes fatigue after 8-12 repetitions. References ACSM (376) for ST prescription in healthy adults.	No.	Yes. All SA are referenced in text. A brief explanation is given for 1-RM and m-RM in text.	Yes. A description of the basic steps of a 1-RM/m-RM test is provided within the book (page 96), but not referenced or signposted within the older adult or COPD section for ST prescription.	Limited detail: 1-RM test is not reference within COPD section. It may be found within other sections, but there was limited access. All other physical tests are referenced in text.	No.	Yes. References ACSM guidance for 1-RM testing (ACSM, 2014, 9th ed.), and equations to predict 1-RM% (564).	No.
Target muscle/body area	Yes. "Where possible a measure of quadriceps muscle strength is highly recommended." (outcome measure).	No.	No.	No.	No.	No.	No.	No.	No.
	Does not discuss SA for outcome				Is not specific to PR. Is difficult to navigate to	It is not specific to PR. I had		Prediction equations are in knee joint	

	measure of quad strength.				get the correct information.	limited access to book.		osteoarthritis, not COPD	
Colour code: green = provides sufficient information, yellow = limited detail provided, red = not mentioned/addressed									

Appendix D

International guidelines and standards for strength training

	NCPR Ireland guidance for setting up PR (2020) (373)	ATS/ERS statement (2013): key concepts and advances in PR (53)	ACCP/AACVPR evidence based clinical guidelines for PR (2007) (374)	ACCP/AACVPR guidelines for PR programmes (2020, 5th ed) (225)	ACSM guidelines for exercise testing and prescription (2014, 9th ed.) (235)	ACSM guidelines for exercise testing and prescription (2018, 10th ed.) (375)	CTS clinical practice guidelines (148)	CTS quality indicators for PR programmes in Canada (147)	Australian and New Zealand PR guidelines (149)
Inclusion of ST	Yes. Each session should contain components, which includes strength training. Programmes should be individualised... This will be achieved through following the training guidelines for strength training (565).	Yes. States a combination of aerobic and ST improves outcomes. Describes and references ST prescription for healthy adults by ACSM (376).	Yes. "Recommendation: The addition of a strength-training component to a program of PR increases muscle strength and muscle mass."	Yes. "Exercise training should encompass upper and lower extremity strength training." Describes and references ACSM (375) (FITT (Frequency, Intensity, Time, and Type) resistive exercise recommendations for COPD and asthma.	Yes. Resistance training should be encouraged for individuals with COPD. The Ex Rx (exercise prescription) for resistance training with pulmonary patients should follow the same FITT principle for older adults.	Yes. Resistance training is the most potent intervention to address the muscle dysfunction seen in COPD and should be an integral part of the exercise prescription.	Yes. "Aerobic training and resistance training is more effective than aerobic training alone in improving endurance and functional ability. While aerobic training is the foundation of PR, it is recommended that both aerobic training and resistance training be prescribed to COPD patients."	Yes. "QI9: Strengthening training is prescribed"	No.
Frequency	Yes. In accordance with PR frequency of a minimum of 2 supervised training sessions per week.	Yes. 2-3 days per week (376)	No.	Yes. 2-3 days a week (375).	Yes. ≥2 days per week.	Yes. At least 2 days a week performed on non-consecutive days	No.	Yes. 2-3 times per week (235).	No.
Intensity/Load	Yes. Many patients will not be able to perform a 1-RM, therefore, this will be calculated using the Oddvar Holten Diagram and formula which is used with pregnant women and athletes alike (563).	Yes. Initial loads equivalent to either 60 to 70% 1-RM or one that evokes fatigue after 8-12 repetitions (376).	No.	Yes. strength resistance exercises (60-70% 1RM for beginners, ≥80% 1-RM for experienced weight trainers); endurance resistance exercise (< 50% 1RM), or assessment of dyspnea or RPE	Yes. Moderate intensity (i.e., 60%–70% 1-RM). Light intensity (i.e., 40%–50% 1-RM) for older adults beginning a resistance training program. When 1-RM is not measured, intensity can be prescribed	Yes. For strength: 60-70% of 1RM for beginners; ≥80% of 1-RM for experienced weight trainers. For endurance: <50% of 1RM. As an alternative to using peak work rate and O2peak to determine	No.	Yes. 60–80% of the 1-RM obtained from the strength test (direct or indirect 1-RM (235)). The intensity threshold for strength training is 60% of maximum, quantified in terms of the 1-RM	No.

				using validated scale may be considered (375).	between moderate (5–6) and vigorous (7–8) intensity on a scale of 0–10.	exercise intensity, dyspnea ratings between 3-6 on the Borg RPE scale 0-10 may be used.		obtained from a strength test.	
Type/Mode (exercises, targeted muscles, equipment)	Limited detail: Minimum equipment required: weights and resistance equipment that can be progressed.	Limited detail: Resistance (or strength) training is an exercise modality in which local muscle groups are trained by repetitive lifting of relatively heavy loads.	No.	Yes. ACSM (2018, 10th ed.) states type of exercise as weight machines, free weights, or body weight exercises. Also mentions bands, hand/ankle weights, dumbbells, and bodyweight. Gives 3 examples and instructions of lower body exercises: sit to stand, squat/knee bend, and leg extension	Limited detail: Progressive weight-training program or weight-bearing calisthenics, stair climbing, and other strengthening activities that use the major muscle groups. 8–10 exercises involving the major muscle groups.	Limited detail: weight machines, free weights, or body weight exercises.	No.	Yes. In general, the major muscles of locomotion (quadriceps, gluteal muscles, gastrocnemius), the major muscles of arm function (biceps, triceps, deltoids, trapezius, latissimus dorsi) and abdominal muscles are targeted. **"QI1**: The PR program has the following EXERCISE resources for program delivery: Strength training equipment (e.g. free weights, machines, elastic bands, elastic tubing)"	No.
Volume	No.	Yes. 1-3 sets of 8-12 reps (376).	No.	Yes. strength resistance exercises (2-4 sets of 8-12 repetitions); endurance resistance exercises (≤2 sets of 15-20 repetitions) (375).	Yes. ≥1 set of 10–15 repetitions each.	Yes. For strength: 2-4 sets of 8-12 repetitions; for endurance: ≤2 sets of 15-20 reps.	No.	Yes. Typically 1–3 sets of 8–12 reps is used but the ACSM provides guidance on other prescription practices (235).	No.
Rest Periods	No.	No.	No.	No.	No.	No.	No.	No.	No.
Progression	Yes. The exercise dosage should increase over time	Yes. Progressive overload, where the exercise	No.	Yes. The most important rate of progression is	Limited detail. Notes a progressive	No. In the COPD specific exercise	No.	Yes. "QI10: Exercise intensity and volume is	No.

	(the overload principle) by increasing resistance, reps per set, number of sets per exercise and/or rest period between sets or exercises (FITT principle - frequency, intensity, time, and type).	dosage must increase over time. This increase occurs when an individual can perform the current workload for 1-2 reps over the desired number of 6-12, on 2 consecutive training sessions (ACSM, 2009). Overload can be achieved by increasing resistance or weight, increasing reps per set, increasing the number of sets per exercise, and/or decreasing the rest period between sets or exercises (376).		utilization of the overload principle. This can be achieved by increasing the intensity (weight or resistance), total repetitions per set, repetition speed or rhythm, number of sets of each exercise, and/or decreasing the rest period between sets or exercises.	exercise programme. Details of progressive overload are addressed in another section of the book but not in the ST prescription for older adults.	prescription section it does to mention exercise progression.		assessed weekly to facilitate progression to achieve the desired workloads. The intensity or volume of exercise must be progressed for improvement to occur. Exercise volume refers to the duration of an aerobic training session and the total number of exercises, repetitions and sets that are performed in a given strength training session."	
Colour code: green = provides sufficient information, yellow = limited detail provided, red = not mentioned/addressed									

Appendix E

Provision of strength assessment and strength training in international PR (surveys)

	Country and Time frame	Survey Aim/Focus	Sample/Population	Is ST included in PR programme?	ST Prescription Details	Is peripheral muscle strength assessed in PR programme?	SA Details.
Wadell (2013) Hospital based PR in patients with COPD in Sweden – a national survey (380)	Sweden Jan to March 2012	The aim of this study was to investigate the availability and content of hospital-based PR programs in patients with COPD in Sweden."	70 out of 71 hospitals responded. Of these, 46 (66%) hospitals reported offering PR programs for patients with COPD during 2011.	Resistance training (n=46): Lower extremity = 96% Upper extremity = 11%	No additional information provided.	Muscle strength test as an outcome measures (n=46): Lower limb = 43% Upper limb = 17%	No additional information provided.
Frisk (2022) How is the organisational settings, content, and availability of comprehensive multidisciplinary PR for people with COPD in primary healthcare in Norway (391)	Norway Feb to April 2019	The main outcome was the question related to accessibility to a PR programme in primary healthcare. We also examined in what degree the single interventions which are a part of a PR programme.	Of the 436 municipalities who were invited to participate, 158 answered the survey (36% response rate).	Not mentioned.	N/A	Not mentioned.	N/A
Spruit et al (2014) Differences in content and organisational aspects of PR programmes (361)	Europe and North America Sept 2012 to Feb 2013	The aim was to study the overall content and organisational aspects of PR programmes from a global perspective in order to get an initial appraisal on the degree of heterogeneity worldwide.	The survey was completed by representatives of 430 centres from 40 countries (primarily across Europe and North America).	Resistance training using training apparatus: Europe (62.8%), North America (67.9%) Resistance training using handheld weights: Europe (71.3%), North America (93.6%)	No additional information provided.	Not mentioned.	N/A
Bickford (1995) National PR Survey (381)	America June 1992 to April 1993	The goal of this survey was to characterise PR programs regarding program size and length, patient population, entrance requirements and testing, and program content (an update of a 1988 survey).	Responses were received from 283 programs in 44 states.	Not mentioned	N/A	Not mentioned.	N/A

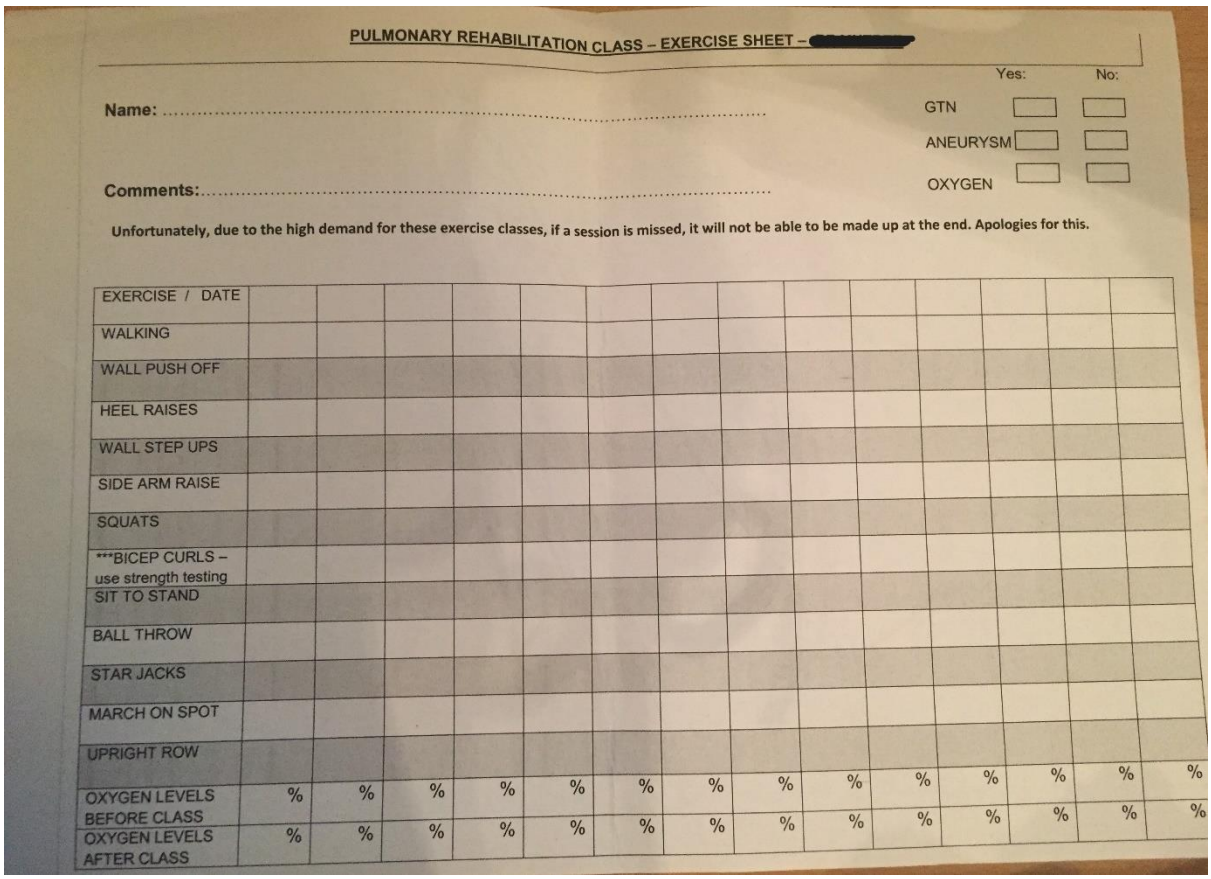
Garvey (2020) Survey of exercise prescription in UR PR programs (386)	America 2016	The purpose of this investigation was to identify current PR exercise prescription practices.	Survey sent to 1758 PR programmes in the US. Responses were retuned from 371 PR providers (20.3% of requests sent).	Do you prescribe resistance training (n=325)? Yes = 93.5% No = 6.5%	If you prescribe resistance training, which components are included (n=303)? Weight lifting = 75.9% Bands = 69.0% Weight/resistance machines = 57.1% Body weight, e.g. wall push-ups = 41.6% If exercise intensity is measured, which measure is used (n=326) 1-RM = 4.6% Method used to determine progression of exercise (n=318): 1-RM = 5.3%	Limited information provided. Only 1-RM SA for prescription addressed.	No additional information provided.
Brooks (2007) Characterization of PR programs in Canada (382)	Canada March to April 2004	To conduct a national survey to characterize adult PR across Canada, in terms of program distribution, utilization, content and outcome measures."	Of 244 surveys mailed, 149 (61%) were returned, from which 60 facilities (40%) reported having one or more PR programs for a total of 98 programs.	ST as a component of PR (n=98): Lower extremity = 76.5% Upper extremity = 64.3%	No additional information provided.	Not mentioned.	N/A
Dechman (2017) Exercise Prescription practices in PR programs (387)	Canada Date range not provided.	The purpose of this investigation was to examine the concordance with guideline recommendations in outpatient PR.	112 of 155 (83%) identified PR programs completed the survey.	Is ST included in PR programme (n=112): Yes = 93% (n=104) Of those that offer ST (n=104): Lower extremity = 97% Upper extremity = 100% Core = 68.3%	Is a training protocol used (i.e. sets and reps) (n=104)? Yes = 60% Is exercise testing used to establish a ST prescription (n=104)? Yes = 30.8% (n=32) If yes, how? (n=32): 1-RM = 9.4% 3-RM = 18.8% 10-RM = 15.6% Patients ability to lift 10x = 43.8% Other = 37.5%	Limited information provided. Only SA for prescription addressed.	No additional information provided.
Johnston (2011) PR in Australia: a national survey (383)	Australia Date range not provided.	To determine the current structure and content of PR programs in Australia.	Of 193 programmes identified, 161 responses were received. 14 were excluded leaving 147 PR sites/programmes.	ST included in PR programmes (n=141): Yes = 74%	Mode of ST (n=141): Lower limb exercises with weights = 56% Exercise using resistance band or similar = 56%	Not mentioned.	N/A
Levack (2012) uptake of PR in New Zealand by people with COPD in 2009 (384)	New Zealand PR in 2009	To estimate the uptake of PR by people with COPD in New Zealand in 2009. The survey requested information on the characteristics of PR programmes.	23 organisations were identified which provided PR, of which 21 gave responses to the survey (91%).	Not mentioned.	N/A	Not mentioned.	N/A

Candy (2022) Characteristics of PR programmes in New Zealand: a survey of practice prior to and during Covid-19 (388)	New Zealand July to Sept 2019	The primary aim of this survey was to develop an understanding of current PR practices in New Zealand.	36 PR services across New Zealand.	Not mentioned.	N/A	Not mentioned.	N/A

NOTE: Green = information provided, yellow = limited information provided, red = information not collected/mentioned or N/A.
Abbreviations: ST = strength training, PR = pulmonary rehabilitation, COPD = chronic obstructive pulmonary disease, N/A = not applicable, ATS = American Thoracic Society, ERS = European Respiratory Society, BTS = British Thoracic Society, CTS = Canadian Thoracic Society, ACCP/AACVPR = American College of Chest Physicians/American Association of Cardiovascular and Pulmonary Rehabilitation, ACSM = American College of Sports Medicine

Appendix F

PR exercise sheet (list of exercises): Site 1



PULMONARY REHABILITATION CLASS – EXERCISE SHEET – [redacted]

Name: .....

Comments:.....

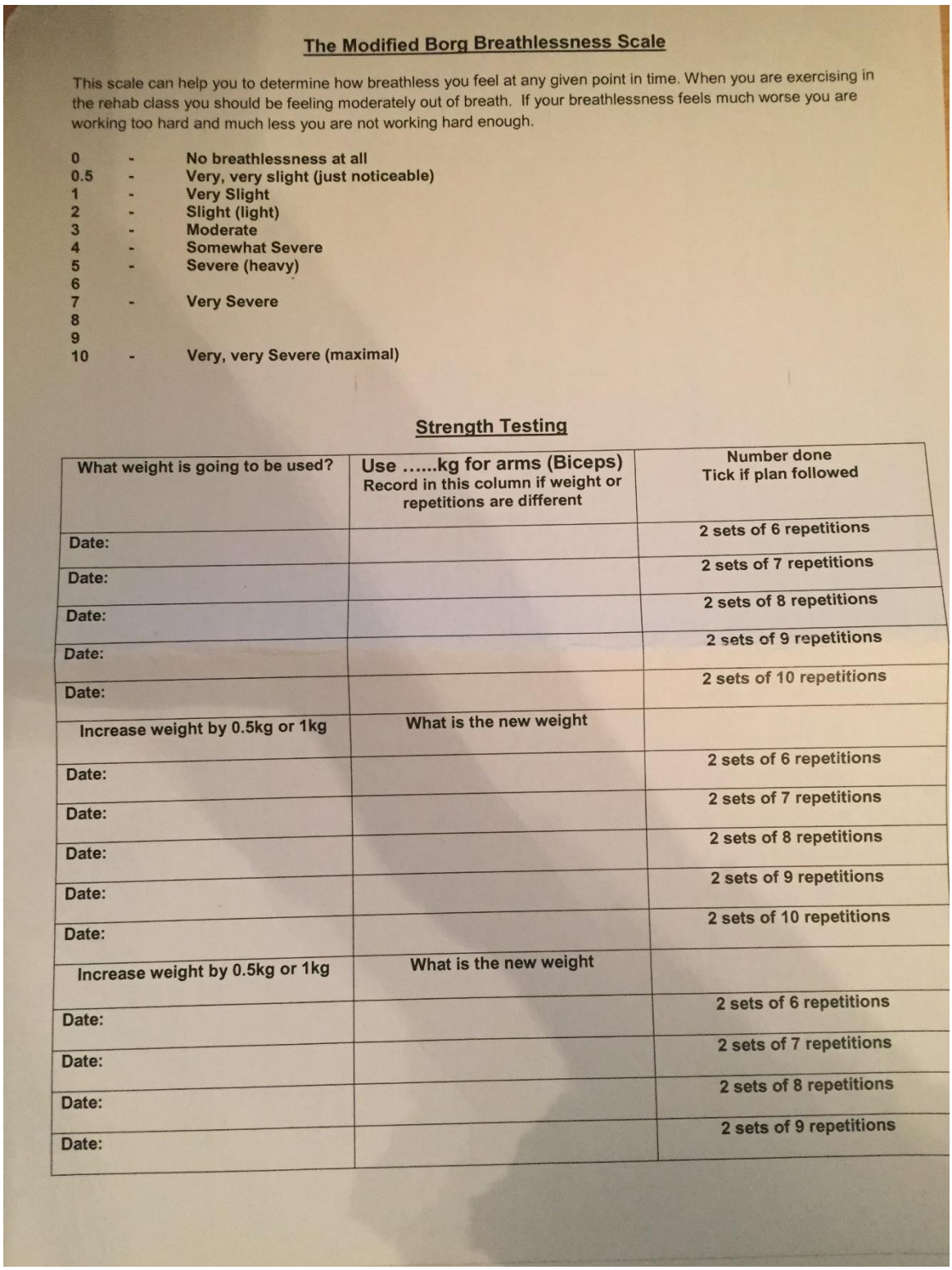
	Yes:	No:
GTN	☐	☐
ANEURYSM	☐	☐
OXYGEN	☐	☐

Unfortunately, due to the high demand for these exercise classes, if a session is missed, it will not be able to be made up at the end. Apologies for this.

EXERCISE / DATE														
WALKING														
WALL PUSH OFF														
HEEL RAISES														
WALL STEP UPS														
SIDE ARM RAISE														
SQUATS														
***BICEP CURLS – use strength testing														
SIT TO STAND														
BALL THROW														
STAR JACKS														
MARCH ON SPOT														
UPRIGHT ROW														
OXYGEN LEVELS BEFORE CLASS	%	%	%	%	%	%	%	%	%	%	%	%	%	%
OXYGEN LEVELS AFTER CLASS	%	%	%	%	%	%	%	%	%	%	%	%	%	%

Appendix G

PR exercise sheet (Borg scale and strength assessment): Site 1



The Modified Borg Breathlessness Scale

This scale can help you to determine how breathless you feel at any given point in time. When you are exercising in the rehab class you should be feeling moderately out of breath. If your breathlessness feels much worse you are working too hard and much less you are not working hard enough.

0	-	No breathlessness at all
0.5	-	Very, very slight (just noticeable)
1	-	Very Slight
2	-	Slight (light)
3	-	Moderate
4	-	Somewhat Severe
5	-	Severe (heavy)
6		
7	-	Very Severe
8		
9		
10	-	Very, very Severe (maximal)

Strength Testing

What weight is going to be used?	Use ……kg for arms (Biceps) Record in this column if weight or repetitions are different	Number done Tick if plan followed
Date:		2 sets of 6 repetitions
Date:		2 sets of 7 repetitions
Date:		2 sets of 8 repetitions
Date:		2 sets of 9 repetitions
Date:		2 sets of 10 repetitions
Increase weight by 0.5kg or 1kg	What is the new weight	
Date:		2 sets of 6 repetitions
Date:		2 sets of 7 repetitions
Date:		2 sets of 8 repetitions
Date:		2 sets of 9 repetitions
Date:		2 sets of 10 repetitions
Increase weight by 0.5kg or 1kg	What is the new weight	
Date:		2 sets of 6 repetitions
Date:		2 sets of 7 repetitions
Date:		2 sets of 8 repetitions
Date:		2 sets of 9 repetitions

Appendix H

Practitioner interviews PIS

INVITATION TO PARTICIPATE IN A RESEARCH STUDY

The use and impact of strength assessments and strength training in Pulmonary Rehabilitation: A Qualitative Study with Practitioners

Thank you for your interest in this study. Before you decide whether to take part, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully before you consent to take part. Your participation is completely voluntary and will not impact your current job or working role in any way. There is information at the end of the leaflet on how to contact us if you have any questions or concerns.

The Study

This research study is being run as part of a PhD Studentship, funded by the University of Essex and Provide.

Exercise is an important part of pulmonary rehabilitation, especially strength (or resistance) training. However, only a small number of patients have their muscle strength assessed. We are inviting up to 12 practitioners to take part in a one to one interview to have a chat about their experiences working in pulmonary rehabilitation.

This study aims to identify and gain a greater understanding of the use and impact of strength training, and the factors that help and hinder the use of strength assessments in pulmonary rehabilitation programmes. We hope the results of this study will help inform further research into finding an appropriate test to assess muscle strength in pulmonary rehabilitation services, which best suits the patients and practitioners.

Who can take part?

You will be able to take part if:

- You are an adult, aged 18 years or older
- Are working/or have worked in an active role running, managing or assisting pulmonary rehabilitation programmes/clinics.
- Willing to be interviewed and audio recorded
- Are not currently taking part in another conflicting study

What will happen if you take part?

If you are interested in taking part in this study, we will check that you are eligible to participate. Once eligibility is confirmed we will ask you to complete a consent form either by post, email or over the phone. After this we can then arrange to do the interview. This will either be by phone, videocall (e.g. Skype) or in person (once government guidance permits), whichever is most convenient for you. However, a quiet environment is needed to limit background noise. The interview will take place one to one with the researcher, Kate Pittaccio. It will take approximately 30-45 minutes to complete, depending on the length of the conversation. The interview will be audio recorded, and notes taken during if needed. The audio of the interview will then be transcribed into written word.

Risks & Benefits

Taking part in this study presents no risks, as the interview does not contain any questions likely to cause distress or discomfort. However, if you don't want to answer a question during the interview, you are completely free to refuse.

We understand there is an element of inconvenience as we are asking you to give us some of your time. But your participation in this study will help improve the understanding of practitioner's experiences and opinions of strength training and the use of strength assessments in pulmonary rehabilitation.

Your Rights

Your participation in this study is entirely voluntary, and you are free to withdraw or stop the interview at any time, no explanation necessary. Also, during the interview, if you need a break (e.g. to stretch your legs or get a drink) you are free to do so.

Your records will be kept strictly confidential. Please note that taking part in this research study is not a requirement of you within your role as a member of staff, and your employment will not be affected if you decide not to participate or drop out.

Data Protection

The University of Essex is the sponsor for this study based in the United Kingdom. We will be using information from you in order to undertake this research and will act as the data controller for this study. This means that we are responsible for looking after your information and using it properly. All information and data you give us will be kept safe and secure. The University of Essex will keep identifiable information about you for up to four weeks after the conclusion of this study, after this it will be destroyed. Data collected from you may be stored for up to 6 years, however this will be anonymised to maintain confidentiality.

Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already

obtained. To safeguard your rights, we will use the minimum personally-identifiable information possible. You can find out more about how we use your information by contacting the Information Assurance Manager on 01206 874853.

Certain individuals from the University of Essex and regulatory organisations may look at your research records to check the accuracy of the research study. The University of Essex will only receive information without any identifying information. The people who analyse the information will not be able to identify you and will not be able to find out your name or contact details.

Please note that during the interview if you disclose anything which is a risk to yourself or others, the Chief Investigator will be obliged to inform your line manager.

The results of this study may be published but there will be no information included which could identify you. We will be happy to provide you with a summary of the main findings, available upon your request. This research project has been granted ethical approval by the London Bromley Research Ethics Committee.

Concerns and complaints

If you have any concerns about any aspect of the study or you have a complaint, in the first instance please contact the Chief Investigator of the project, Kate Pittaccio. If you are still concerned or you think your complaint has not been addressed to your satisfaction, please contact the Director of Research in the principal investigator's department, Prof Jo Jackson. If you are still not satisfied, please contact the University's Research Governance and Planning Manager, Sarah Manning-Press. **All contact details are below.**

Contact details

Principal investigator
Kate Pittaccio
School of Sports, Rehabilitation & Exercise Sciences, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.
Email: kp19988@essex.ac.uk. Phone/Text: 07463427327

Co-investigators
Dr Ben Jones, Izzie Easton and Dr Leanne Andrews
School of Sports, Rehabilitation & Exercise Science, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.

Director of Research School of Sports, Rehabilitation & Exercise Science
Prof Jo Jackson
School of Sports, Rehabilitation & Exercise Science, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.

Email: jo.jackson@essex.ac.uk. Phone: 01206-874277

University of Essex Research Governance and Planning Manager

Sarah Manning-Press
Research & Enterprise Office, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.
Email: sarahm@essex.ac.uk. Phone: 01206-873561

We would like to thank you for your interest in this study.

Appendix I

Practitioner interview consent form

The use and impact of strength assessments and strength training in Pulmonary Rehabilitation: A Qualitative Study with Practitioners

INFORMED CONSENT FORM

Chief Investigator: Kate Pittaccio
IRAS ID: 276749
Participant Name:
Participant Number:

	Enter your initials in each box below
I confirm that I have read (or someone else has read to me) and I understand the Participant Information Sheet (version 2.0).	
I have had the opportunity to consider the information, ask questions and have had these questions answered satisfactorily.	
I understand that my participation is voluntary (my choice) and that I may withdraw from the study at any time without giving reason, and that my employment or legal rights will not be affected because of this.	
Unless I explicitly stated otherwise, I agree for the data collected up to the point of my withdrawal to be used for the study.	
I agree to the interview being audio recorded, and notes being taken during the interview if needed.	
I understand that the research data collected during the study may be looked at by other individuals from the research team, sponsor, or regulatory authorities, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my data.	
I understand that all information collected will be in accordance to the Data Protection Act 2018 and the General Data Protection Regulation 2018.	
I understand that all study related data will be anonymised (will not identify me in any way) and I agree to my personal identifiable information to be stored (separately to my anonymised study data) for the purposes of contacting me throughout the study. I understand that all data collected will be stored in the University of Essex archive facility for 6 years.	
Unless I explicitly stated otherwise, I agree for anonymised quotes to be used in the dissemination of findings (e.g. in publications).	
I understand that data collected during the study may be looked at by individuals from the University of Essex, from regulatory authorities or from the NHS Trust. Where it is relevant to my taking part in this research, I give permission for these individuals to have access to my data.	
I understand that if I disclose anything which is a risk to myself or others, the Chief Investigator will be obliged to inform my line manager.	
I agree to take part in the above study.	

PLEASE SEE NEXT PAGE

Please print and sign your name, and include today's date. If you are completing this via email, include an electronic signature if possible. If you do not have an electronic signature, please type your name clearly instead.

Participant Name (please print): _____

Signature of Participant: _____

Date: _____

Researcher Name (please print): _____

Signature of Researcher: _____

Date: _____

Where possible, one copy of the consent form will be for the participant, and one copy will be for the researcher/Chief Investigator.

Appendix J

Practitioner interview guide

Introduction

I'd like to thank you once again for willing to participant in this interview. As mentioned before, I am a PhD student working on a project to understand the use and impact of strength training exercises and muscle strength assessments in pulmonary rehabilitation. Our interview today will last approximately **30-45 minute** during which I will ask you about your experiences, views and opinions of these main topics. A moment ago you completed a consent form indicating you have given your permission for this conversation to be audio recorded. Are you still ok with me recording our conversation today?

Yes – Thank you! At any point during the interview if you don't want to answer a question or would like to stop at any time you are free to do so. Also, if you'd like a break to stretch your legs or get a drink please don't hesitate to let me know.

Before we start the interview do you have any questions? (Answer queries). If you have any questions at any point during the interview, please feel free to ask them at any time.

TRANSITION: Now we've gone over the introductory information I'd really like for you to tell me a bit more about yourself, and your work in pulmonary rehabilitation.

Background

Please could you briefly explain what your current role is, and how it fits into Pulmonary Rehabilitation?

- Physio/Nurse/Assistant?

How long have you been working in this role?

How did you come to work in this role?

- What is your background?
- What previous education and qualifications have you completed?
- What specific training have you done to work in this role?

Please could you briefly explain what pulmonary rehabilitation is?

- What are the important components?
- E.g. exercise, education, socializing

TRANSITION: Thank you for your responses. We're now going to move on and talk generally about the use of strength training exercise in pulmonary rehabilitation.

Strength Training

It is generally recommended that Pulmonary Rehabilitation programmes should include some Strength (resistance) Training. Is this currently incorporated into your service's programme? If so, how?

- How long has Strength Training been implemented in the Pulmonary Rehabilitation programmes?
- Definition: is the use of resistance (such as weights or bands) to work the muscle to help build strength (e.g. bicep curl using a free weight)

Do you have any specific training in the understanding and implementation of Strength Training?

- Was it included in any of your background education/qualifications?
    - If yes, do you think you have a good breadth of understanding about strength training?
- Is training offered?
    - If not, would it be useful to have the option of gaining some specific training?

In your opinion how important is Strength Training in Pulmonary Rehabilitation?

- Pros?
- Cons?

What resources are available to you to implement Strength Training in Pulmonary Rehabilitation?

- E.g. setting, equipment, staff, money

Do you currently face any problems/issues implementing Strength Training in Pulmonary Rehabilitation?

TRANSITION: Thank you for your responses. We're now going to move on and talk specifically about muscle strength assessments and their use in pulmonary rehabilitation

<u>Strength Assessments</u>

Do you currently use any assessments to measure muscle strength in Pulmonary Rehabilitation?

- Yes – how do you currently assess muscle strength?
- Do you have any previous experience assessing muscle strength e.g. in other jobs?
    - How did you find it?
    - Easy/Difficult?

A Pulmonary Rehabilitation National Report from 2017 stated only 27% of patients had muscle strength assessed. What do you think of this?

In your opinion how important are Strength Assessments in Pulmonary Rehabilitation?

- Are they helpful/useful?
- Are they needed?
- Pros/Cons?

Would it be possible to implement and perform Strength Assessments in current Pulmonary Rehabilitation?

- Would you face a problems/issues?
    - Is there anything that could be done to overcome these difficulties and make it easier?
- Would it be easy? If difficult, what would need to change to make it easier?
- What current resources are available to you to assess muscle strength?
- What's the maximum time you could give to performing another assessment?

How would you feel about implementing and completing Strength Assessments?

- How confident would you be using them, if needed?
- Do you feel you have the skills required at the moment to use them?
    - How equipped would you feel as a practitioner?

Are you encouraged to implement recommended changes in Pulmonary Rehabilitation? E.g. strength assessments?

- If yes, how?
- If no, why do you think you're not encouraged?

What is the general view of using Strength Assessments in Pulmonary Rehabilitation amongst your colleagues?

- Do you agree with this?
- Any reasons why this is the general view?

If Strength Assessments were implemented, how would this impact Pulmonary Rehabilitation as a whole?

- Would it have a positive or negative impact, or both?
- In the short term/long term?
- If already implemented, what impact has it had?

How would the use of Strength Assessments impact on you, as a practitioner?

How would the use of Strength Assessments impact on patients?

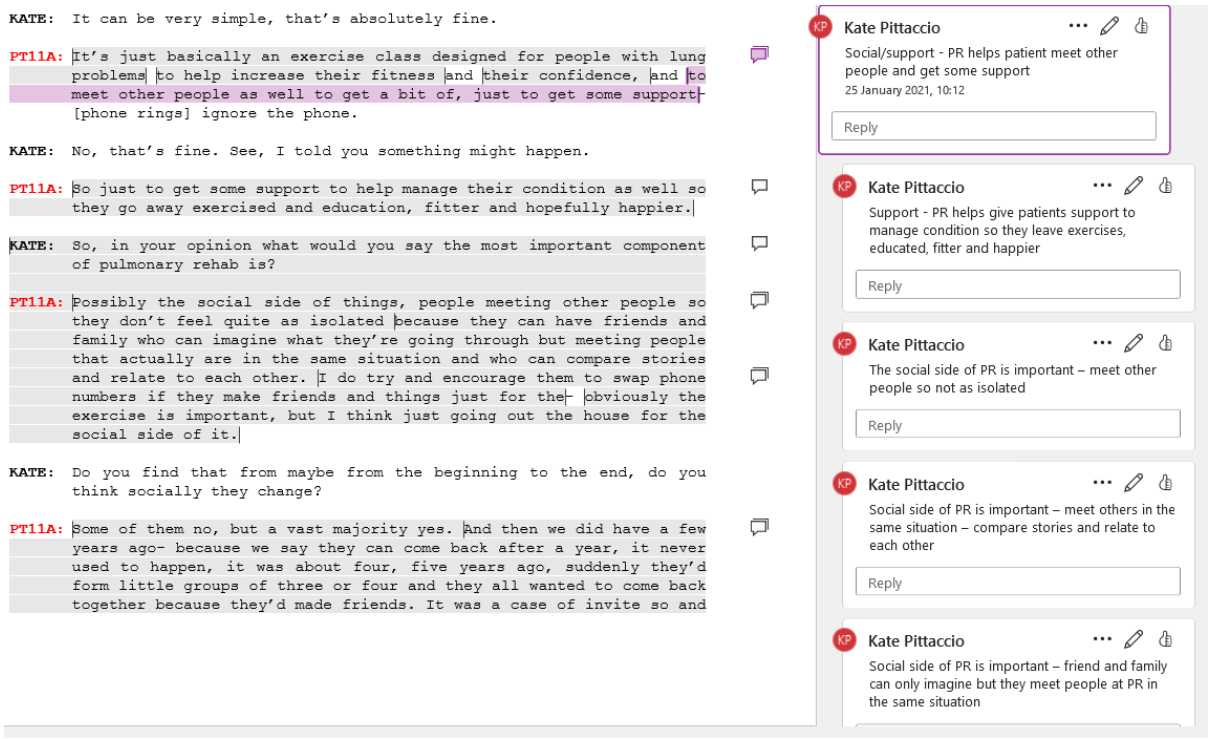
- Psychological? Physical?

Closing

Before we come to an end, is there anything else you would like to add or anything we haven't yet discussed that you think is important?

Appendix K

Practitioner interviews - coded transcript example (Microsoft Word)



KATE: It can be very simple, that's absolutely fine.

PT11A: It's just basically an exercise class designed for people with lung problems to help increase their fitness and their confidence, and to meet other people as well to get a bit of, just to get some support- [phone rings] ignore the phone.

KATE: No, that's fine. See, I told you something might happen.

PT11A: So just to get some support to help manage their condition as well so they go away exercised and education, fitter and hopefully happier.

KATE: So, in your opinion what would you say the most important component of pulmonary rehab is?

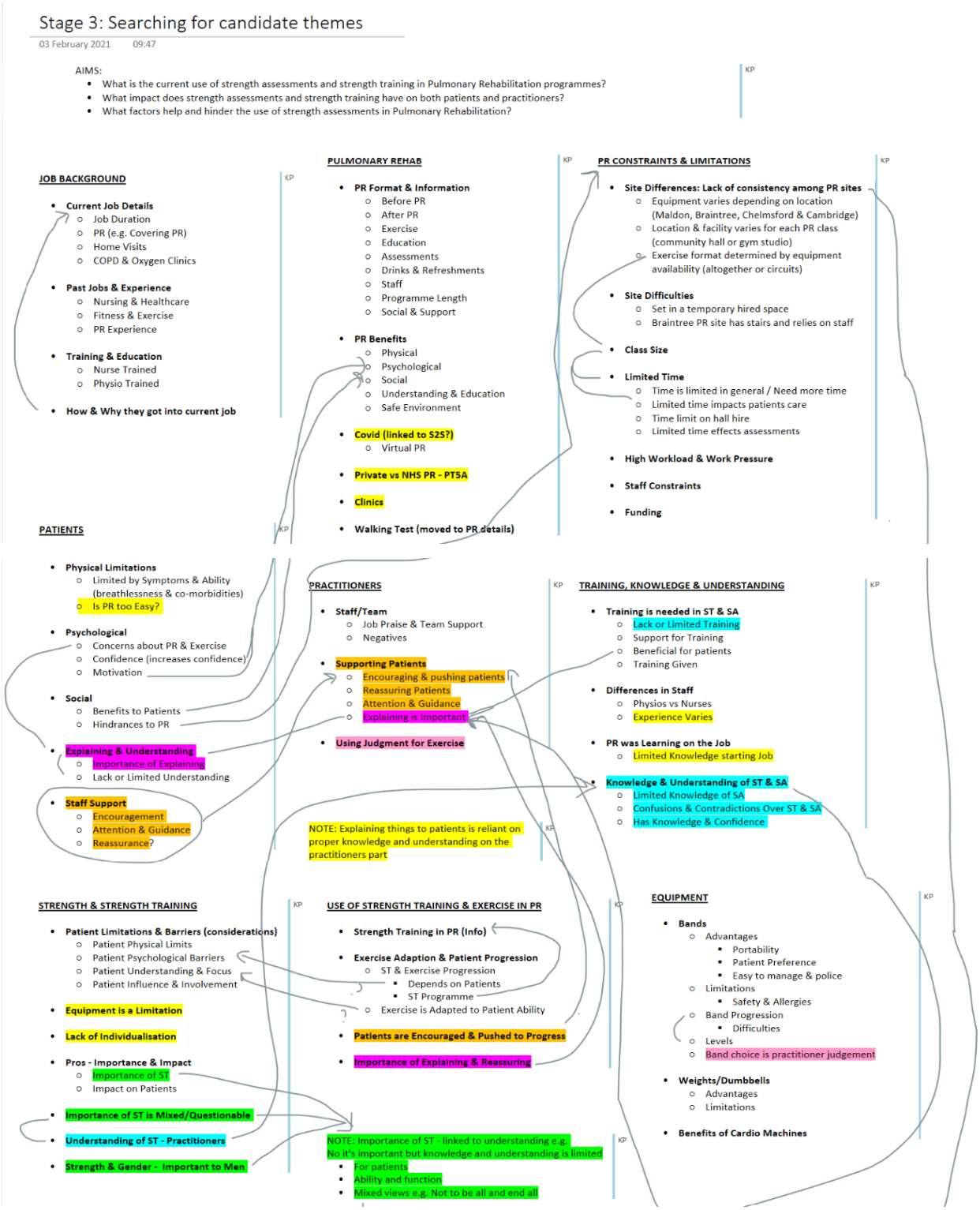
PT11A: Possibly the social side of things, people meeting other people so they don't feel quite as isolated because they can have friends and family who can imagine what they're going through but meeting people that actually are in the same situation and who can compare stories and relate to each other. I do try and encourage them to swap phone numbers if they make friends and things just for the- obviously the exercise is important, but I think just going out the house for the social side of it.

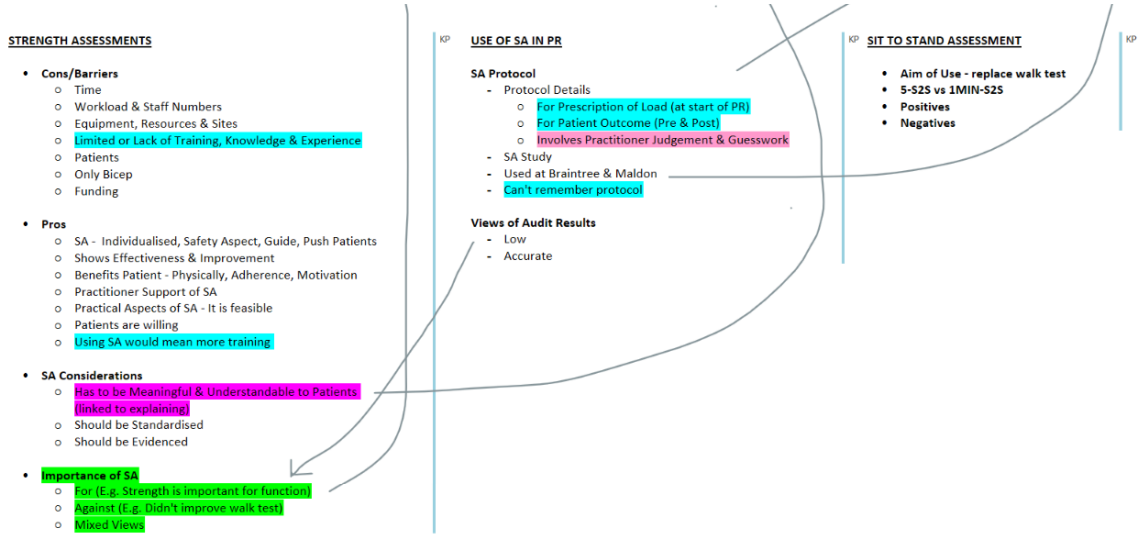
KATE: Do you find that from maybe from the beginning to the end, do you think socially they change?

PT11A: Some of them no, but a vast majority yes. And then we did have a few years ago- because we say they can come back after a year, it never used to happen, it was about four, five years ago, suddenly they'd form little groups of three or four and they all wanted to come back together because they'd made friends. It was a case of invite so and

Appendix L

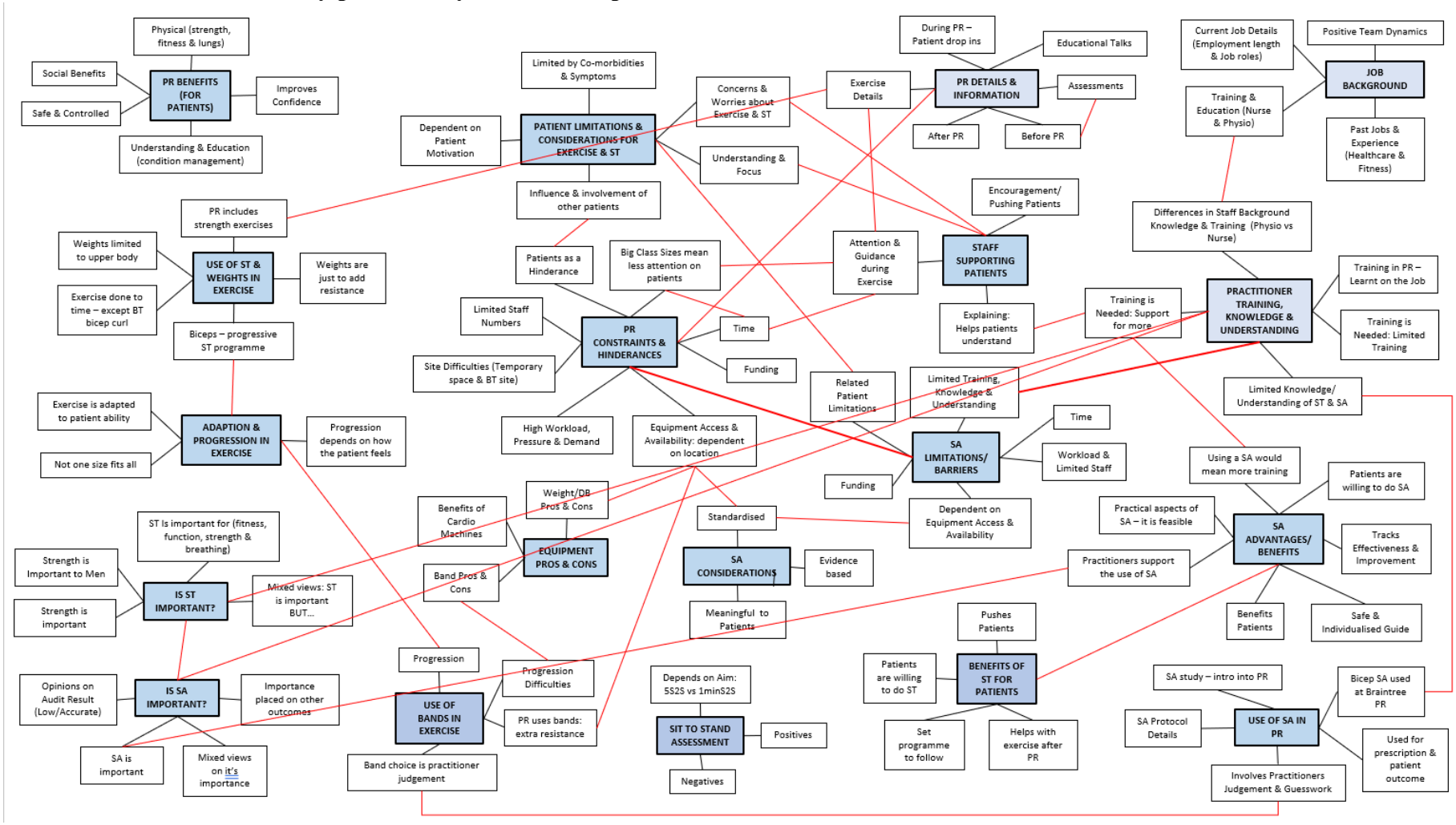
Practitioner interviews - example of electronically annotation lists/notes used for theme development/generation




STRENGTH ASSESSMENTS
Cons/Barriers
Time
Workload & Staff Numbers
Equipment, Resources & Sites
Limited or Lack of Training, Knowledge & Experience
Patients
Only Bicep
Funding
Pros
SA - Individualised, Safety Aspect, Guide, Push Patients
Shows Effectiveness & Improvement
Benefits Patient - Physically, Adherence, Motivation
Practitioner Support of SA
Practical Aspects of SA - It is feasible
Patients are willing
Using SA would mean more training
SA Considerations
Has to be Meaningful & Understandable to Patients (linked to explaining)
Should be Standardised
Should be Evidenced
Importance of SA
For (E.g. Strength is important for function)
Against (E.g. Didn't improve walk test)
Mixed Views
KP
USE OF SA IN PR
SA Protocol
Protocol Details
For Prescription of Load (at start of PR)
For Patient Outcome (Pre & Post)
Involves Practitioner Judgement & Guesswork
SA Study
Used at Braintree & Maldon
Can't remember protocol
Views of Audit Results
Low
Accurate
KP
SIT TO STAND ASSESSMENT
Aim of Use - replace walk test
5-S2S vs 1MIN-S2S
Positives
Negatives
KP

Appendix M

Practitioner interviews - early/preliminary thematic map



Appendix N

NHS/HRA ethical approval letter for practitioner and patient interviews

NHS
Health Research Authority

London - Bromley Research Ethics Committee
Level 3, Block B
Whitefriars
Lewins Mead
Bristol
BS1 2NT

Telephone: 0207 972 2496
Fax:

01 April 2020

Miss Kate Pittaccio
School of Sports, Rehabilitation and Exercise Sciences
Wivenhoe Park
Colchester
CO4 3SQ

Dear Miss Pittaccio

Study title:	**Strength Assessments and Strength Training in Pulmonary Rehabilitation**
REC reference:	**20/LO/0339**
IRAS project ID:	**276749**

The Proportionate Review Sub-committee of the London - Bromley Research Ethics Committee reviewed the above application on 05 March 2020.

Ethical opinion

On behalf of the Committee, the sub-committee gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

The REC favourable opinion is subject to the following conditions being met prior to the start of the study.

Confirmation of Capacity and Capability (in England, Northern Ireland and Wales) or NHS management permission (in Scotland) should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements. Each NHS organisation must confirm through the signing of agreements and/or other documents that it has given

permission for the research to proceed (except where explicitly specified otherwise).

Guidance on applying for HRA and HCRW Approval (England and Wales)/ NHS permission for research is available in the Integrated Research Application System.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of management permissions from host organisations.

Registration of Clinical Trials

It is a condition of the REC favourable opinion that **all clinical trials are registered** on a publicly accessible database. For this purpose, 'clinical trials' are defined as the first four project categories in IRAS project filter question 2. Registration is a legal requirement for clinical trials of investigational medicinal products (CTIMPs), except for phase I trials in healthy volunteers (these must still register as a condition of the REC favourable opinion).

Registration should take place as early as possible and within six weeks of recruiting the first research participant at the latest. Failure to register is a breach of these approval conditions, unless a deferral has been agreed by or on behalf of the Research Ethics Committee (see here for more information on requesting a deferral:
https://www.hra.nhs.uk/planning-and-improving-research/research-planning/research-registration-research-project-identifiers/

As set out in the UK Policy Framework, research sponsors are responsible for making information about research publicly available before it starts e.g. by registering the research project on a publicly accessible register. Further guidance on registration is available at:
https://www.hra.nhs.uk/planning-and-improving-research/research-planning/transparency-responsibilities/

You should notify the REC of the registration details. We routinely audit applications for compliance with these conditions.

Publication of Your Research Summary

We will publish your research summary for the above study on the research summaries section of our website, together with your contact details, no earlier than three months from the date of this favourable opinion letter. Should you wish to provide a substitute contact point, make a request to defer, or require further information, please visit:
https://www.hra.nhs.uk/planning-and-improving-research/application-summaries/research-summaries/

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

After ethical review: Reporting requirements

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study, including early termination of the study
- Final report

The latest guidance on these topics can be found at
https://www.hra.nhs.uk/approvals-amendments/managing-your-approval/.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion").

Approved documents

The documents reviewed and approved were:

Document	*Version*	*Date*
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [Insurance Letter]	1.0	01 August 2019
Interview schedules or topic guides for participants [Patient Interview Guide]	1.0	10 February 2020
Interview schedules or topic guides for participants [Practitioner Interview Guide]	1.0	10 February 2020
IRAS Application Form [IRAS_Form_13022020]		13 February 2020
Letter from sponsor [Sponsor Letter]	1.0	10 February 2020
Other [Patient Contact Details Form]	1.0	10 February 2020
Other [Practitioner Recruitment Email]	1.0	10 February 2020
Participant consent form [Consent Form Patient]	1.0	10 February 2020
Participant consent form [Consent Form Practitioner]	1.0	10 February 2020
Participant information sheet (PIS) [PIS Patient]	1.0	10 February 2020
Participant information sheet (PIS) [PIS Practitioner]	1.0	10 February 2020
Research protocol or project proposal [Protocol]	1.0	10 February 2020
Summary CV for Chief Investigator (CI) [Kate Pittaccio CV]	1.0	30 January 2020
Summary CV for student [Kate Pittaccio CV]	1.0	30 January 2020
Summary CV for supervisor (student research) [Ben Jones CV]	1.0	07 January 2020
Summary CV for supervisor (student research) [Izzie Easton CV]	1.0	03 February 2020
Summary CV for supervisor (student research) [Leanne Andrews CV]	1.0	10 January 2020

Membership of the Proportionate Review Sub-Committee

The members of the Sub-Committee who took part in the review are listed on the attached

sheet.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website:
http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/

HRA Learning

We are pleased to welcome researchers and research staff to our HRA Learning Events and online learning opportunities– see details at:
https://www.hra.nhs.uk/planning-and-improving-research/learning/

With the Committee's best wishes for the success of this project.

IRAS project ID: 276749	**Please quote this number on all correspondence**

Yours sincerely

Dr Koula Asimakopoulou (Chair)
Chair

Email: bromley.rec@hra.nhs.uk

Enclosures: List of names and professions of members who took part in the review

Copy to: Ms Sarah Manning-Press

London - Bromley Research Ethics Committee

Attendance at PRS Sub-Committee of the REC meeting on 05 March 2020

Committee Members:

Name	*Profession*	*Present*	*Notes*
Dr Koula Asimakopoulou (Chair)	Reader in Health Psychology	Yes	
Miss Linda Grubb	Associate Director European Trade Strategy and Operations (Retired)	Yes	
Mr Abdulzahra Hussain	Upper GI Consultant Surgeon	Yes	

Also in attendance:

Name	*Position (or reason for attending)*
Nina Bakhshayesh	Approvals Administrator

Appendix O

University of Essex ethical approval for practitioner and patient interviews

From: ERAMS
Sent: 04 June 2020 08:59
To: Pittaccio, Kate F
Subject: Decision - Ethics ETH1920-1511: Miss Kate Pittaccio

University of Essex ERAMS

04/06/2020

Miss Kate Pittaccio

Sport, Rehabilitation, and Exercise Science, Sport, Rehabilitation, and Exercise Science

University of Essex

Dear Kate,

Ethics Committee Decision

I am writing to advise you that your research proposal entitled "Strength Assessments and Training in Pulmonary Rehabilitation v1.0" has been reviewed by the REO Research Governance Team.

The Committee is content to give a favourable ethical opinion of the research. I am pleased, therefore, to tell you that your application has been granted ethical approval by the Committee.

Please do not hesitate to contact me if you require any further information or have any queries.

Yours sincerely,

REO Research Governance Team

Ethics ETH1920-1511: Miss Kate Pittaccio

Appendix P

Patient interviews PIS

INVITATION TO PARTICIPATE IN A RESEARCH STUDY

The use and impact of strength assessments and strength training in Pulmonary Rehabilitation: A Qualitative Study with Patients

Thank you for your interest in this study. Before you decide whether to take part, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully before you consent to take part. Your participation is completely voluntary and will not affect any access to treatment or services that you may be currently receiving. There is information at the end of the leaflet on how to contact us if you have any questions or concerns.

The Study

This research study is being run as part of a PhD Studentship, funded by the University of Essex and Provide.

Exercise is an important part of pulmonary rehabilitation, especially strength (or resistance) training. These are the exercises that focus on making your muscles stronger. Although strength training is a vital part of the programme, there are no assessments used to see if these strength exercises make a difference.

We are inviting 12 patients to take part in a one to one interview to have a chat about their pulmonary rehabilitation experiences. It aims to gain a greater understanding of the use and impact of the strength training exercises that you do in the programme. We hope the results of this study will help inform further research into finding an appropriate test to assess muscle strength in pulmonary rehabilitation services.

Who can take part?

You will be able to take part if:

- You are an adult, aged 18 years or older
- Have successfully completed/or will soon complete a pulmonary rehabilitation programme.
- Willing to be interviewed and audio recorded
- Are not currently taking part in another conflicting study

What will happen if you take part?

If you are interested in taking part in this study, we will check that you are eligible to participate. Once eligibility is confirmed we will ask you to complete a consent form either by post, email or over the phone. After this we can then arrange to do the interview. This will either be by phone, videocall (e.g. Skype) or in person (once government guidance permits), whichever is most convenient for you. However, a quiet environment is needed to limit background noise. The interview will take place one to one with the researcher, Kate Pittaccio. It will take approximately 30-45 minutes to complete, depending on the length of the conversation. The interview will be audio recorded, and notes taken during if needed. The audio of the interview will then be transcribed into written word.

Risks & Benefits

Taking part in this study presents no risks, as the interview does not contain any questions likely to cause distress or discomfort. However, if you don't want to answer a question during the interview, you are completely free to refuse.

We understand there is an element of inconvenience as we are asking you to give us some of your time. Nevertheless, your participation in this study will help improve the understanding of patient's experience in pulmonary rehabilitation, specifically exercise.

Your Rights

Your participation in this study is entirely voluntary, and you are free to withdraw or stop the interview at any time, no explanation necessary. Also, during the interview, if you need a break (e.g. to stretch your legs or get a drink) you are free to do so.

Your records will be kept strictly confidential and your ordinary medical care will not be put at risk if you decide not to take part or drop out.

Data Protection

The University of Essex is the sponsor for this study based in the United Kingdom. We will be using information from you in order to undertake this research and will act as the data controller for this study. This means that we are responsible for looking after your information and using it properly. All information and data you give us will be kept safe and secure. The University of Essex will keep identifiable information about you for up to four weeks after the conclusion of this study, after this it will be destroyed. Data collected from you may be stored for up to 6 years, however this will be anonymised to maintain confidentiality.

Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained. To safeguard your rights, we will use the minimum personally identifiable

information possible. You can find out more about how we use your information by contacting the Information Assurance Manager on 01206 874853.

Certain individuals from the University of Essex and regulatory organisations may look at your research records to check the accuracy of the research study. The University of Essex will only receive information without any identifying information. The people who analyse the information will not be able to identify you and will not be able to find out your name or contact details.

Please note that during the interview if you disclose anything which is a risk to yourself or others, the Chief Investigator will be obliged to inform clinical staff.

The results of this study may be published but there will be no information included which could identify you. We will be happy to provide you with a summary of the main findings, available upon your request. This research project has been granted ethical approval by the London Bromley Research Ethics Committee.

Concerns and complaints

If you have any concerns about any aspect of the study or you have a complaint, in the first instance please contact the Chief Investigator of the project, Kate Pittaccio. If you are still concerned or you think your complaint has not been addressed to your satisfaction, please contact the Director of Research in the principal investigator's department, Prof Jo Jackson. If you are still not satisfied, please contact the University's Research Governance and Planning Manager, Sarah Manning-Press. **All contact details are below.**

Patient Advocacy and Liaison Service (PALS)
If you wish to make a complaint about any aspect of your care, you can contact the Patient Advocacy and Liaison Service (PALS) at: https://www.swlstg.nhs.uk/patients-carers/feedback/pals-new

Contact Details

Principal investigator
Kate Pittaccio
School of Sports, Rehabilitation & Exercise Sciences, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.
Email: kp19988@essex.ac.uk. Phone/Text: 07463427327

Co-investigators
Dr Ben Jones, Izzie Easton and Dr Leanne Andrews
School of Sports, Rehabilitation & Exercise Science, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.

Director of Research School of Sports, Rehabilitation & Exercise Science
Prof Jo Jackson
School of Sports, Rehabilitation & Exercise Science, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.
Email: jo.jackson@essex.ac.uk. Phone: 01206-874277

University of Essex Research Governance and Planning Manager
Sarah Manning-Press
Research & Enterprise Office, University of Essex, Wivenhoe Park, CO4 3SQ, Colchester.
Email: sarahm@essex.ac.uk. Phone: 01206-873561

We would like to thank you for your interest in this study.

Appendix Q

Patient interviews consent form

The use and impact of strength assessments and strength training in Pulmonary Rehabilitation: A Qualitative Study with Patients

INFORMED CONSENT FORM

Chief Investigator: Kate Pittaccio
IRAS ID**:** 276749
Participant Name:
Participant Number:

	Enter your initials in each box below
I confirm that I have read (or someone else has read to me) and I understand the Participant Information Sheet (version 2.0).	
I have had the opportunity to consider the information, ask questions and have had these questions answered satisfactorily.	
I understand that my participation is voluntary (my choice) and that I may withdraw from the study at any time without giving reason, and that my medical care or legal rights will not be affected because of this.	
Unless I explicitly stated otherwise, I agree for the data collected up to the point of my withdrawal to be used for the study.	
I agree to the interview being audio recorded, and notes being taken during the interview if needed.	
I understand that the research data collected during the study may be looked at by other individuals from the research team, sponsor, or regulatory authorities, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my data.	
I understand that all information collected will be in accordance to the Data Protection Act 2018 and the General Data Protection Regulation 2018.	
I understand that all study related data will be anonymised (will not identify me in any way) and I agree to my personal identifiable information to be stored (separately to my anonymised study data) for the purposes of contacting me throughout the study. I understand that all data collected will be stored in the University of Essex archive facility for 6 years.	
Unless I explicitly stated otherwise, I agree for anonymised quotes to be used in the dissemination of findings (e.g. in publications).	
I understand that data collected during the study may be looked at by individuals from the University of Essex, from regulatory authorities or from the NHS Trust. Where it is relevant to my taking part in this research, I give permission for these individuals to have access to my data.	
I understand that if I disclose anything which is a risk to myself or others, the Chief Investigator will be obliged to inform clinical staff.	
I agree to take part in the above study.	

PLEASE SEE NEXT PAGE

Please print and sign your name, and include today's date. If you are completing this via email, include an electronic signature if possible. If you do not have an electronic signature, please type your name clearly instead.

Participant Name (please print): _____

Signature of Participant: _____

Date: _____

Researcher Name (please print): _____

Signature of Researcher: _____

Date: _____

Where possible, one copy of the consent form will be for the participant, and one copy will be for the researcher/Chief Investigator.

Appendix R

Patient interview guide

Introduction

I'd like to thank you once again for willing to participant in this interview. As mentioned before, I am a PhD student working on a project to understand the use and impact of strength training exercises and muscle strength assessments in pulmonary rehabilitation. Our interview today will last approximately **30-45 minutes** during which I will ask you about your experiences, views and opinions of these main topics. A moment ago you completed a consent form indicating you have given your permission for this conversation to be audio recorded. Are you still ok with me recording our conversation today?

Yes – Thank you! At any point during the interview if you don't want to answer a question or would like to stop you are free to do so. Also, if you'd like a break to stretch your legs or get a drink please don't hesitate to let me know.

Before we start the interview do you have any questions? (Answer queries). If you have any questions at any point during the interview, please feel free to ask them at any time.

TRANSITION: Now we've gone over the introductory information I'd really like for you to tell me a bit more about yourself and your involvement with pulmonary rehabilitation.

Background

Please could you tell me what led up to you attending pulmonary rehabilitation?

- Diagnosis?
- How did it come about? E.g. a referral?

Do you have any previous experiences attending pulmonary rehabilitation?

- Is this your first time?
- Have you attended anything similar before?

TRANSITION: Thank you for your responses. As you already know a big part of pulmonary rehabilitation programmes is doing exercise. We're now going to talk about this, with specific focus on strength training exercises. But first…

Exercise and Strength Training

Please could you tell me, as a whole, what does exercise mean to you?

- How would you describe what exercise is? What is your idea of exercise?
- Has this view changed since you started the programme?

What experience of exercise do you have, aside from pulmonary rehabilitation?

- Do you participate in any other exercise (or activities) outside of pulmonary rehabilitation? (e.g. walking or sport clubs)
- Did you do exercise before the programme? (Even in earlier life?)

What does strength training mean to you?

- What do you think of when you hear ‘strength training?’

Within the exercise class you complete various strength (resistance) training exercises. What exercises did you have to do?

- Definition: is the use of resistance (such as weights or bands) to work the muscle to help build strength (e.g. bicep curl using a free weight/bands)
- How did you find this?
  - Did you enjoy it?
  - Was it challenging?
  - Any fears about lifting weight?

Did you have any prior knowledge or experience with strength training before attending pulmonary rehabilitation?

- Yes – please could you explain what these were? Did it come in useful?
- No – Do you feel you now have some knowledge and understanding about strength training? If so, what specifically?

In your opinion, how important are the strength training exercises?

- Why are they important/ not important?

Support

When you first started, were the strength training exercises easy to understand and perform?

- If possible, please could you explain the process of how you learnt these exercises?
  - What resources were available to you?
  - Were you shown how to perform each exercise correctly?

How are you supported during the exercise classes?

- Do you think you are given enough time from the nurses/physios?
- Are you given enough opportunities to ask for help if you’re unsure of an exercise?

Do you know how the/How does the pulmonary team support you after you finish the programme?

- Advice and resources?
- If you haven’t finish rehab yet, do you know of anything to far?

TRANSITION: Thank you for your responses. We’re now going to move on and discuss if pulmonary rehabilitation made any difference to your capabilities. But first…

Improvements and assessments

Please could you briefly describe what your capabilities were like before attending pulmonary rehabilitation?

- How has pulmonary rehabilitation made a difference?
- physically, emotionally, confidence, strength?
- Has it made you feel stronger?
- In your day to day life?

How do you know how you’ve changed/improved over the course of the programme?

- From start to finish?

- Subjective feeling of improvement? Objective assessment outcome?

You complete the shuttle walk test at the beginning and end of the programme. Did you find this useful?

- Knowing if there's a difference in your walking capacity?

Would it be useful to know how your muscle strength has changed over the programme?

- Similar objective assessment to the walk test but measuring muscle strength.
- Do you think this would be useful? If so, how?
    - To you as a patient?
    - For the practitioners/service?
- Is it needed?

TRASNITION: Thank you for your responses. We're not going to move on and talk about the impact of pulmonary rehabilitation.

Impact

What was your overall experience like completing pulmonary rehabilitation?

- How important was it to you?
- What do you enjoy about the programme?
- What was your favourite part of the exercise class?

Has pulmonary rehabilitation improved your confidence in anyway?

- In your physical capabilities?

What has pulmonary rehabilitation taught you?

- Do you intend to use what you've learnt?
- Will you continue to exercise as you did in the class?

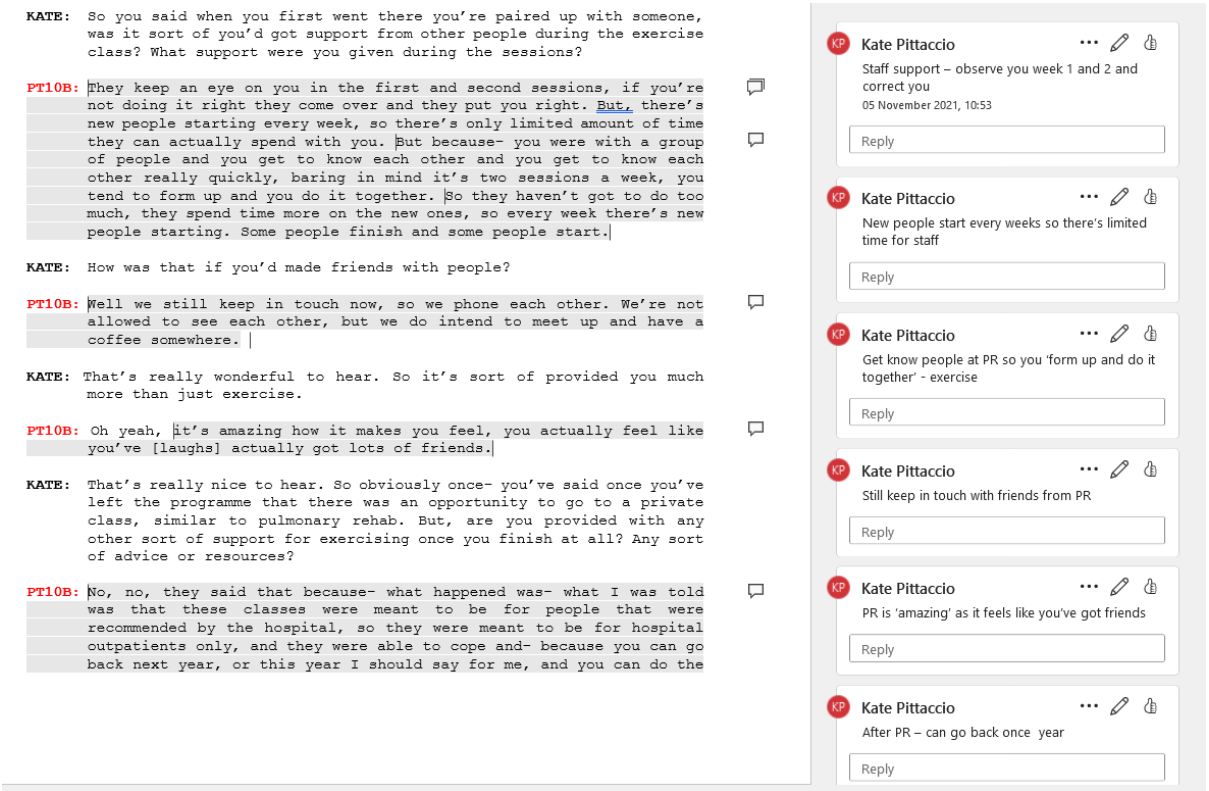
How do you think the programme could be improved?

Closing

Before we come to an end, is there anything else you would like to add or anything we haven't yet discussed that you think is important?

Appendix S

Patient interviews - coded transcript example (Microsoft Word)



KATE: So you said when you first went there you're paired up with someone, was it sort of you'd got support from other people during the exercise class? What support were you given during the sessions?

PT10B: They keep an eye on you in the first and second sessions, if you're not doing it right they come over and they put you right. But, there's new people starting every week, so there's only limited amount of time they can actually spend with you. But because- you were with a group of people and you get to know each other and you get to know each other really quickly, baring in mind it's two sessions a week, you tend to form up and you do it together. So they haven't got to do too much, they spend time more on the new ones, so every week there's new people starting. Some people finish and some people start.

KATE: How was that if you'd made friends with people?

PT10B: Well we still keep in touch now, so we phone each other. We're not allowed to see each other, but we do intend to meet up and have a coffee somewhere.

KATE: That's really wonderful to hear. So it's sort of provided you much more than just exercise.

PT10B: Oh yeah, it's amazing how it makes you feel, you actually feel like you've [laughs] actually got lots of friends.

KATE: That's really nice to hear. So obviously once- you've said once you've left the programme that there was an opportunity to go to a private class, similar to pulmonary rehab. But, are you provided with any other sort of support for exercising once you finish at all? Any sort of advice or resources?

PT10B: No, no, they said that because- what happened was- what I was told was that these classes were meant to be for people that were recommended by the hospital, so they were meant to be for hospital outpatients only, and they were able to cope and- because you can go back next year, or this year I should say for me, and you can do the

Kate Pittaccio
Staff support – observe you week 1 and 2 and correct you
05 November 2021, 10:53
Reply

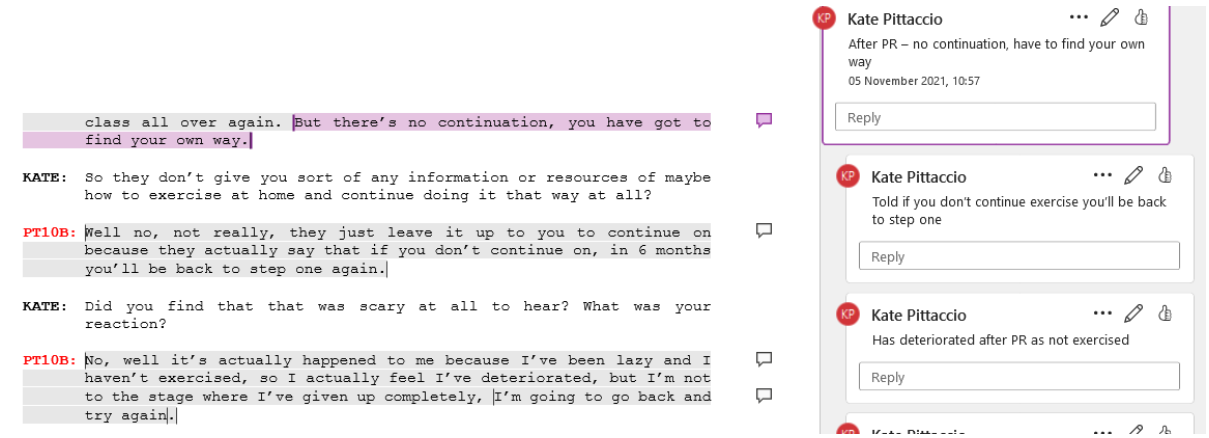
Kate Pittaccio
New people start every weeks so there's limited time for staff
Reply

Kate Pittaccio
Get know people at PR so you 'form up and do it together' - exercise
Reply

Kate Pittaccio
Still keep in touch with friends from PR
Reply

Kate Pittaccio
PR is 'amazing' as it feels like you've got friends
Reply

Kate Pittaccio
After PR – can go back once year
Reply



class all over again. But there's no continuation, you have got to find your own way.

KATE: So they don't give you sort of any information or resources of maybe how to exercise at home and continue doing it that way at all?

PT10B: Well no, not really, they just leave it up to you to continue on because they actually say that if you don't continue on, in 6 months you'll be back to step one again.

KATE: Did you find that that was scary at all to hear? What was your reaction?

PT10B: No, well it's actually happened to me because I've been lazy and I haven't exercised, so I actually feel I've deteriorated, but I'm not to the stage where I've given up completely, I'm going to go back and try again.

Kate Pittaccio
After PR – no continuation, have to find your own way
05 November 2021, 10:57
Reply

Kate Pittaccio
Told if you don't continue exercise you'll be back to step one
Reply

Kate Pittaccio
Has deteriorated after PR as not exercised
Reply

Appendix T

Patient interviews - example of electronically annotation lists/notes used for theme development/generation

Trail of theme development

21 April 2022 10:53

Initial coding groups (28th March 2022) - 18 groups of codes

Social - friends - peer support
- Friendships and family
- Opportunity to socialise
- Patient supporting each other
- Exercising with others
- Having a laugh
- Same condition
- Negatives

PR should be continuous or longer
- Want to go again
- Harder class after

Strength, ST and SA
- Strength assessment (pros and cons)
- Understanding of ST (uncertainty, misinformation)
- ST exercise and equipment details
- ST benefits and importance
- Weight selection
- Negatives
- Progression and improvement

Background to PR referral

PR exercise
- Exercises (structure and time)
- PR exercise was easy/hard
- Pushing yourself
- Exercise sheet and bands

Exercise after PR
- Difficulties
- Continued exercise after PR
- Intention to continue exercising

Exercise is important

Awareness they should exercise

Exercise barriers
- Covid/Lockdown
- Laziness
- Setting, environment, and life

Staff support
- Limited support
- Guidance
- Staff praise
- Don't push you
- Exercise modifications
- Exercise supervision
- Encouragement

ISWT

Exercise Limitations
- Comparison between then and now (age and condition)
- Breathlessness
- Physical limitations

Positive impact and benefits of PR and exercise
- PR praise and patient positive experience
- Psychological and mental benefit
- Shows there are worse people

Difference after PR
- Minor/no difference
- General notion of improvement
- Breathing
- Walking
- Daily activities

Previous exercise experience

Patient exercise (walking, gardening, daily activities)

Other aspects of PR (e.g. education, breathing exercises)

PR issues and constraints

2nd coding groups (21st April 2022) - 9 groups

Social - friends - peer support - community
- Friendships and family
- Opportunity to socialise
- Patient supporting each other
- Exercising with others
- Having a laugh and fun
- Meet people with the same condition
- Negatives (not a social club)

Exercise after PR
- Patients do continue exercise after PR
- Difficulties and barriers
- PR should be continuous or longer

Understanding of strength and ST
- ST is lifting weights etc
- Strength ST importance and benefits (lungs, muscles, daily activity)
- Misunderstanding of ST
- Negatives

Assessing strength has it's pros and cons
- SA helps exercise and motivation
- Patients have an interest I having strength assessed
- But, are unsure how it would be assessed
- And query relevance and usefulness

Understanding of exercise
- Exercise is important (e.g. for breathing/lungs and prevent decline)
- Awareness/Acknowledgement they should exercise
- Exercise limitations (breathlessness, health and physical ability)
- What is exercise to patients?
- Aim of exercise/PR is not to get fitter
- Impact of age and condition on physical ability (then and now comparison)

Positive impact and benefits from PR and exercise
- PR praise and positive experiences
- Psychological and mental benefit
- Comparison - There are worse people
- Positive impact on exercise? (does this go here?)

Improvements and differences after PR
- Improvements after PR
- Minor or no difference after PR
- Assumes there was a difference
- ISWT - pros and cons

Staff support with exercise
- Staff praise
- Exercise guidance and support
- Limited guidance due to time and class capacity
- Staff don't push (safety)
- Educational talks were informative and interesting

PR constraints - equipment and funding

Miscellaneous
- PR Exercise e.g. exercise and programme details
- Potential points of interest e.g. weight selection, progression, and varied perceptions of exercise being easy/hard
- Background to PR referral
- Previous exercise experience

3rd coding groups (5th July 2022) - 4 groups

Understanding
- Patients show understanding about ST, it's importance and benefits
- Patients show interest in SA and how it would be a benefit
  - But many didn't experience having their strength assessed
- Patients acknowledge the importance of exercise for maintaining health and preventing decline
  - Positive impact of exercise? (or is this already mentioned in above?)
  - Acknowledge they should exercise more?

Relevance (lack of understanding?)
- The aim/importance of ST has to be realistic and what they deem important e.g. daily function/activity
  - ST and body builders? - misunderstanding
- ST and going to the gym are not necessarily something patients and older adults would do (the gym is for young people?)
- Patients question the relevance of SA to them as a group/population

- Patients noticed improvements after PR – described them in terms of daily activities, breathing and walking (not DB weights/reps)
  - Patients describe exercise in terms of general activity e.g. walking, gardening, keeping active
- When talking about improvements patient referred to the ISWT – is this because it is relevant to something they do day to day i.e. walking

Exercise Support (during and after PR)
- Patients praise PR staff
- Staff provide exercise guidance and support
- Exercise is self-regulated staff (don't push them, go at own pace)
  - Picking weights/progression? Or is that linked with guidance and support above? Make sure it's what the patients are saying not my bias thoughts
- Staff support is limited by time and class capacity - patients are aware of constraints (could equipment/funding constraints go here?)
- Patient help/guided each other (due to limited staff support)
- Patients prefer exercising in a group (support from others e.g. motivation) - exercise barrier
- Patients wish PR was continuous/longer (e.g. for motivation and social enjoyment)
  - Notion that patients rely on annual PR? - patients say they can get invited to do it every year (sort of them thinking, it's ok as I'll be able to do it again)
- Continuing exercise after PR is down to the individual - exercise barrier?
- Acknowledge they should exercise more?
- Limited exercise class options after PR - exercise barrier

Psychosocial (benefits? of PR and exercise?)
- PR is a social event to meet new people
- PR is fun (can have a laugh)
- PR allows people to make friends
- Patients consider PR a family
- Social event – negative (not enough effort into exercise)
- PR praise and positive experience
- Psychological benefit of attending PR (improved mental wellbeing)
- PR allows for social comparisons (there are worse people)

Other
- Patients continue exercises after PR
- Equipment and funding constraints
- Some patients said they only noticed minor or no difference after PR. But, assume it must have made a difference some how

Lack of motivation (laziness) - barrier to exercise/support for PR group exercise (or is this more linked to group exercise and continuing PR)

Previous experience of ST/exercise? - look at interviews transcripts?

Many patients hadn't experienced having their strength assessed (only PT9 and PT11) - study limitation? Further research - opinion/experiences after?

Exercise limitations (breathing and physical ability)?

Check all comments about SA - e.g. progression

Appendix U

Survey recruitment email

Participant Recruitment Email

Dear,

RE: Invitation to participate in research - pulmonary rehabilitation survey

A research study is being conducted by a PhD researcher at the University of Essex to investigate the use/provision of strength training and strength assessment in pulmonary rehabilitation. For more information, please read the **Participant Information Sheet** attached.

STUDY INFORMATION

TITLE: Strength assessment and strength training in pulmonary rehabilitation: an online survey of services in England

BRIEF DESCRIPTION: This study is looking for people who manage, run, or assist in pulmonary rehabilitation exercise programmes (e.g. service/site leads, physiotherapists, nurses, assisting staff and volunteers) to complete an online survey. It will ask questions about the use of strength training and strength assessment in the programme provided. Some questions will focus on standard face-to-face programmes before the Covid-19 pandemic. It will take about 20-25 minutes to complete, and you will only have to complete the survey once. More information can be found in the **Participant Information Sheet** attached.

SURVEY: To access and complete the survey either click the link below or scan the QR code to complete it on your smartphone/mobile device.

Link: https://essex.eu.qualtrics.com/jfe/form/SV_dbY8b5SQSlUEVp4

QR Code:

If you have any questions about this study, please contact the lead researcher, Kate Pittaccio, at kp19988@essex.ac.uk

If you know of anyone else who works in pulmonary rehabilitation and would be interested in taking part, please feel free to share the study information and survey link.

Kind regards,

Appendix V

Survey PIS

PARTICIPANT INFORMATION SHEET

Strength assessment and strength training in pulmonary rehabilitation: An online survey of services in England

We would like to invite you to take part in this study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. There are details at the end on how to contact us if you have any questions or concerns.

This study is being run as part of a PhD Studentship, funded by the University of Essex and the pulmonary rehabilitation service, Provide.

The Study

Exercise is an important part of pulmonary rehabilitation, especially strength (or resistance) training. However, it is unclear how services are delivering it in their programmes. It has also been reported that the majority of services in England do not assess patient muscle strength. Therefore, this study aims to gain a greater understanding of strength training and strength assessment in pulmonary rehabilitation, as well as identify any factors that may influence or impact their use. As this study is interested in standard face-to-face pulmonary rehabilitation exercise programmes, some of the questions will focus on the time before the Covid-19 pandemic i.e. before March 2020.

We are inviting people who work in pulmonary rehabilitation (e.g. service managers/leads, site leads, physiotherapists, nurses, assistants, and volunteers) to take part in this study by completing an online survey.

Who can take part?

You will be able to take part if:

- You are an adult, aged 18 years or older
- You have a job role in pulmonary rehabilitation either running, managing, or assisting in pulmonary rehabilitation exercise programmes
- You worked in pulmonary rehabilitation conducting standard face-to-face exercise programmes before the Covid-19 pandemic started i.e. before March 2020
- You work for a pulmonary rehabilitation service located in England
- You are not currently taking part in another conflicting study

What will happen if you take part?

You will be asked to complete an online survey, hosted on Qualtrics, a web-based survey tool and platform. You can complete it on any computer, smartphone, or tablet device with internet access. No

other resources will be needed. The survey will take about 20-25 minutes to complete. At the start, you will be asked some questions to make sure you are eligible. You will also be asked to give your consent to take part.

During the survey, you will be asked questions about:

- You and the pulmonary rehabilitation service you work for
- How strength training is delivered in the pulmonary rehabilitation exercise programme
- If the pulmonary rehabilitation service measures patient muscle strength, and if so, how
- Any relevant training you may have done, both inside and outside of your pulmonary rehabilitation job
- Your attitudes and opinions towards strength training and strength assessment in pulmonary rehabilitation
- Potential difficulties faced in pulmonary rehabilitation when delivering strength training and assessing patient muscle strength

Risks & Benefits

Taking part in this study presents no risks, as the survey does not contain any questions likely to cause distress or discomfort. Nevertheless, when completing the survey, if there is a question you do not want to answer you will have the opportunity to skip it and refuse/decline to answer. We understand there is an element of inconvenience as we are asking you to give up some of your time. However, your participation will help further our understanding and provide a clearer picture of strength training and strength assessment provision in pulmonary rehabilitation. The results of this study have the potential to improve this area of clinical practice and make positive change, benefiting both patients and staff.

Your Rights

All data collected will be anonymous and confidential. Your participation in this study is completely voluntary, and you are free to stop filling in the survey and exit at any time, no explanation necessary. You can do this by simply closing the web browser tab/window displaying the survey. Please note, if you start the survey but do not finish it, the responses you have provided up until that point will still be collected and may still be included in the study analysis. Furthermore, as all data collected is anonymous, it is not possible for your data to be excluded as it cannot be identified. Taking part in this research study is not a requirement of you within your role working in pulmonary rehabilitation, and your employment or job will not be affected if you decide not to participate or do not finish the survey.

Data Protection

The University of Essex is the sponsor for this study based in the United Kingdom. We will be using information from you in order to undertake this research and will act as the data controller for this study. This means that we are responsible for looking after your information and using it properly. All information you give us will be anonymous and confidential. It will be kept safe and secure. This study is not actively collecting personal identifiable information (e.g. names, addresses, contact details etc). Nevertheless, on the chance that such information is presented within survey responses, measures will be taken to ensure anonymity and uphold confidentiality wherever possible. Please note, certain individuals from the University of Essex and regulatory organisations may look at the research data to

check the accuracy of the research study. Once the study has concluded, the anonymised survey dataset will be deposited into the University of Essex's Research Data Repository, so it is available for future research and learning activities by other individuals. The dataset will be stored here for 20 years, after which it will be destroyed.

Your rights to access, change, or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. Again, if you provide a partial response to the survey (i.e. you do not finish it), we will keep the responses that we have already obtained. You can find out more about how we use your information by contacting the Information Assurance Manager at dpo@essex.ac.uk or 01206 874853.

The results of this study will be included in the PhD thesis and may also contribute to other academic outputs, such as papers in relevant conferences and journals. Direct quotes may be used, but if so, measures will be taken to ensure confidentiality. We will be happy to provide you with a summary of the main findings, available upon your request, please contact the Chief Investigator. This research project has been granted approval by the Health Research Authority and University of Essex.

Concerns and complaints

If you have concerns about any aspect of the study or you have a complaint, in the first instance please contact the Chief Investigator, Kate Pittaccio. If you are still concerned or you think your complaint has not been addressed to your satisfaction, please contact the Director of Research, Dr Ruth Lowry. If you are still not satisfied, please contact the University's Research Governance and Planning Manager, Sarah Manning-Press. **All contact details are below.**

Contact Details

Chief Investigator
Kate Pittaccio
School of Sports, Rehabilitation & Exercise Sciences, University of Essex, Wivenhoe Park, CO4 3SQ
Email: kp19988@essex.ac.uk Phone: 07463427327

Academic PhD Supervisors
Dr Benjamin Jones
School of Sports, Rehabilitation & Exercise Sciences, University of Essex, Wivenhoe Park, CO4 3SQ
Email: bjonesa@essex.ac.uk Phone: 01206 872414
Izzie Easton
School of Sports, Rehabilitation & Exercise Sciences, University of Essex, Wivenhoe Park, CO4 3SQ
Email: eeaston@essex.ac.uk Phone: 01206 873071
Dr Leanne Andrews
School of Health and Social Care, University of Essex, Wivenhoe Park, CO4 3SQ
Email: landre@essex.ac.uk Phone: 01206 874547

Director of Research - School of Sports, Rehabilitation & Exercise Sciences
Dr Ruth Lowry

School of Sports, Rehabilitation & Exercise Sciences, University of Essex, Wivenhoe Park, CO4 3SQ
Email: r.lowry@essex.ac.uk Phone: 01206 872046

Research Governance and Planning Manager - University of Essex

Sarah Manning-Press
Research & Enterprise Office, University of Essex, Wivenhoe Park, CO4 3SQ
Email: sarahm@essex.ac.uk Phone: 01206 873561

We would like to thank you for your interest in this study.

Appendix W

Survey consent form

Participant Consent Form (embedded in survey)

Strength assessment and strength training in pulmonary rehabilitation: A survey of services in England

Hello!

We would like to thank you for your interest in this study.

It is being carried out as part of a PhD research project at the University of Essex and aims to explore strength assessment and strength training in pulmonary rehabilitation services across England, specifically in standard face-to-face exercise programmes.

Before deciding to take part, it is **very important** you read the Participant Information Sheet. Please click here: [INSERT FILE]

The survey will take about 20-25 minutes to complete, and you only have to complete it once.

Your responses are completely anonymous and confidential. Questions marked with an asterisk (*) are required. If you have any questions about the study or survey, please email Kate Pittaccio at kp19988@essex.ac.uk

Click the arrow below and it will take you through to the next page.

Eligibility

Before you start, we need to make sure you are eligible to take part. Please read the questions below carefully and answer 'yes' or 'no' to each.

Q1 Are you aged 18 years or older? *

- ○ Yes
- ○ No

Q2 Does your job role in pulmonary rehabilitation involve running, managing, or assisting pulmonary rehabilitation exercise programmes? *

- ○ Yes
- ○ No

Q3 Did you work in pulmonary rehabilitation conducting standard face-to-face exercise programmes before the Covid-19 pandemic started i.e. before March 2020? *

- ○ Yes
- ○ No

Q4 Do you work for a pulmonary rehabilitation service located in England? *

- ○ Yes
- ○ No

Q5 Are you currently taking part in any other conflicting study? *

- ○ Yes
- ○ No

Display This Question:

If Q1 = No

Or Q2 = No

Or Q3 = No

Or Q4 = No

Or Q5 = Yes

If ineligible:
Thank you for answering those questions. Unfortunately, you are not eligible to take part. We would like to thank you for your interest and time. If this is incorrect, please go back or start the survey again. If you have any questions or concerns about this, please contact us at: kp19988@essex.ac.uk

Skip To: End of Survey If ineligible message Is Displayed

Consent

We are happy to let you know you are eligible to take part!

One last thing. It is very important we get your consent before you start the survey. Please read the statements below carefully, and answer 'yes' or 'no' to each.

Your participation is entirely voluntary, and you are free to stop filling in the survey and exit at any time. To exit, simply close the web browser tab/window displaying the survey.

Q6 I confirm that I have read and understand the Participant Information Sheet (Version 0.1, 9th August 2021), and have had the opportunity to consider the information, ask questions and have had these questions answered satisfactorily. *

- ○ Yes
- ○ No

Q7 I agree to take part in this study. *

- ○ Yes
- ○ No

Display This Question:

If Q6 = No

Or Q7 = No

If do not consent:
You have decided not to take part. We would like to thank you for your interest and time. If this is incorrect, please go back or start the survey again. If you have any questions or concerns about this, please contact us at: kp19988@essex.ac.uk

Skip To: End of Survey If non_consent_message Is Displayed

Appendix X

HRA ethical approval letter for PR survey study

Ymchwil Iechyd a Gofal Cymru
Health and Care Research Wales

NHS
Health Research Authority

Miss Kate Pittaccio
Postgraduate PhD Student
University of Essex
School of Sports, Rehabilitation and Exercise Sciences
Wivenhoe Park
Colchester
CO4 3SQN/A

Email: approvals@hra.nhs.uk
HCRW.approvals@wales.nhs.uk

15 September 2021 **Re-issued 07 October 2021 to reflect that the study involves research sites**

Dear Miss Pittaccio

HRA and Health and Care Research Wales (HCRW) Approval Letter

Study title:	**Strength assessment and strength training in pulmonary rehabilitation: an online survey of services in England**
IRAS project ID:	**302999**
REC reference:	**21/HRA/4032**
Sponsor	**University of Essex**

I am pleased to confirm that **HRA and Health and Care Research Wales (HCRW) Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications received. You should not expect to receive anything further relating to this application.

Please now work with participating NHS organisations to confirm capacity and capability, in line with the instructions provided in the "Information to support study set up" section towards the end of this letter.

How should I work with participating NHS/HSC organisations in Northern Ireland and Scotland?
HRA and HCRW Approval does not apply to NHS/HSC organisations within Northern Ireland and Scotland.

If you indicated in your IRAS form that you do have participating organisations in either of these devolved administrations, the final document set and the study wide governance report (including this letter) have been sent to the coordinating centre of each participating nation. The relevant national coordinating function/s will contact you as appropriate.

Please see IRAS Help for information on working with NHS/HSC organisations in Northern Ireland and Scotland.

How should I work with participating non-NHS organisations?
HRA and HCRW Approval does not apply to non-NHS organisations. You should work with your non-NHS organisations to obtain local agreement in accordance with their procedures.

What are my notification responsibilities during the study?

The *"After HRA Approval – guidance for sponsors and investigators"* document on the HRA website gives detailed guidance on reporting expectations for studies with HRA and HCRW Approval, including:

- Registration of Research
- Notifying amendments
- Notifying the end of the study

The HRA website also provides guidance on these topics and is updated in the light of changes in reporting expectations or procedures.

Who should I contact for further information?
Please do not hesitate to contact me for assistance with this application. My contact details are below.

Your IRAS project ID is **302999**. Please quote this on all correspondence.

Yours sincerely,
Andrea Bell

Approvals Specialist

Email: approvals@hra.nhs.uk

Copy to: *Ms Sarah Manning-Press*

List of Documents

The final document set assessed and approved by HRA and HCRW Approval is listed below.

Document	*Version*	*Date*
Copies of materials calling attention of potential participants to the research [Recruitment Advert]	1.0	09 August 2021
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [Sponsor Insurance and Indemnity]	1.0	01 August 2021
IRAS Application Form [IRAS_Form_07092021]		07 September 2021
IRAS Application Form XML file [IRAS_Form_07092021]		07 September 2021
IRAS Checklist XML [Checklist_07092021]		07 September 2021
Letter from sponsor [Letter from Sponsor]	1.0	03 September 2021
Letters of invitation to participant [Participant Recruitment Email]	1.0	09 August 2021
Non-validated questionnaire [Survey]	1.0	09 August 2021
Organisation Information Document [Organisation Information Document]	1.0	09 August 2021
Participant consent form [Consent Form]	1.0	09 August 2021
Participant information sheet (PIS) [PIS]	1.0	09 August 2021
Research protocol or project proposal [Research Protocol]	1.0	09 August 2021
Schedule of Events or SoECAT [Schedule of Events]	1.0	09 August 2021
Summary CV for Chief Investigator (CI) [Kate Pittaccio CV]		09 August 2021
Summary CV for student [Kate Pittaccio CV]	1.0	09 August 2021
Summary CV for supervisor (student research) [Ben Jones CV]	1.0	07 January 2020
Summary CV for supervisor (student research) [Izzie Easton CV]	1.0	06 August 2021
Summary CV for supervisor (student research) [Leanne Andrews CV]	1.0	06 August 2021

IRAS project ID	302999

Information to support study set up

The below provides all parties with information to support the arranging and confirming of capacity and capability with participating NHS organisations in England and Wales. This is intended to be an accurate reflection of the study at the time of issue of this letter.

Types of participating NHS organisation	Expectations related to confirmation of capacity and capability	Agreement to be used	Funding arrangements	Oversight expectations	HR Good Practice Resource Pack expectations
All sites will perform the same research activities therefore there is only one site type.	Organisations will not be required to formally confirm capacity and capability, and research procedures may begin 35 days after provision of the local information pack, provided the following conditions are met. • You have contacted participating NHS organisations (see below for details) • HRA and HCRW Approval has been issued • The NHS organisation has not provided a reason as to why they cannot participate • The NHS organisation has not requested additional time to	An Organisation Information Document has been submitted and the sponsor is not requesting and does not expect any other site agreement to be used.	No study funding will be provided to sites as per the Organisation Information Document.	The Chief Investigator will be responsible for all research activities performed at study sites.	The sponsor has indicated that local staff in participating organisations in England who have a contractual relationship with the organisation will undertake the expected activities. Therefore, no honorary research contracts or letters of access are expected for this study.

	confirm. You may start the research prior to the above deadline if HRA and HCRW Approval has been issued and the site positively confirms that the research may proceed. You should now provide the local information pack for your study to your participating NHS organisations. A current list of R&D contacts is accessible at the NHS RD Forum website and these contacts MUST be used for this purpose. The password to access the R&D contact list is Redhouse1.				

Other information to aid study set-up and delivery

This details any other information that may be helpful to sponsors and participating NHS organisations in England and Wales in study set-up.
The applicant has indicated they do not intend to apply for inclusion on the NIHR CRN Portfolio.

Appendix Y

University of Essex ethical approval for PR survey study

From: ERAMS
Sent: 16 October 2021 09:32
To: Pittaccio, Kate F
Subject: Decision - Ethics ETH2122-0177: Miss Kate Pittaccio

University of Essex ERAMS

16/10/2021

Miss Kate Pittaccio

Sport, Rehabilitation, and Exercise Sciences, Sport, Rehabilitation, and Exercise Sciences

University of Essex

Dear Kate,

Ethics Committee Decision

Application: ETH2122-0177

I am writing to advise you that your research proposal entitled "Strength assessment and strength training in pulmonary rehabilitation: an online survey of services in England" has been reviewed by the Ethics Sub Committee 2.

The Committee is content to give a favourable ethical opinion of the research. I am pleased, therefore, to tell you that your application has been granted ethical approval by the Committee.

Please do not hesitate to contact me if you require any further information or have any queries.

Yours sincerely,

Aaron Wyllie

Ethics ETH2122-0177: Miss Kate Pittaccio

Appendix Z

Survey

Survey: Strength Assessment and Strength Training in Pulmonary Rehabilitation

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About you

In this first section you will be asked questions about yourself and your job in pulmonary rehabilitation.

Q8

What is your current age?

Years _____

Q9

Which gender do you most identify with?

- ○ Male
- ○ Female
- ○ Transgender Male
- ○ Transgender Female
- ○ Gender variant/non-conforming
- ○ Prefer not to say
- ○ Other (please specify) _____

Q10

What is your ethnic origin?

- ○ Asian or Asian British (Indian, Pakistani, Bangladeshi)
- ○ Black or Black British (Caribbean, African)
- ○ Mixed/multiple ethnic groups
- ○ White (English, Welsh, Scottish, Northern Irish, British, Irish, gypsy/Irish traveler)
- ○ Chinese
- ○ Arab
- ○ Other (please specify) _____

Q11

What is the highest level of education you have completed or the highest degree you have received?

- ○ Less than GCSE's
- ○ GCSE’s or equivalent
- ○ AS/A Levels or equivalent
- ○ Undergraduate degree
- ○ Postgraduate degree
- ○ Doctoral Level degree
- ○ I don't know/Unsure
- ○ Other (please specify) _____

Q12

What best describes your job role in pulmonary rehabilitation?
Please select from the drop-down menu below. If your job role is not named, please select 'other' at the bottom of the list.

- ○ Physiotherapist
- ○ Registered nurse
- ○ Healthcare assistant
- ○ Therapy assistant
- ○ Fitness instructor
- ○ Exercise physiologist
- ○ Dietitian/nutritionist
- ○ Occupational therapist
- ○ Clinical psychologist
- ○ Technical instructor
- ○ Health psychologist
- ○ Respiratory physician
- ○ Respiratory physiologist
- ○ Social worker
- ○ Doctor
- ○ Pharmacist
- ○ Volunteer
- ○ Other

Display This Question:

If Q12 = Other

Q13

You selected 'other', please specify.

_____

Q14

What is your NHS grade/pay band?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8a
- ○ 8b
- ○ 8c
- ○ 8d
- ○ 9
- ○ I don't know/Unsure
- ○ Not applicable (N/A)

Q15

How long have you worked in this job role?

Year(s) _____

Month(s) _____

Q16

How long have you worked in pulmonary rehabilitation overall?

Year(s) _____

Month(s) _____

Q17

What is the extent of your involvement in pulmonary rehabilitation?
(Tick all that apply)
Please select the duties that were included in your job role, when conducting standard face-to-face

pulmonary rehabilitation, before the Covid-19 pandemic i.e. before March 2020.

- ☐ Service manager
- ☐ Site lead
- ☐ Leading exercise sessions
- ☐ Assisting exercise sessions
- ☐ Conducting patient assessments
- ☐ Delivering educational sessions
- ☐ Other (please specify) _____

End of Block: Demographics and Job Details

Start of Block: Service and Site Details

Service and site details

In this section you will be asked questions about the pulmonary rehabilitation service you work for and the sites it runs from.

As we are concerned with standard face-to-face pulmonary rehabilitation, please answer these questions thinking back to the pulmonary rehabilitation programme before the Covid-19 pandemic i.e. before March 2020.

Q18

What is the name of the pulmonary rehabilitation service?
Please select from the drop-down menu below. If the service is not named, please select 'other' at the bottom of the list.

- ACE Pulmonary Rehabilitation Service
- Acute Respiratory Assessment Service (ARAS) COPD support team - North Manchester
- Aintree Pulmonary Rehabilitation Programme
- AIR Service
- Airedale - Wharfedale and Craven Pulmonary Rehabilitation Service
- Atrium Coventry and Warwickshire Pulmonary Rehabilitation Service
- Barnet COPD Respiratory Service
- Bassetlaw Pulmonary Rehabilitation Service
- BCHC Community Respiratory Service
- Bedford Hospital Pulmonary Rehabilitation
- BEET: Breathing, Exercise, Education Training
- Berkshire West Cardiac and Respiratory Specialist Services
- Bexley CCG Pulmonary Rehabilitation
- Blackburn with Darwen Pulmonary Rehabilitation Team
- Blackpool Pulmonary Rehabilitation Service
- Bolton Pulmonary Rehabilitation Programme
- Bradford Pulmonary Rehabilitation Service
- Brent Pulmonary Rehabilitation Service

- ○ Bristol Community Respiratory Service
- ○ Bromley Pulmonary Rehabilitation
- ○ Buckinghamshire Pulmonary Rehabilitation Services
- ○ Calderdale Pulmonary Rehabilitation Service
- ○ Camden COPD & Home Oxygen Service
- ○ Central and West London Pulmonary Rehabilitation Service
- ○ Central Cheshire Integrated Care Partnership Pulmonary Rehabilitation Service
- ○ Central Lancashire Pulmonary Rehabilitation Service
- ○ Chelsea and Westminster Hospital Pulmonary Rehabilitation
- ○ Cheshire and Wirral Partnership Respiratory Service
- ○ Community COPD Team Carlisle
- ○ COPD Coastal Service
- ○ Crawley Horsham and Mid Sussex COPD Adult Community Services
- ○ Croydon Pulmonary Rehabilitation Programme
- ○ CSH Surrey Pulmonary Rehabilitation Programme
- ○ Darlington Pulmonary Rehabilitation
- ○ Derby and Burton ImpACT+
- ○ Doncaster Pulmonary Rehabilitation Services
- ○ Dorset Healthcare Pulmonary Rehabilitation Programme
- ○ Dorset Pulmonary Rehabilitation service
- ○ Dudley Pulmonary Rehabilitation Programme

- ○ Durham Dales Easington and Sedgefield (DDES) Pulmonary Rehabilitation Programme
- ○ Ealing Pulmonary Rehabilitation service
- ○ East Cheshire Pulmonary Rehabilitation Service
- ○ East London Pulmonary Rehabilitation Service
- ○ East Riding Pulmonary Rehabilitation Programme
- ○ East Staffordshire Pulmonary Rehabilitation Service
- ○ East Suffolk Pulmonary Rehabilitation Service
- ○ ELHT Pulmonary Rehabilitation Service
- ○ Enfield Respiratory Service
- ○ Enhanced Respiratory Service (ERS) – Rochdale Infirmary
- ○ EPUT Pulmonary Rehabilitation Programme
- ○ First Community Health and Care Surrey Community Respiratory Service
- ○ Furness Pulmonary Rehabilitation Service
- ○ Gateshead Acute Pulmonary Rehabilitation Service
- ○ George Eliot Hospital Pulmonary Rehabilitation - Physiotherapy
- ○ Glenfield and Leicester Hospitals Pulmonary Rehabilitation Programme
- ○ Greater Huddersfield Pulmonary Rehabilitation Service
- ○ Greenwich Pulmonary Rehabilitation Team
- ○ Halton Pulmonary Rehabilitation service
- ○ Hammersmith & Fulham Cardio-Respiratory Service
- ○ Hampshire Pulmonary Rehabilitation Programme

- ○ Harefield Hospital Pulmonary Rehabilitation
- ○ Harrogate Respiratory and Cardiac Physiotherapy
- ○ Harrow COPD Respiratory Service
- ○ Havering Respiratory Team
- ○ Herefordshire Pulmonary Rehabilitation Programme
- ○ Hertfordshire Community Pulmonary Rehab Service
- ○ Homerton Adult Cardiorespiratory Enhanced and Responsive service (ACERs)
- ○ Hope Street Specialist Service
- ○ Hounslow Community Respiratory Team
- ○ Hull Pulmonary Rehabilitation Team
- ○ Huntingdon Pulmonary Rehabilitation
- ○ Integrated Community Respiratory Team East Cornwall (ICRTEC)
- ○ Integrated Respiratory Service Basildon, Brentwood and Thurrock
- ○ Kent Community Health Pulmonary Rehabilitation Team
- ○ King's College Hospital Pulmonary Rehabilitation Team
- ○ Knowsley Community Respiratory Service
- ○ Leeds Community Healthcare, Community Respiratory Service
- ○ Leicestershire Partnership Pulmonary Rehabilitation Team
- ○ Lewisham LEEP Pulmonary Rehabilitation Programme
- ○ Lincolnshire Community Health Services Pulmonary Rehabilitation Service
- ○ Livewell SW Community Respiratory Service

- ○ Luton and Dunstable Hospital Pulmonary Rehabilitation Service
- ○ Luton Community Respiratory Service
- ○ Manchester Community Respiratory Service
- ○ Manchester Integrated Lung Service – Central site
- ○ Manchester Royal Infirmary Pulmonary Rehabilitation Service
- ○ Mansfield and Ashfield Respiratory Service
- ○ Medway Community Respiratory Team
- ○ Merton Pulmonary Rehabilitation Service
- ○ Mid Yorkshire Therapy Services - Community Pulmonary Rehabilitation
- ○ Mid, West, North Cornwall Pulmonary Rehabilitation Programme
- ○ Midland Partnership South Respiratory Team
- ○ Midlands Partnership – North Staffordshire and Stoke on Trent Pulmonary Rehabilitation Team
- ○ Milton Keynes Community Pulmonary Rehabilitation Service
- ○ Milton Keynes Hospital Pulmonary Rehabilitation Programme
- ○ Newark and Sherwood Pulmonary Rehabilitation Service
- ○ Newcastle Healthy Lungs Programme
- ○ Norfolk and Norwich Pulmonary Rehabilitation Service
- ○ Norfolk Community Pulmonary Rehabilitation Service
- ○ North Bristol Lung Exercise and Education Programme (LEEP)
- ○ North Cumbria Hospitals Pulmonary Rehabilitation Programme

- ○ North Derbyshire Community Respiratory Service
- ○ North Devon Pulmonary Rehabilitation Service
- ○ North Durham Pulmonary Rehabilitation
- ○ North East Hampshire and Farnham (NEH&F) Pulmonary Rehabilitation Service
- ○ North Kirklees Pulmonary Rehabilitation Programme
- ○ North Lancashire Pulmonary Rehabilitation
- ○ North Somerset Pulmonary Rehabilitation
- ○ North Tees and Hartlepool Pulmonary Rehabilitation Service
- ○ North West Surrey Respiratory Care Team
- ○ Northumbria Healthcare Pulmonary Rehabilitation Service
- ○ Nottingham Integrated Respiratory Service
- ○ Nottingham North and East Adult Community Services
- ○ Nottingham West Pulmonary Rehabilitation
- ○ One Gloucestershire Respiratory Service
- ○ Oxfordshire Pulmonary Rehabilitation Service
- ○ Papworth Hospital Pulmonary Rehabilitation Programme
- ○ Pennine Lung Service
- ○ Pennine Pulmonary Rehabilitation - Fairfield Hospital
- ○ Peterborough Pulmonary Rehabilitation Service
- ○ Portsmouth Pulmonary Rehabilitation Programme
- ○ Provide - Cambridgeshire Pulmonary Rehabilitation

- ○ Provide – Mid-Essex Pulmonary Rehabilitation
- ○ Pulmonary Rehabilitation Service Fylde and Wyre
- ○ Redbridge Respiratory Service
- ○ Regional East Sussex Pulmonary Service (RESPS)
- ○ Respiratory Services - Barking and Dagenham
- ○ Restart Team – Northampton General Hospital
- ○ Richmond Respiratory Care Team
- ○ Rocket Team Kettering General Hospital
- ○ Rotherham Breathing Space
- ○ Royal Berkshire Hospital Pulmonary Rehabilitation Service
- ○ Royal Brompton Pulmonary Rehabilitation Service
- ○ Royal Devon & Exeter Pulmonary Rehabilitation/Physiotherapy Service
- ○ Royal Surrey Pulmonary Rehabilitation Programme
- ○ RUH Respiratory Outpatient Department
- ○ Rushcliffe Cardiorespiratory service
- ○ Salford's Breathing Better Pulmonary Rehabilitation Programme
- ○ Salisbury Lung Exercise and Education Programme (LEEP)
- ○ Sandwell and West Birmingham Community Respiratory Service
- ○ Sarum Community Based Pulmonary Rehabilitation Team
- ○ Sefton Community Respiratory Service
- ○ Sheffield Community Pulmonary Rehabilitation Service

- ○ Shropshire Pulmonary Rehabilitation
- ○ Solihull Community Respiratory Team
- ○ Solway Community Respiratory Team
- ○ Somerset Pulmonary Rehabilitation Service
- ○ South East Essex Pulmonary Rehabilitation Service
- ○ South East Staffordshire Pulmonary Rehabilitation Service
- ○ South Gloucestershire Pulmonary Rehabilitation
- ○ South Lakes Community Respiratory Service
- ○ South Tees Pulmonary Rehabilitation Service
- ○ South Tyneside Pulmonary Rehabilitation Programme (Acute)
- ○ South Warwickshire Physiotherapy Services
- ○ South West Yorkshire Cardiac and Pulmonary Rehabilitation Service
- ○ Southampton Integrated COPD Team
- ○ St Mary’s Hospital Pulmonary Rehabilitation Programme
- ○ St Richards Hospital Pulmonary Rehabilitation
- ○ St Thomas' Hospital Pulmonary Rehabilitation programme
- ○ St. Helens Pulmonary Rehabilitation Service
- ○ Stockport Pulmonary & Heart Failure Rehabilitation Service
- ○ Sunderland Community Pulmonary Rehabilitation Programme
- ○ Surrey Heath Respiratory Care Team
- ○ Sussex Community Respiratory Service Brighton and Hove

- ○ Sutton Community Respiratory Service
- ○ Swale Pulmonary Rehabilitation
- ○ Swindon Healthy Lives Pulmonary Rehabilitation Programme
- ○ Tameside and Glossop Pulmonary Rehabilitation
- ○ The Bournemouth Hospital's Pulmonary Rehabilitation Service
- ○ The Breathe Programme
- ○ The High Weald Lewis and Haven Community Respiratory Service
- ○ The Newcastle Hospitals Respiratory Services
- ○ The North Lincolnshire Respiratory Service
- ○ Torbay and South Devon Pulmonary Rehabilitation Programme
- ○ Tower Hamlets Pulmonary Rehabilitation Service
- ○ Trafford Pulmonary Rehabilitation Service
- ○ University Hospital Southampton Pulmonary Rehabilitation Programme
- ○ University Hospitals Birmingham HGS Pulmonary Rehabilitation Programme
- ○ Virgin Care Community Respiratory Service - Bath and North East Somerset
- ○ Walsall Pulmonary Rehabilitation Service
- ○ Waltham Forest Pulmonary Rehabilitation Service
- ○ Wandsworth Pulmonary Rehabilitation Service
- ○ Warrington Pulmonary Rehabilitation Service
- ○ West Cumbria Community Respiratory Team
- ○ West Hampshire Community Integrated Respiratory Service

- ○ West Hertfordshire Community Respiratory Service
- ○ West Kent Pulmonary Rehabilitation Service
- ○ West Lancashire Pulmonary Rehabilitation
- ○ West Norfolk BOC Pulmonary Rehabilitation Service
- ○ West Suffolk Pulmonary Rehabilitation Service
- ○ Whittington Health Pulmonary Rehabilitation
- ○ Wiltshire Community Respiratory Team
- ○ Wirral COPD, Pulmonary Rehabilitation & Oxygen Service
- ○ Wolverhampton Pulmonary Rehabilitation Service
- ○ Worcestershire COPD Team
- ○ Worthing & Southlands Pulmonary Rehabilitation Programme
- ○ Wrightington Wigan and Leigh tier 2 Respiratory Services
- ○ York and Selby Pulmonary Rehabilitation
- ○ Your Healthcare Pulmonary Rehabilitation Service
- ○ Other

Display This Question:

If Q18 = Other

Q19

You selected 'other', please specify.

_____

Q20

What type of organisation provides the pulmonary rehabilitation service?

- [ ] NHS acute trust
- [ ] NHS non-acute or community trust
- [ ] NHS health board
- [ ] Community interest company (CIC)
- [ ] Private healthcare provider
- [ ] Integrated Care Organisation (ICO)
- [ ] Charity
- [ ] Council
- [ ] Research
- [ ] GP federation
- [ ] I don't know/Unsure
- [ ] Other (please specify) _____

Q21

How many sites does the pulmonary rehabilitation service run from?
Please answer thinking back to the pulmonary rehabilitation service before the Covid-19 pandemic i.e. before March 2020

_____

Q22
Of these sites, how many do you regularly work at?

Please provide the geographical location name of each site (e.g. village or town). If you work at multiple sites, please order the sites from most to least worked, with Site 1 being the site you predominately work at.

Please answer thinking back to before the Covid-19 pandemic i.e. before March 2020

- ○ Site 1: _____
- ○ Site 2: _____
- ○ Site 3: _____
- ○ Site 4: _____
- ○ Site 5: _____
- ○ Site 6: _____

Page Break

Q23
What type of venue does the pulmonary rehabilitation programme run from?
Please select the option from the drop-down menu which best describes the venue for each site you work at.

	Church or community hall	Local leisure centre or gym	Community hospital	Acute hospital	Health centre	GP surgery	Other
Site 1:	○	○	○	○	○	○	○
Site 2:	○	○	○	○	○	○	○
Site 3:	○	○	○	○	○	○	○
Site 4:	○	○	○	○	○	○	○
Site 5:	○	○	○	○	○	○	○
Site 6:	○	○	○	○	○	○	○

Display This Question:
If Q23 = Other

Q24

You selected 'other', please specify.

_____

End of Block: Service and Site Details

Start of Block: Strength Assessments: Overview

Strength assessment in pulmonary rehabilitation

In this section you will be asked if the pulmonary rehabilitation service you work for assesses patient

muscle strength, and if so, what strength assessment is used.

As we are concerned with standard face-to-face pulmonary rehabilitation, please answer these questions thinking back to the pulmonary rehabilitation programme before the Covid-19 pandemic i.e. before March 2020.

Q25
Does the pulmonary rehabilitation service assess patient muscle strength or use a strength assessment?
NOTE: A strength assessment is a procedure/device used to measure, test, or assess a patient's peripheral muscle strength e.g. arms or legs

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: End of Block If Q25 = No
Skip To: End of Block If Q25 = I don't know/Unsure

Q26

How does the pulmonary rehabilitation service assess patient muscle strength i.e. what strength assessment is used? (Tick all that apply)

- ☐ One Repetition Maximum (1-RM) i.e. maximum weight lifted for one exercise repetition
- ☐ Multiple Repetition Maximum (m-RM) i.e. maximum weight lifted for a certain number of exercise repetitions
- ☐ 5 Repetition Sit to Stand (5S2S)
- ☐ Dynamometer e.g. hand grip
- ☐ Strain Gauge
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Skip To: End of Block If Q26 = I don't know/Unsure

End of Block: Strength Assessments: Overview

Start of Block: Strength Assessments: Specific

Please answer the following questions in relation to the [Q26 selected option] strength assessment.

Q27

If possible, please reference any specific protocol/guidelines followed or provide a brief description of how this strength assessment is conducted.

_____

_____

_____

Q28

On average, how long does it take to conduct this strength assessment from start to finish in minutes?

Minute(s) _____

Q29

What is the purpose of conducting this strength assessment?

- ○ Outcome measure i.e. before and after pulmonary rehabilitation to measure change
- ○ Exercise/load prescription i.e. used to calculate the weight for exercises
- ○ Both (outcome measure AND exercise/load prescription)
- ○ I don't know/Unsure
- ○ Other (please specify) _____

Q30

When is this strength assessment conducted in the pulmonary rehabilitation programme?

(Tick all that apply)

- ☐ At the start e.g. first session/class or Initial assessment
- ☐ At the end e.g. last session/class or discharge assessment
- ☐ Another time point during the programme e.g. halfway (please specify) _____
- ☐ I don't know/ Unsure
- ☐ Other (please specify) _____

Q31

What part(s) of the body is this strength assessment carried out on? (Tick all that apply)

- ☐ Lower Body/Legs
- ☐ Upper Body/Arms
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q31 = Lower Body/Legs

Q32

Please select which specific muscles of the lower body/legs are assessed. (Tick all that apply)

- ☐ Quadriceps
- ☐ Hamstrings
- ☐ Calves
- ☐ Glutes
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q31 = Upper Body/Arms

Q33

Please select which specific muscles of the upper body/arms are assessed. (Tick all that apply)

- ☐ Bicep
- ☐ Tricep
- ☐ Forearm
- ☐ Hand Grip
- ☐ Chest
- ☐ Shoulder
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Q34

Is this strength assessment conducted at the pulmonary rehabilitation sites you regularly work at? Please answer using the drop-down menu for each site.

Please answer thinking back to the pulmonary rehabilitation service before the Covid-19 pandemic i.e. before March 2020.

	Yes	No	I don't know/Unsure
Site 1:	○	○	○
Site 2:	○	○	○
Site 3:	○	○	○
Site 4:	○	○	○
Site 5:	○	○	○
Site 6:	○	○	○

End of Block: Strength Assessments: Specific

Start of Block: Staff Training: Strength Assessment

Staff training in strength assessment

In this section you will be asked questions about any training you have done or other opportunities (e.g. learning on the job, shadowing etc) you have had that are relevant to assessing muscle strength. You will be asked about any training done whilst working in pulmonary rehabilitation, as well as any training from other places/experiences e.g. past jobs and education.

Q35

In your current pulmonary rehabilitation job, or anytime working in pulmonary rehabilitation, have you participated in any training or other opportunities to gain/improve your knowledge and skills in assessing muscle strength?

- ○ Yes
- ○ No
- ○ I don’t know/Unsure

Skip To: Q46 If Q35 = I don’t know/Unsure

Skip To: Q46 If Q35 = No

Q36

How much of this training was 'learning on the job' (e.g. shadowing, coaching etc)?

- ○ All of it
- ○ Some of it
- ○ None of it
- ○ I don't know/Unsure

Skip To: Q45 If Q36 = All of it

Display This Question:

If Q36 = Some of it

Q37

Aside from learning on the job training, was the other training provided by your pulmonary rehabilitation workplace?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: Q41 If Q37 = Yes

Display This Question:

If Q36 = None of it

Q38

Was this training provided by your pulmonary rehabilitation workplace?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: Q41 If Q38 = Yes

Q39

Who provided this training?

_____

Q40

Did your pulmonary rehabilitation workplace support this training (e.g. did they give you time off to attend, or pay the training fee)?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Q41

What year did you attend this training (YYYY)?

_____

Q42

How many hours was this training?

Hour(s) _____

Q43

Did this training result in a qualification?

- ○ Yes (please specify) _____
- ○ No
- ○ I don’t know/unsure

Q44

How helpful was this training in relation to assessing muscle strength?

- Extremely unhelpful
- Moderately unhelpful
- Slightly unhelpful
- Neither helpful nor unhelpful
- Slightly helpful
- Moderately helpful
- Extremely helpful

Display This Question:

If Q36 = None of it is Not Selected

Q45

How helpful was the learning on the job training in relation to assessing muscle strength?

- Extremely unhelpful
- Moderately unhelpful
- Slightly unhelpful
- Neither helpful nor unhelpful
- Slightly helpful
- Moderately helpful
- Extremely helpful

Page Break

Q46

Now you will be asked about any training you have done that was **NOT** in your current pulmonary rehabilitation job, or anytime working in pulmonary rehabilitation.

Have you participated in any training or other opportunities **outside** of working in pulmonary rehabilitation to gain/improve your knowledge and skills in assessing muscle strength?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: Q52 If Q46 = No

Skip To: Q52 If Q46 = I don't know/Unsure

Q47

Where did you do this training or what did you receive it for (e.g. past job, education, qualification etc)? Please specify.

_____

_____

_____

Q48

What year did you attend this training (YYYY)?

_____

Q49

How many hours was this training?

Hour(s) _____

Q50

Did this training result in a qualification?

- ○ Yes (please specify) _____
- ○ No
- ○ I don't know/Unsure

Q51

How helpful was this training in relation to assessing muscle strength?

- ○ Extremely unhelpful
- ○ Moderately unhelpful
- ○ Slightly unhelpful
- ○ Neither helpful nor unhelpful
- ○ Slightly helpful
- ○ Moderately helpful
- ○ Extremely helpful

Page Break

Q52

Please read the following three statements carefully and indicate the extent to which you agree or disagree with each.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
I feel I would benefit from training/additional training to support me in assessing patient muscle strength in pulmonary rehabilitation.	○	○	○	○	○	○	○
I feel my colleagues would benefit from training/additional training to support them in assessing patient muscle strength in pulmonary rehabilitation.	○	○	○	○	○	○	○
I am confident assessing a patient's muscle strength in pulmonary rehabilitation.	○	○	○	○	○	○	○

End of Block: Staff Training: Strength Assessment

Start of Block: Strength Assessments: Attitudes

Attitudes and opinions about strength assessment

In this section you will be asked about your attitudes and opinions towards assessing patient muscle strength in pulmonary rehabilitation.

Q53

Please read the following five statements carefully and indicate the extent to which you agree or disagree with each.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
Assessing patient muscle strength is important.	○	○	○	○	○	○	○
Muscle strength is a useful outcome measure in pulmonary rehabilitation.	○	○	○	○	○	○	○
Assessing patient muscle strength is safe.	○	○	○	○	○	○	○
Assessing patient muscle strength is easy.	○	○	○	○	○	○	○
Assessing patient muscle strength should be standardised across all pulmonary rehabilitation services.	○	○	○	○	○	○	○

End of Block: Strength Assessments: Attitudes

Start of Block: Strength Assessment: Barriers

Q54

Barriers to strength assessment in pulmonary rehabilitation

In this section you will be asked about potential barriers/difficulties faced when assessing patient muscle strength in pulmonary rehabilitation. Please consider each statement below carefully and indicate the extent to which you agree or disagree with each.

If the service assesses patient muscle strength, please answer these statements reflecting on your experience doing so in pulmonary rehabilitation. If the service DOES NOT assess patient muscle strength, please answer these statements thinking about if the assessment of patient muscle strength was to be introduced into pulmonary rehabilitation.

As we are concerned with standard face-to-face pulmonary rehabilitation, please answer these

questions thinking back to the pulmonary rehabilitation programme before the Covid-19 pandemic i.e. before March 2020.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
Time is limited for assessing patient muscle strength	○	○	○	○	○	○	○
Staff workloads are too high for assessing patient muscle strength	○	○	○	○	○	○	○
There are not enough staff for assessing patient muscle strength	○	○	○	○	○	○	○
Class sizes are too large for assessing patient muscle strength	○	○	○	○	○	○	○
Funding is limited for assessing patient muscle strength	○	○	○	○	○	○	○
Exercise equipment is inadequate for assessing patient muscle strength	○	○	○	○	○	○	○
It is difficult to get patients to comply with the directions/instructions when assessing their muscle strength	○	○	○	○	○	○	○
Patients have physical limitations which makes it difficult to assess their muscle strength	○	○	○	○	○	○	○
Patients have psychological limitations which makes it difficult to assess their muscle strength (e.g. concerns and worries, or limited understanding)	○	○	○	○	○	○	○
I am uncertain about the safety of assessing patient muscle strength	○	○	○	○	○	○	○

I am uncertain about the benefit of assessing patient muscle strength	○	○	○	○	○	○	○
I do not have the training needed to assess patient muscle strength	○	○	○	○	○	○	○
I do not have the knowledge and understanding needed to assess patient muscle strength	○	○	○	○	○	○	○
My colleagues are uncertain about the safety of assessing patient muscle strength	○	○	○	○	○	○	○
My colleagues are uncertain about the benefit of assessing patient muscle strength	○	○	○	○	○	○	○
My colleagues do not have the training needed to assess patient muscle strength	○	○	○	○	○	○	○
My colleagues do not have the knowledge and understanding needed to assess patient muscle strength	○	○	○	○	○	○	○

End of Block: Strength Assessment: Barriers

Start of Block: Exercise Programme

Pulmonary rehabilitation exercise programme

In this section you will be asked questions about the pulmonary rehabilitation exercise programme.

Please answer the following questions in relation to the **predominate site** you work at (i.e. Site 1)

As we are concerned with standard face-to-face pulmonary rehabilitation, please answer these

questions thinking back to the pulmonary rehabilitation programme before the Covid-19 pandemic i.e. before March 2020.

Q55

On average, how many weeks does the pulmonary rehabilitation programme last?

Weeks _____

Q56

On average, how many times do patients complete a supervised pulmonary rehabilitation exercise session per week?

_____

Q57

On average, how long are the pulmonary rehabilitation **exercise** sessions in minutes?

Minutes _____

Q58

In total, how many individual exercises are included in the pulmonary rehabilitation exercise programme?

_____

Q59

During the pulmonary rehabilitation exercise sessions, how is general/overall exercise intensity

monitored? (Tick all that apply)
NOTE: Exercise intensity refers to how hard the body is working during exercise i.e. the difficulty.

- ☐ Exercise intensity is NOT monitored
- ☐ Heart Rate
- ☐ Borg Rating of Perceived Exertion Scale of 6-20
- ☐ Modified Borg CR10 Scale of 0-10
- ☐ I don’t know/unsure
- ☐ Other (please specify) _____

Q60

What equipment or training modality is predominately used by patients in the pulmonary rehabilitation exercise sessions? (Tick all that apply)

- ☐ Free weights
- ☐ Resistance bands
- ☐ Multi gym apparatus / Machines with weights
- ☐ Bodyweight (i.e. using one's own bodyweight as resistance)
- ☐ Cardio machines (e.g. treadmill or exercise bike)
- ☐ No equipment
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q60 = Free weights

Q61

If possible, please specify what type(s) of free weight equipment is predominately used. (Tick all that apply)

- ☐ Dumbbells/hand weights
- ☐ Barbells with/without weight plates
- ☐ Weight plates alone
- ☐ Kettlebells
- ☐ Ankle weights
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q60 = Resistance bands

Q62

If possible, please specify what type(s) of resistance band equipment is predominately used. (Tick all that apply)

- ☐ TheraBand's/Therapy bands
- ☐ Long loop bands
- ☐ Tubing/Tube bands
- ☐ Mini circle bands
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q60 = Cardio machines (e.g. treadmill or exercise bike)

Q63

If possible, please specify what type(s) of cardio equipment is predominately used. (Tick all that apply)

- ☐ Treadmill (i.e. walking/running machine)
- ☐ Stationary exercise bike (i.e. cycling machine)
- ☐ Stair climber machine
- ☐ Elliptical/Cross trainer machine
- ☐ Rowing machine
- ☐ Other (please specify) _____

End of Block: Exercise Programme

Start of Block: Strength Training in the Exercise Programme

Strength training in pulmonary rehabilitation

In this section you will be asked about strength training (also known as resistance training) and if/how it is delivered in the pulmonary rehabilitation exercise programme.

As we are concerned with standard face-to-face pulmonary rehabilitation, please answer these questions thinking back to the pulmonary rehabilitation programme before the Covid-19 pandemic i.e. before March 2020.

Q64

How would you describe '**Strength/Resistance Training**'? Please give as much information as you feel is appropriate.

_____

_____

_____

_____

_____

Page Break

Q65
Now, thinking about the pulmonary rehabilitation exercise programme offered by your service, does it include **Strength/Resistance Training**?

For the purposes of this question, strength (or resistance) training is defined as a form of physical activity that is designed to improve muscle strength (i.e. the ability to generate muscle force) by exercising a muscle or a muscle group against resistance (e.g. free weights, resistance bands or bodyweight).

- ○ Yes
- ○ No
- ○ I don’t know/Unsure

Skip To: End of Block If Q65 = No
Skip To: End of Block If Q65 = I don’t know/Unsure

Page Break

In this section, please answer the following questions in relation to the site you **predominately** work at (i.e. Site 1)

Q66
Of the individual exercises included in the pulmonary rehabilitation exercise programme, how many are strength training exercises?
NOTE: An exercise is considered a strength training exercise if it aims to improve muscle strength by working against resistance e.g. using free weights, resistance bands or bodyweight.

_____

Q67

Please select which area(s) of the body these strength training exercises target. (Tick all that apply)

- ☐ Upper body
- ☐ Lower body
- ☐ Trunk
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Q68

For strength training, if an exercise uses **load/resistance**, how is it prescribed to patients i.e. how is it chosen? (Tick all that apply)
NOTE: Load refers to the specific weight used for an exercise e.g. an 4kg dumbbell used for bicep

curls. Resistance refers to what the patient is working against e.g. the weight of a dumbbell, the force of a band, or their own bodyweight.

- ☐ Load/resistance is **NOT** prescribed
- ☐ Patient selected
- ☐ Practitioner/staff selected
- ☐ Borg Rating of Perceived Exertion Scale of 6-20
- ☐ Modified Borg CR10 Scale of 0-10
- ☐ Using a strength assessment / measuring muscle strength (e.g. 1-RM, % of 1-RM, m-RM)
- ☐ To time (i.e. continuous exercise for a certain amount of time)
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q68 = Using a strength assessment / measuring muscle strength (e.g. 1-RM, % of 1-RM, m-RM)

Q69

If possible, please select which strength assessment approach is used to prescribe **load/resistance.** (Tick all that apply)

- [ ] One Repetition Maximum (1-RM) i.e. maximum weight lifted for one exercise repetition
- [ ] Multiple Repetition Maximum (m-RM) i.e. maximum weight lifted for a certain number of exercise repetitions
- [ ] Predicted 1-RM i.e. using a formula/calculation to predict 1-RM
- [ ] I don't know/Unsure
- [ ] Other (please specify) _____

Page Break

Q70
For strength training, how is **exercise intensity** prescribed to patients? (Tick all that apply)
NOTE: Exercise intensity refers to how hard the body is working during exercise i.e. the difficulty.

- ☐ Exercise intensity is **NOT** prescribed
- ☐ Heart Rate
- ☐ Borg Rating of Perceived Exertion Scale of 6-20
- ☐ Modified Borg CR10 Scale of 0-10
- ☐ Using a strength assessment / measuring strength (e.g. 1-RM, % of 1-RM, M-RM)
- ☐ To time (i.e. continuous exercise for a certain amount of time)
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q70 = Using a strength assessment / measuring strength (e.g. 1-RM, % of 1-RM, M-RM)

Q71

If possible, please select which strength assessment approach/test is used to prescribe **exercise intensity**.
(Tick all that apply)

- ☐ One Repetition Maximum (1-RM) i.e. maximum weight lifted for one exercise repetition
- ☐ Multiple Repetition Maximum (m-RM) i.e. maximum weight lifted for a certain number of exercise repetitions
- ☐ Predicted 1-RM i.e. using a formula/calculation to predict 1-RM
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Display This Question:

If Q70 = I don't know/Unsure is Not Selected

Q72

If applicable, please specify the parameters of the exercise intensity prescription (e.g. 60% heart rate, 60% 1-RM, 6 RPE etc.). If you selected more than one approach, please specify for each.

_____

Page Break

Q73
For strength training, how is the amount of exercise done by patients determined (i.e. how is overall exercise volume quantified)? (Tick all that apply)

- ☐ Patient reported
- ☐ To Time
- ☐ Number of exercise repetitions (i.e. the number of times a given exercise is performed e.g. 10 reps of bicep curls)
- ☐ Number of exercise sets (i.e. how many times a particular number of repetitions for a given exercise is repeated e.g. 3 sets of 10 reps)
- ☐ I don’t know/Unsure
- ☐ Other (please specify) _____

Page Break

Display This Question:

If Q73 = Number of exercise repetitions (i.e. the number of times a given exercise is performed e.g. 10 reps of bicep curls)

Q74

If possible, please specify the number of exercise repetitions, or the repetition range, prescribed to patients at the start of the pulmonary rehabilitation exercise programme e.g. 10-12 reps.

_____

Display This Question:

If Q73 = Number of exercise sets (i.e. how many times a particular number of repetitions for a given exercise is repeated e.g. 3 sets of 10 reps)

Q75

If possible, please specify the number of sets per exercise prescribed to patients at the start of the pulmonary rehabilitation exercise programme e.g. 3 sets of 10 reps.

_____

Display This Question:

If Q73 = To Time

Q76

If possible, please specify the amount of time prescribed to patients at the start of the pulmonary rehabilitation exercise programme e.g. number of minutes per exercise.

_____

Q77

For strength training, how are exercise rest periods/intervals prescribed to patients? (Tick all that apply)

- ☐ Rest periods/intervals are **NOT** prescribed
- ☐ Practitioner selected
- ☐ Patient selected
- ☐ Specific rest periods in line with the completion of exercise repetitions and sets
- ☐ I don't know/Unsure
- ☐ Other (please specify) _____

Page Break

Q78

For strength training, does the exercise programme focus on exercise progression?
NOTE: Exercise progression means advancing an exercise once it can be easily completed.

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Display This Question:

If Q78 = Yes

Q79

How are the strength training exercises progressed? (Tick all that apply)

- ☐ Increase in load/resistance (e.g. exercising with a heavier dumbbell or a thicker resistance band)
- ☐ Increase in the number of exercise repetitions
- ☐ Increase in the number of exercise sets
- ☐ Increase in time (e.g. doing the exercise for longer)
- ☐ Decrease in rest periods between exercises or exercise sets
- ☐ I don’t know/Unsure
- ☐ Other (please specify) _____

End of Block: Strength Training in the Exercise Programme

Start of Block: Strength Training: Knowledge/Awareness

Knowledge and awareness of strength training

In this section you will be asked questions related to your knowledge and awareness of strength training, and its use in pulmonary rehabilitation.

Q80

Current COPD guidelines/statements published by leading respiratory organisations e.g. British Thoracic Society (BTS), American Thoracic Society (ATS) and European Respiratory Society (ERS), recommend the inclusion of strength training in pulmonary rehabilitation exercise programmes. How much were you aware of this?

- ○ Not at all aware
- ○ Slightly aware
- ○ Moderately aware
- ○ Very aware
- ○ Extremely aware

For COPD patients, the American Thoracic Society (ATS) and European Respiratory Society (ERS) recommend following the American College of Sports Medicine (ACSM) guidelines for strength training in healthy older adults.

The ACSM guidelines recommend the following exercise prescription for strength training:

- **Frequency** (e.g. how often to exercise): 2 or more days a week
- **Intensity** (e.g. how hard to exercise): a light intensity of 40-50% of 1-RM for beginners, progressing to a moderate intensity of 60-70% of 1-RM. If 1-RM is not measured, intensity

can be prescribed between a moderate (5-6) and vigorous (7-8) RPE on the Modified Borg CR10 Scale (0-10).

- **Type** (e.g. what mode or kind of equipment is used): can include equipment such as free weights, weighted machines, resistance bands, and/or weight bearing/bodyweight exercises.

- **Volume** (e.g. the amount of exercise done): 8-10 exercises per session involving major muscle groups, with 1 or more sets of 10-15 repetitions per exercise.
- **Progression** (e.g. advancement in an exercise once it is easily completed): gradual increase in load/resistance, repetitions, sets, and/or frequency.

Q81

To what extent were you aware of these ACSM guidelines?

- ○ Not at all aware
- ○ Slightly aware
- ○ Moderately aware
- ○ Very aware
- ○ Extremely aware

Q82

To what extent were you aware of these ACSM guidelines being recommended for use with COPD patients?

- ○ Not at all aware
- ○ Slightly aware
- ○ Moderately aware
- ○ Very aware
- ○ Extremely aware

Q83

Considering the ACSM guidelines. Does the pulmonary rehabilitation exercise programme use any of the following exercise prescription principles when delivering/prescribing strength training to patients?
(Tick all that apply)

Please answer this question thinking back to the pulmonary rehabilitation exercise programme before the Covid-19 pandemic i.e. before March 2020.

- [ ] 40-50% of 1-RM (light intensity)
- [ ] 60-70% of 1-RM (medium intensity), if patients are able
- [ ] 5-6 RPE (moderate intensity) on modified Borg CR10 Scale of 0-10
- [ ] 7-8 RPE (vigorous intensity) on modified Borg CR10 Scale of 0-10
- [ ] 8-10 exercises per session
- [ ] 10-15 repetitions per set
- [ ] 1 or more sets of each exercise
- [ ] Strength training two or more times a week
- [ ] Use of free weight, machine weights or resistance bands
- [ ] Inclusion of bodyweight exercises
- [ ] Gradual progression of exercises
- [ ] None of the above

End of Block: Strength Training: Knowledge/Awareness

Start of Block: Staff Training: Strength Training

Staff training in delivering strength training

In this section you will be asked questions about any training you have done or other opportunities (e.g. learning on the job) you have had that are relevant to delivering strength training. You will be

asked about training whilst working in pulmonary rehabilitation, as well as any training from other places/experiences e.g. past jobs and education.

Q84

In your current pulmonary rehabilitation job, or anytime working in pulmonary rehabilitation, have you participated in any training or other opportunities to gain/improve your knowledge and skills in delivering strength training?

- ○ Yes
- ○ No
- ○ I don’t know/Unsure

Skip To: Q95 If Q84 = I don’t know/Unsure

Skip To: Q95 If Q84 = No

Q85

How much of this training was 'learning on the job' (e.g. shadowing, coaching etc)?

- ○ All of it
- ○ Some of it
- ○ None of it
- ○ I don't know/Unsure

Skip To: Q94 If Q85 = All of it

Display This Question:

If Q85 = Some of it

Q86

Aside from learning on the job training, was the other training provided by your pulmonary rehabilitation workplace?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: Q90 If Q86 = Yes

Display This Question:

If Q85 = None of it

Q87

Was this training provided by your pulmonary rehabilitation workplace?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: Q90 If Q87 = Yes

Q88

Who provided this training?

_____

Q89

Did your pulmonary rehabilitation workplace support this training e.g. did they give you time off to attend, or pay the training fee?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Q90

What year did you attend this training (YYYY)?

_____

Q91

How many hours was this training?

Hour(s) _____

Q92

Did this training result in a qualification?

- ○ Yes (please specify) _____
- ○ No
- ○ I don’t know/unsure

Q93

How helpful was this training in relation to delivering strength training?

- Extremely unhelpful
- Moderately unhelpful
- Slightly unhelpful
- Neither helpful nor unhelpful
- Slightly helpful
- Moderately helpful
- Extremely helpful

Display This Question:

If Q85 = None of it is Not Selected

Q94

How helpful was the learning on the job training in relation to delivering strength training?

- Extremely unhelpful
- Moderately unhelpful
- Slightly unhelpful
- Neither helpful nor unhelpful
- Slightly helpful
- Moderately helpful
- Extremely helpful

Page Break

Q95

Now you will be asked about any training you have done or other opportunities (e.g. learning on the job) you have had that were **NOT** in your current pulmonary rehabilitation job, or anytime working in pulmonary rehabilitation.

Have you participated in any training or other opportunities **outside** of working in pulmonary rehabilitation to gain/improve your knowledge and skills in delivering strength training?

- ○ Yes
- ○ No
- ○ I don't know/Unsure

Skip To: Q101 If Q95 = No

Skip To: Q101 If Q95 = I don't know/Unsure

Q96

Where did you do this training or what did you receive it for (e.g. past job, education, qualification etc)? Please specify.

_____

_____

_____

_____

_____

Q97

What year did you attend this training (YYYY)?

_____

Q98

How many hours was this training?

Hour(s) _____

Q99

Did this training result in a qualification?

- ○ Yes (please specify) _____
- ○ No
- ○ I don't know/Unsure

Q100

How helpful was this training in relation to delivering strength training?

- ○ Extremely unhelpful
- ○ Moderately unhelpful
- ○ Slightly unhelpful
- ○ Neither helpful nor unhelpful
- ○ Slightly helpful
- ○ Moderately helpful
- ○ Extremely helpful

Page Break

Q101

Please read the following three statements carefully and indicate the extent to which you agree or disagree with each.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
I feel I would benefit from training/additional training to support me in delivering strength training in pulmonary rehabilitation.	○	○	○	○	○	○	○
I feel my colleagues would benefit from training/additional training to support them in delivering strength training in pulmonary rehabilitation.	○	○	○	○	○	○	○
I am confident delivering strength training in pulmonary rehabilitation.	○	○	○	○	○	○	○

End of Block: Staff Training: Strength Training

Start of Block: Strength Training: Attitudes

Attitudes and opinions about strength training

In this section you will be asked about your attitudes and opinions towards strength training in pulmonary rehabilitation.

Q102

Please read the following six statements carefully and indicate the extent to which you agree or disagree with each.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
Strength training is important for patients.	○	○	○	○	○	○	○
Strength training is beneficial for patients.	○	○	○	○	○	○	○
Strength training is safe for patients.	○	○	○	○	○	○	○
Strength training is easy to deliver in pulmonary rehabilitation.	○	○	○	○	○	○	○
Strength training should be individually prescribed to patients.	○	○	○	○	○	○	○
Strength training should be standardised across all pulmonary rehabilitation services.	○	○	○	○	○	○	○

End of Block: Strength Training: Attitudes

Start of Block: Strength Training: Barriers

Q103

Barriers to strength training in pulmonary rehabilitation

In this last section you will be asked about potential barriers/difficulties faced when delivering strength training in pulmonary rehabilitation. Please consider each statement below carefully and indicate the extent to which you agree or disagree with each.

As we are concerned with standard face-to-face pulmonary rehabilitation, please answer these

questions thinking back to the pulmonary rehabilitation programme before the Covid-19 pandemic i.e. before March 2020.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
Time is limited for delivering strength training	○	○	○	○	○	○	○
Staff workloads are too high for delivering strength training	○	○	○	○	○	○	○
There are not enough staff for delivering strength training	○	○	○	○	○	○	○
Class sizes are too large for delivering strength training	○	○	○	○	○	○	○
Funding is limited for delivering strength training	○	○	○	○	○	○	○
Exercise equipment is inadequate for delivering strength training	○	○	○	○	○	○	○
There is not enough exercise equipment to go around all patients.	○	○	○	○	○	○	○
It is difficult to get patients to comply with the directions/instructions for strength training.	○	○	○	○	○	○	○
Patients have physical limitations which makes it difficult for them to do strength training.	○	○	○	○	○	○	○
Patients have psychological limitations which makes it difficult for them to do strength training (e.g. concerns and worries, or limited understanding).	○	○	○	○	○	○	○
I am uncertain about the safety of strength training for patients.	○	○	○	○	○	○	○

I am uncertain about the benefit of strength training for patients.	○	○	○	○	○	○	○
I do not have the training needed to deliver strength training to patients.	○	○	○	○	○	○	○
I do not have the knowledge and understanding to deliver strength training to patients.	○	○	○	○	○	○	○
My colleagues are uncertain about the safety of strength training for patients.	○	○	○	○	○	○	○
My colleagues are uncertain about the benefit of strength training to patients.	○	○	○	○	○	○	○
My colleagues do not have the training needed to deliver strength training to patients.	○	○	○	○	○	○	○
My colleagues do not have the knowledge and understanding to deliver strength training to patients.	○	○	○	○	○	○	○

End of Block: Strength Training: Barriers

Start of Block: Last Question

Q104

You have now reached the end of the survey. If there is anything else you would like to add, which you think is important, please write it in the text box below.

_____

_____

_____

_____

_____

To finish the survey and submit your answers, please click the 'submit' button below.

End of Block: Last Question

Appendix AA

Survey - participant demographics (full table of results)

Age (Years)	
Mean (*SD*)	42.81 (*10.19*)
Missing (%)	0/219 (0%)
Gender	
Female	180 (82.2%)
Male	37 (16.9%)
Transgender Male	0 (0%)
Transgender Female	0 (0%)
Gender variant/non-conforming	0 (0%)
Prefer not to say	1 (0.5%)
Other	0 (0%)
Missing (%)	1/219 (0.5%)
Ethnicity	
Asian or Asian British (Indian, Pakistani, Bangladeshi)	8 (3.7%)
Black or Black British (Caribbean, African)	2 (0.9%)
Mixed/multiple ethnic groups	3 (1.4%)
White (English, Welsh, Scottish, Northern Irish, British, Irish, gypsy/Irish traveller)	200 (91.3%)
Chinese	0 (0%)
Arab	0 (0%)
Other	5 (2.3%)
Missing (%)	1/219 (0.5%)
Highest level of education	
Less than GCSE's	2 (0.9%)
GCSE's or equivalent	14 (6.4%)
AS/A Levels or equivalent	18 (8.2%)
Undergraduate degree	113 (51.6%)
Postgraduate degree	55 (25.1%)
Doctoral level degree	3 (1.4%)
I don't know/Unsure	1 (0.5%)
Other	13 (5.9%)
Missing (%)	0/219 (0%)

Appendix AB

Survey - participant job details (full table of results)

Job Role	
Physiotherapist	135 (61.6%)
Therapy Assistant	30 (13.7%)
Registered Nurse	21 (9.6%)
Healthcare Assistant	9 (4.1%)
Technical Instructor	10 (4.6%)
Fitness Instructor	5 (2.3%)
Exercise Physiologist	2 (0.9%)
Occupational Therapist	4 (1.8%)
Other	2 (0.9%)
Missing (%)	1/219 (0.5%)
Job Duties*	
Leading exercise sessions	154 (70.6%)
Assisting exercise sessions	98 (45%)
Conducting patient assessments	156 (71.6%)
Delivering education	156 (71.6%)
Site Lead	73 (33.5%)
Service Manager	35 (16.1%)
Other	10 (4.6%)
Missing (%)	1/219 (0.5%)
NHS Pay Scale	
Median (*IQR*)	Grade 6 (*2*)
Grade 1	0 (0%)
Grade 2	1 (0.5%)
Grade 3	24 (11%)
Grade 4	27 (12.3%)
Grade 5	6 (2.7%)
Grade 6	66 (30.1%)
Grade 7	79 (36.1%)
Grade 8a	15 (6.8%)
Grade 8b	0 (0%)
Grade 8c	0 (0%)
Grade 9	0 (0%)
Missing (%)	1/219 (0.5%)
Job Role Duration (Years)	
Median (*IQR*)	6.67 (*8.7*)
Missing (%)	1/219 (0.5%)
Duration working in PR (Years)	
Median (*IQR*)	7.75 (*8.6*)
Missing (%)	1/219 (0.5%)

Note. * = 'tick all that apply' question format (% does not add up to 100%)

Appendix AC

Survey - PR service and site details (full table of results)

Type of Organisation Provider	
NHS acute trust	78 (35.9%)
NHS non-acute or community trust	103 (47.5%)
NHS health board	1 (0.5%)
Community Interest Company (CIC)	23 (10.6%)
Private healthcare provider	4 (1.8%)
Integrated Care Organisation (ICO)	6 (2.8%)
Charity	0 (0%)
Council	1 (0.5%)
Research	0 (0%)
GP Federation	0 (0%)
I don't know/Unsure	4 (1.8%)
Other	5 (2.3%)
Missing (%)	2/219 (0.9%)
Venue Type (predominant site)	
Church or Community Hall	75 (34.2%)
Local Leisure Centre or Gym	45 (20.5%)
Community Hospital	24 (11%)
Acute Hospital	39 (17.8%)
Health Centre	19 (8.7%)
GP Surgery	1 (0.5)
Other	15 (6.8%)
Missing (%)	1/219 (0.5%)
Venue Type (all sites)*	
Church or Community Hall	245 (112.4%)
Local Leisure Centre or Gym	183 (83.9%)
Community Hospital	86 (39.4%)
Acute Hospital	56 (25.7%)
Health Centre	44 (20.2%)
GP Surgery	3 (1.4)
Other	48 (22%)
Missing (%)	1/219 (0.5%)
Number of PR sites in service	
Mean (*SD*)	4.15 (*2.62*)
Missing	3/219 (1.4%)
Number of PR sites regularly worked at	
Mean (*SD*)	3.03 (*1.64*)
Missing	4/219 (1.8%)

Note. * = 'tick all that apply' question format (% does not add up to 100%)

Appendix AD

Survey - details of strength assessments used in PR programmes (full table of results)

	1-RM	m-RM	S2S Variation	5epS2S	30secS2S	1minS2S	Dynamometer	Strain Gauge
Duration (mins)	6.52 (3.4)	6.4 (3.13)	2.83 (2.32)	3.2 (2.62)	2.38 (2.1)	2.13 (1.5)	4.24 (2.7)	8.2 (4.26)
Mean (*SD*)	4 (13.8%)	1 (3.8%)	2 (5.7%)	1 (4.5%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)
Missing (%)	25 of 29	25 of 26	33 of 35	21 of 22	4 of 4	8 of 9	17 of 17	6 of 6
n								
Purpose								
Outcome	18 (64.3%)	13 (53%)	34 (100%)	22 (100%)	4 (100%)	8 (100%)	17 (100%)	6 (100%)
Measure	24 (85.7%)	24 (96%)	6 (17.6%)	4 (18.2%)	1 (25%)	1 (12.5%)	3 (17.6%)	1 (16.7%)
Exercise	-	-	-	-	-	-	-	-
Prescription	-	-	-	-	-	-	-	-
Unsure	1 (3.4%)	1 (3.8%)	1 (2.9%)	0 (0%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)
Other	28 of 29	25 of 26	34 of 35	22 of 22	4 of 4	8 of 9	17 of 17	6 of 6
Missing								
n								
Timepoint Conducted	28 (100%)	29 (100%)	34 (100%)	22 (100%)	4 (100%)	8 (100%)	17 (100%)	6 (100%)
At the Start	17 (60.7%)	11 (42.3%)	31 (91.2%)	19 (86.4%)	4 (100%)	8 (100%)	16 (94.1%)	6 (100%)
At the End	1 (3.6%)	3 (11.5%)	-	-	-	-	-	-
Another	-	-	-	-	-	-	-	-
Time Point	-	-	1 (2.9%)	-	-	-	-	-
Unsure	1 (3.5%)	0 (0%)	1 (2.9%)	0 (0%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)
Other	28 of 29	26 of 26	34 of 35	22 of 22	4 of 4	8 of 9	17 of 17	6 of 6
Missing								
n								
Body Area Targeted	12 (42.9%)	13 (50%)	34 (100%)	22 (100%)	4 (100%)	8 (100%)	1 (6.3%)	6 (100%)
Lower Body	26 (92.9%)	26 (100%)	1 (2.9%)	1 (4.5%)	-	-	15 (93.8%)	-
Upper Body	-	-	-	-	-	-	-	-
Unsure	-	1 (3.8%)	1 (2.9%)	1 (4.5%)	-	-	-	-
Other	1 (3.4%)	0 (0%)	1 (2.9%)	0 (0%)	0 (0%)	1 (11.1%)	1 (5.9%)	0 (0%)
Missing	28 of 29	26 of 26	34 of 35	22 of 22	4 of 4	8 of 9	16 of 17	6 of 6

n								
Lower Body								
Quadriceps	12 (100%)	13 (100%)	33 (97.1%)	21 (95.5%)	4 (100%)	8 (100%)	1 (100%)	6 (100%)
Hamstrings	2 (16.7%)	4 (30.8%)	13 (38.2%)	9 (40%)	-	4 (50%)	-	-
Calves	2 (16.7%)	0 (0%)	9 (25.5%)	7 (31.8%)	-	1 (25%)	-	-
Glutes	2 (16.7%)	1 (7.7%)	19 (55.9%)	14 (63.6%)	-	5 (62.5%)	-	-
Unsure	-	-	1 (1.3%)	1 (4.5%)	-	-	-	-
Other	1 (8.3%)	-	-	-	-	-	-	-
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
n	12 of 12	13 of 13	34 of 34	22 of 22	4 of 4	8 of 8	1 of 1	6 of 6
Upper Body								
Biceps	26 (100%)	26 (100%)	-	-	-	-	1 (6.7%)	-
Triceps	2 (7.7%)	3 (11.5%)	1 (100%)	1 (100%)	-	-	-	-
Forearm	2 (7.7%)	2 (7.7%)	-	-	-	-	3 (20%)	-
Hand Grip	2 (7.7%)	2 (7.7%)	-	-	-	-	15 (100%)	-
Shoulder	4 (15.4%)	4 (15.4%)	-	-	-	-	-	-
Chest	-	1 (3.8%)	-	-	-	-	-	-
Unsure	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-	-	0 (0%)	-
n	26 of 26	26 of 26	1 of 1	1 of 1	-	-	15 of 15	-

Appendix AE

Survey – strength training prescription variables (full table of results)

	n of participants (%)	*n* of PR services *(%)*
Target Body Area		
Upper Body	197 (97%)	74 (100%)
Lower Body	201 (99%)	74 (100%)
Trunk	71 (32%)	44 (59.5%)
Other	0 (0%)	-
Unsure	2 (1%)	-
Missing	2/205 (1%)	
Load/Resistance		
Not Prescribed	12 (5.9%)	11 (14.9%)
Practitioner/Staff Selected	143 (70.4%)	65 (87.8%)
Patient Selected	75 (36.9%)	40 (54.1%)
Breathlessness Scale	120 (59.1%)	50 (67.6%)
Borg Rating Scale of Perceived Exertion (6-10)	47 (39.5%)	
Modified Borg CR10 Scale (0-10)	78 (65.5%)	
Missing	1/120 (0.8%)	
Strength assessment	56 (27.6%)	34 (45.9%)
1-RM	25 (44.6%)	
m-RM	21 (37.5%)	
Predicted 1-RM	10 (17.9%)	
Unsure	2 (3.6%)	
Other	1 (1.8%)	
Missing	0/56 (0%)	
To Time	67 (33%)	39 (52.7%)
Other	8 (3.9%)	8 (10.8%)
Unsure	3 (1.5%)	-
Missing (%)	2/205 (1%)	
Exercise Intensity		
Not Prescribed	10 (5%)	9 (12.2%)
Heart Rate	38 (18.5%)	24 (32.3%)
Breathlessness Scale	165 (81.7%)	70 (94.6%)
Borg rating of perceived exertion Scale (6-20)	50 (30.5%)	
Modified Borg CR10 Scale (0-10)	125 (76.2%)	
Missing	1/165 (0.6%)	
Strength Assessment	33 (16.3%)	20 (27%)
1-RM	12 (40%)	
m-RM	8 (26.7%)	
Predicted 1-RM	11 (36.7%)	
Other	2 (7.1%)	
Missing	3/33 (9.1%)	40 (54.1%)
To Time	73 (36.1%)	-
Unsure	3 (1.5%)	13 (17.6%)
Other	15 (7.4%)	
Missing (%)	3/205 (1.5%)	
Exercise Volume		
To Time	85 (42.5%)	43 (58.1%)
Patient Reported	71 (35.5%)	42 (56.8%)
Number of Reps	161 (80.5%)	65 (87.8%)
Number of Sets	139 (69.5%)	60 (81.1%)
Unsure	1 (0.2%)	-
Other	4 (0.9%)	4 (5.4%)
Missing (%)	5/205 (2.4%)	

Rest Periods		
Not Prescribed	29 (14.4%)	22 (29.7%)
Practitioner/Staff Selected	84 (41.8%)	51 (68.9%)
Patient Selected	115 (57.2%)	58 (78.4%)
In line with Reps and Sets	80 (39.8%)	44 (59.5%)
Unsure	2 (1%)	-
Other	9 (4.5%)	9 (12.2%)
Missing (%)	4/215 (2%)	
Exercise Progression		
Not Prescribed	4 (2%)	4 (5.4%)
Increase in Load/Resistance	189 (95.5%)	74 (100%)
Increase in Reps	125 (63.1%)	60 (81.1%)
Increase in Sets	93 (47%)	46 (62.2%)
Increase in Time	54 (27.3%)	36 (48.6%)
Decrease in Rest Periods	47 (23.7%)	29 (39.2%)
Unsure	0 (0%)	-
Other	3 (1.5%)	3 (4.1%)
Missing (%)	7/215 (3.4%)	

Note: **n* = 205 (participants who answered "yes" to inclusion of ST in PR exercise programme).
Note. All questions were 'tick all that apply'.

Appendix AF

Survey – strength assessment barrier statements (full table of results)

Appendix AF. *Strength assessment barriers (Table 1 of 2)*

	Time is limited for assessing patient muscle strength	Staff workloads are too high for assessing patient muscle strength	There are not enough staff for assessing patient muscle strength	Class sizes are too large for assessing patient muscle strength	Funding is limited for assessing patient muscle strength	Exercise equipment is inadequate for assessing patient muscle strength	Patients have physical limitations which makes it difficult to assess their muscle strength	It is difficult to get patients to comply with the directions/instructions when assessing their muscle strength	Patients have psychological limitations which makes it difficult to assess their muscle strength
Median (*IQR*)	5 (*2*)	4 (*2*)	4 (*3*)	3 (*3*)	4 (*3*)	5 (*2*)	5 (*1*)	4 (*2*)	4 (*3*)
1 - Strongly Disagree	9 (4.1%)	12 (5.5%)	12 (5.5%)	20 (9.1%)	10 (4.6%)	7 (3.2%)	4 (1.8%)	12 (5.5%)	11 (5%)
2 - Disagree	18 (8.2%)	38 (17.4%)	44 (21.1%)	58 (26.5%)	39 (17.8%)	24 (11%)	15 (6.8%)	50 (22.8%)	50 (22.8%)
3 - Somewhat Disagree	21 (9.6%)	39 (17.8%)	37 (16.9%)	42 (19.2%)	20 (9.1%)	9 (4.1%)	21 (9.6%)	32 (14.6%)	32 (14.6%)
4 - Neither Agree nor Disagree	22 (10%)	35 (16%)	39 (17.8%)	37 (16.9%)	56 (25.6%)	38 (17.4%)	47 (21.5%)	85 (38.8%)	62 (28.3%)
5 - Somewhat Agree	57 (26%)	49 (22.4%)	39 (17.8%)	31 (14.2%)	34 (15.5%)	39 (17.8%)	84 (38.4%)	30 (13.7%)	43 (19.6%)
6 - Agree	64 (29.2%)	30 (13.7%)	26 (11.9%)	20 (9.1%)	35 (16%)	52 (23.7%)	35 (16%)	7 (3.2%)	18 (8.2%)
7 - Strongly Agree	28 (12.8%)	16 (7.3%)	22 (10%)	11 (5%)	25 (11.4%)	50 (22.8%)	12 (5.5%)	2 (0.9%)	2 (0.9%)
Missing (%)	0/219 (0%)	0/219 (0%)	0/219 (0%)	0/219 (0%)	0/219 (0%)	0/219 (0%)	1/219 (0.5%)	1/219 (0.5%)	1/219 (0.5%)

Appendix AF (Cont.). *Strength assessment barriers (Table 2 of 2)*

	I am uncertain about the safety of assessing patient muscle strength	**I am uncertain about the benefit of assessing patient muscle strength**	**I do not have the knowledge and understanding needed to assess patient muscle strength**	**I do not have the training needed to assess patient muscle strength**	**My colleagues are uncertain about the safety of assessing patient muscle strength**	**My colleagues are uncertain about the benefit of assessing patient muscle strength**	**My colleagues do not have the training needed to assess patient muscle strength**	**My colleagues do not have the knowledge and understanding needed to assess patient muscle strength**
Median (*IQR*)	3 (*2*)	2 (*2*)	3 (*3*)	4 (*3*)	4 (*2*)	4 (*2*)	4 (*3*)	4 (*3*)
1 - Strongly Disagree	31 (14.2%)	39 (17.8%)	30 (13.7%)	28 (12.8%)	23 (10.5%)	22 (10%)	20 (9.1%)	24 (11%)
2 - Disagree	72 (32.9%)	74 (33.8%)	60 (27.4%)	42 (19.2%)	60 (27.4%)	62 (28.3%)	45 (20.5%)	54 (24.7%)
3 - Somewhat Disagree	32 (14.6%)	37 (16.9%)	34 (15.5%)	29 (13.2%)	25 (11.4%)	25 (11.4%)	24 (11%)	25 (11.4%)
4 - Neither Agree nor Disagree	52 (23.7%)	27 (12.3%)	25 (11.4%)	39 (17.8%)	60 (27.4%)	56 (25.6%)	49 (22.4%)	51 (23.3%)
5 - Somewhat Agree	19 (8.7%)	26 (11.9%)	32 (14.6%)	36 (16.4%)	23 (10.5%)	28 (12.8%)	38 (17.4%)	36 (16.4%)
6 - Agree	8 (3.7%)	12 (5.5%)	23 (10.5%)	23 (10.5%)	18 (8.2%)	19 (8.7%)	23 (10.5%)	18 (8.2%)
7 - Strongly Agree	1 (0.5%)	3 (1.4%)	15 (6.8%)	21 (9.6%)	8 (3.7%)	7 (3.2%)	20 (9.1%)	11 (5%)
Missing (%)	4/219 (1.8%)	1/219 (0.5%)	0/219 (0%)	1/219 (0.5%)	2/219 (0.9%)	0/219 (0%)	0/219 (0%)	0/219 (0%)

Appendix AG

Survey – strength training barrier statements (full table of results)

Appendix AG. *Strength training barriers (Table 1 of 2)*

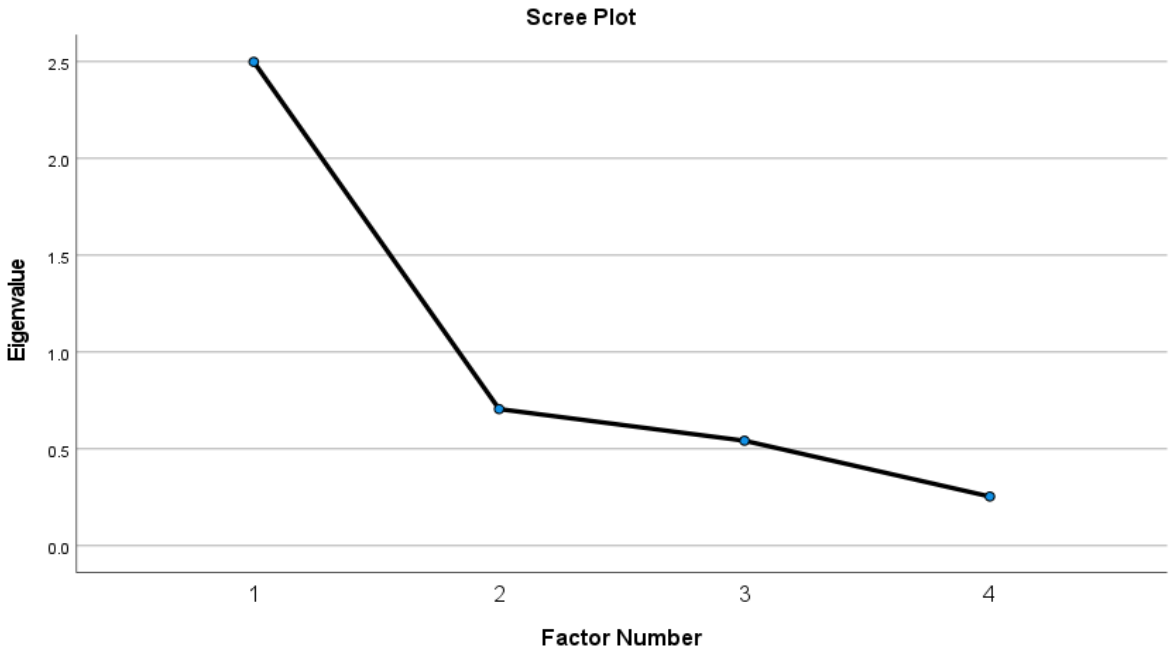
	Time is limited for delivering strength training.	Staff workloads are too high for delivering strength training.	There are not enough staff for delivering strength training.	Class sizes are too large for delivering strength training.	Funding is limited for delivering strength training.	Exercise equipment is inadequate for delivering strength training.	There is not enough exercise equipment to go around all patients.	It is difficult to get patients to comply with the directions /instructions for strength training.	Patients have physical limitations which makes it difficult for them to do strength training.	Patients have psychological limitations which makes it difficult for them to do strength training.
Median (*IQR*)	3 (*3*)	3 (*2*)	3 (*2*)	3 (*2*)	4 (*3*)	4 (*3*)	4 (*4*)	4 (*3*)	5 (*1*)	4 (*3*)
1 - Strongly Disagree	18 (8.2%)	19 (8.7%)	19 (8.7%)	20 (9.1%)	13 (5.9%)	9 (4.1%)	15 (6.8%)	10 (4.6%)	4 (1.8%)	11 (5.0%)
2 - Disagree	65 (29.7%)	67 (30.6%)	69 (31.5%)	72 (32.9%)	53 (24.2%)	47 (21.5%)	43 (19.6%)	52 (23.7%)	22 (10.0%)	42 (19.2%)
3 - Somewhat Disagree	20 (9.1%)	30 (13.7%)	26 (11.9%)	31 (14.2%)	26 (11.9%)	24 (11.0%)	30 (13.7%)	37 (16.9%)	22 (10.0%)	34 (15.5%)
4 - Neither Agree nor Disagree	35 (16%)	39 (17.8%)	40 (18.3%)	35 (16%)	48 (21.9%)	31 (14.2%)	16 (7.3%)	36 (16.4%)	46 (21.0%)	41 (18.7%)
5 - Somewhat Agree	31 (14.2%)	24 (11%)	20 (9.1%)	22 (10%)	28 (12.8%)	43 (19.6%)	33 (15.1%)	35 (16.0%)	61 (27.9%)	46 (21.0%)
6 - Agree	26 (11.9%)	14 (6.4%)	14 (6.4%)	12 (5.5%)	17 (7.8%)	26 (11.9%)	33 (15.1%)	20 (9.1%)	36 (16.4%)	21 (9.6%)
7 - Strongly Agree	4 (1.8%)	6 (2.7%)	11 (5%)	4 (1.8%)	14 (6.4%)	17 (7.8%)	29 (13.2%)	9 (4.1%)	7 (3.2%)	3 (1.4%)
Missing (%)	20/219 (9.1%)	20/219 (9.1%)	20/219 (9.1%)	23/219 (10.5%)	20/219 (9.1%)	22/219 (10%)	20/219 (9.1%)	20/219 (9.1%)	21/219 (9.6%)	21/219 (9.6%)

Appendix AG (Cont.). *Strength training barriers (Table 2 of 2)*

	I am uncertain about the safety of strength training for patients.	**I am uncertain about the benefit of strength training for patients.**	**I do not have the knowledge and understanding to deliver strength training to patients.**	**I do not have the training needed to deliver strength training to patients.**	**My colleagues are uncertain about the safety of strength training for patients.**	**My colleagues are uncertain about the benefit of strength training to patients.**	**My colleagues do not have the training needed to deliver strength training to patients.**	**My colleagues do not have the knowledge and understanding to deliver strength training to patients.**
Median (*IQR*)	2 (*1*)	2 (*2*)	2 (*2*)	3 (*2*)	3 (*2*)	2 (*2*)	3 (*2*)	3 (*2*)
1 - Strongly Disagree	32 (14.6%)	51 (23.3%)	30 (13.7%)	26 (11.9%)	30 (13.7%)	31 (14.2%)	23 (10.5%)	25 (11.4%)
2 - Disagree	89 (40.6%)	88 (40.2%)	78 (35.6%)	69 (31.5%)	78 (35.6%)	77 (35.2%)	64 (29.2%)	68 (31.1%)
3 - Somewhat Disagree	38 (17.4%)	27 (12.3%)	37 (16.9%)	29 (13.2%)	37 (16.9%)	31 (14.2%)	29 (13.2%)	32 (14.6%)
4 - Neither Agree nor Disagree	28 (12.8%)	18 (8.2%)	24 (11.0%)	28 (12.8%)	24 (11.0%)	39 (17.8%)	37 (16.9%)	34 (15.5%)
5 - Somewhat Agree	8 (3.7%)	5 (2.3%)	15 (6.8%)	28 (12.8%)	15 (6.8%)	10 (4.6%)	21 (9.6%)	22 (10%)
6 - Agree	3 (1.4%)	5 (2.3%)	13 (5.9%)	15 (6.8%)	13 (5.9%)	3 (1.4%)	15 (6.8%)	10 (4.6%)
7 - Strongly Agree	1 (0.5%)	2 (0.9%)	2 (0.9%)	4 (1.8%)	2 (0.9%)	6 (2.7%)	8 (3.7%)	6 (2.7%)
Missing (%)	20/219 (9.1%)	23/219 (10.5%)	20/219 (9.1%)	20/219 (9.1%)	21/219 (9.6%)	22/219 (10%)	22/219 (10%)	22/219 (10%)

Appendix AH

Strength assessment attitude EFA scree plot



Appendix AI

Strength assessment barriers EFA - correlation matrix of all 17 items

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.Time is limited for assessing patient muscle strength	1.000																
2. Staff workloads are too high for assessing patient muscle strength	.700**	1.000															
3. There are not enough staff for assessing patient muscle strength	.656**	.888**	1.000														
4. Class sizes are too large for assessing patient muscle strength	.548**	.717**	.762**	1.000													
5. Funding is limited for assessing patient muscle strength	.441**	.601**	.625**	.532**	1.000												
6. Exercise equipment is inadequate for assessing patient muscle strength	.326**	.395**	.401**	.316**	.528**	1.000											
7. It is difficult to get patients to comply with the directions/instructions when assessing their muscle strength	.325**	.388**	.387**	.449**	.327**	.280**	1.000										
8. Patients have physical limitations which makes it difficult to assess their muscle strength	.212**	.218**	.215**	.324**	.255**	.210**	.459**	1.000									
9. Patients have psychological limitations which makes it difficult to assess their muscle strength	.215**	.373**	.422**	.494**	.275**	.157*	.600**	.576**	1.000								
10. I am uncertain about the safety of assessing patient muscle strength	.145*	.303**	.284**	.323**	.255**	.153*	.414**	.288**	.412**	1.000							
11. I am uncertain about the benefit of assessing patient muscle strength	.212**	.328**	.333**	.323**	.293**	.163*	.415**	.265**	.399**	.621**	1.000						
12. I do not have the training needed to assess patient muscle strength	.180*	.263**	.252**	.234**	.240**	.274**	.336**	.055	.230**	.459**	.434**	1.000					
13 I do not have the knowledge and understanding needed to assess patient muscle strength	.145*	.230**	.225**	.181*	.238**	.227**	.263**	.015	.195*	.504**	.475**	.806**	1.000				
14. My colleagues are uncertain about the safety of assessing patient muscle strength	.214**	.341**	.296**	.300**	.328**	.334**	.309**	.215**	.337**	.462**	.395**	.414**	.500**	1.000			
15. My colleagues are uncertain about the benefit of assessing patient muscle strength	.259**	.355**	.304**	.271**	.364**	.344**	.336**	.212**	.251**	.413**	.482**	.388**	.448**	.823**	1.000		
16. My colleagues do not have the training needed to assess patient muscle strength	.292**	.318**	.313**	.261**	.362**	.456**	.290**	.144*	.141*	.335**	.283**	.480**	.523**	.713**	.654**	1.000	

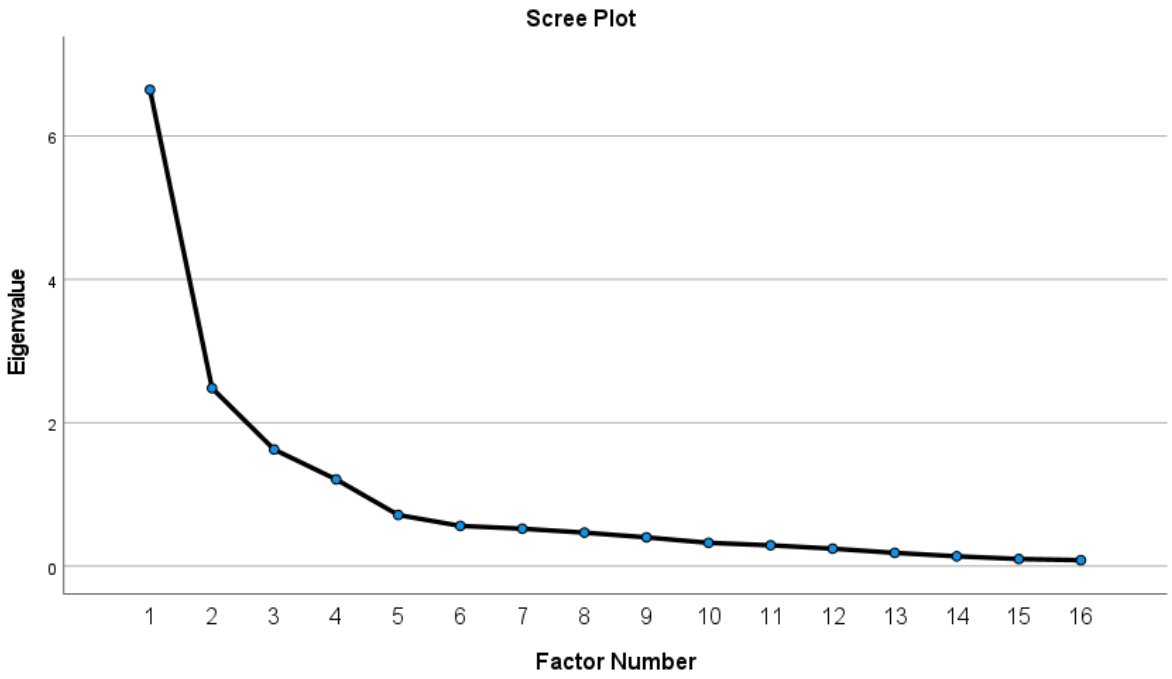
17. My colleagues do not have the knowledge and understanding needed to assess patient muscle strength.	.232**	.276**	.288**	.204**	.383**	.419**	.272**	.150*	.139*	.302**	.292**	.400**	.520**	.749**	.725**	.878**	1.000

Note. * correlation is significant at ≤0.05 level, ** correlation is significant at ≤0.001

Note. Correlations in red are <.3, correlations of items in each factor are highlighted in green

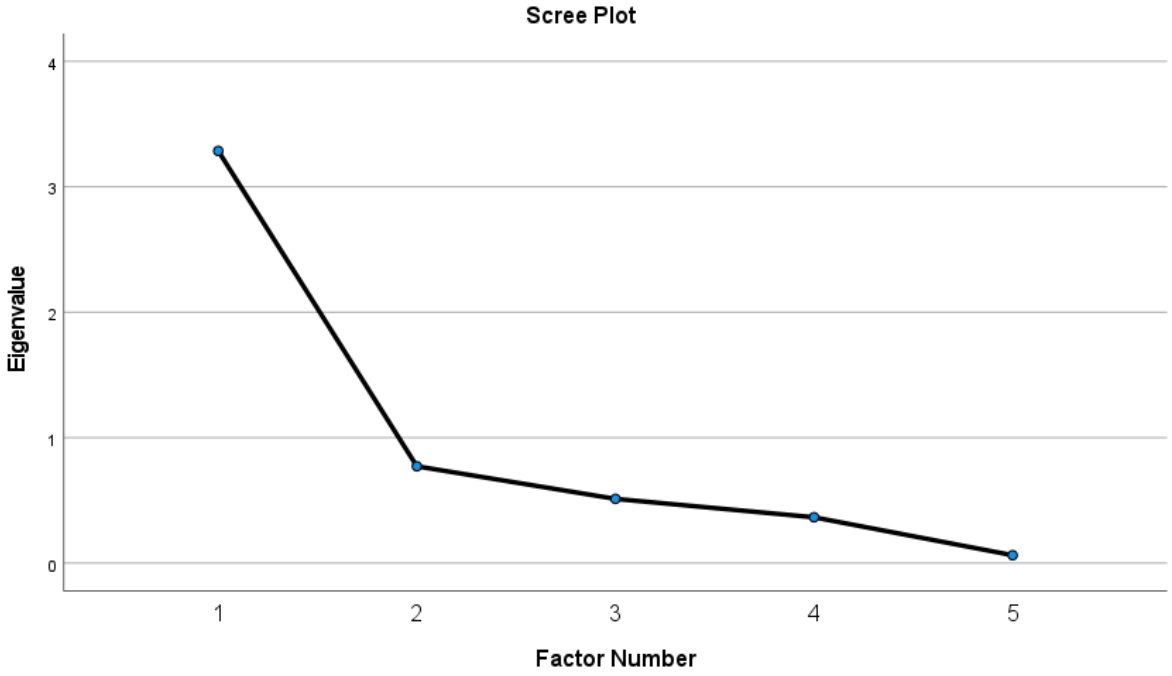
Appendix AJ

Strength assessment barriers EFA Scree Plot



Appendix AK

Strength training attitude EFA scree plot



Appendix AL

Strength training barriers EFA - correlation matrix of all 18 items

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.Time is limited for delivering strength training	1.000																	
2. Staff workloads are too high for delivering strength training	.847**	1.000																
3. There are not enough staff for delivering strength training	.775**	.884**	1.000															
4. Class sizes are too large for delivering strength training	.669**	.778**	.820**	1.000														
5. Funding is limited for delivering strength training	.566**	.642**	.683**	.642**	1.000													
6. Exercise equipment is inadequate for delivering strength training	.416**	.465**	.526**	.488**	.639**	1.000												
7. There is not enough exercise equipment to go round all patients	.424**	.404**	.437**	.436**	.569**	.687**	1.000											
8. It is difficult to get patients to comply with the directions/instructions for strength training	.420**	.425**	.421**	.459**	.403**	.436**	.549**	1.000										
9. Patients have physical limitations which makes it difficult for them to do strength training	.267**	.287**	.270**	.288**	.252**	.278**	.253**	.499**	1.000									
10. Patients have psychological limitations which makes it difficult for them to do strength training	.362**	.401**	.338**	.338**	.255**	.286**	.307**	.583**	.663**	1.000								
11. I am uncertain about the safety of strength training for patients	.438**	.444**	.478**	.411**	.266**	.261**	.292**	.343**	.304**	.350**	1.000							

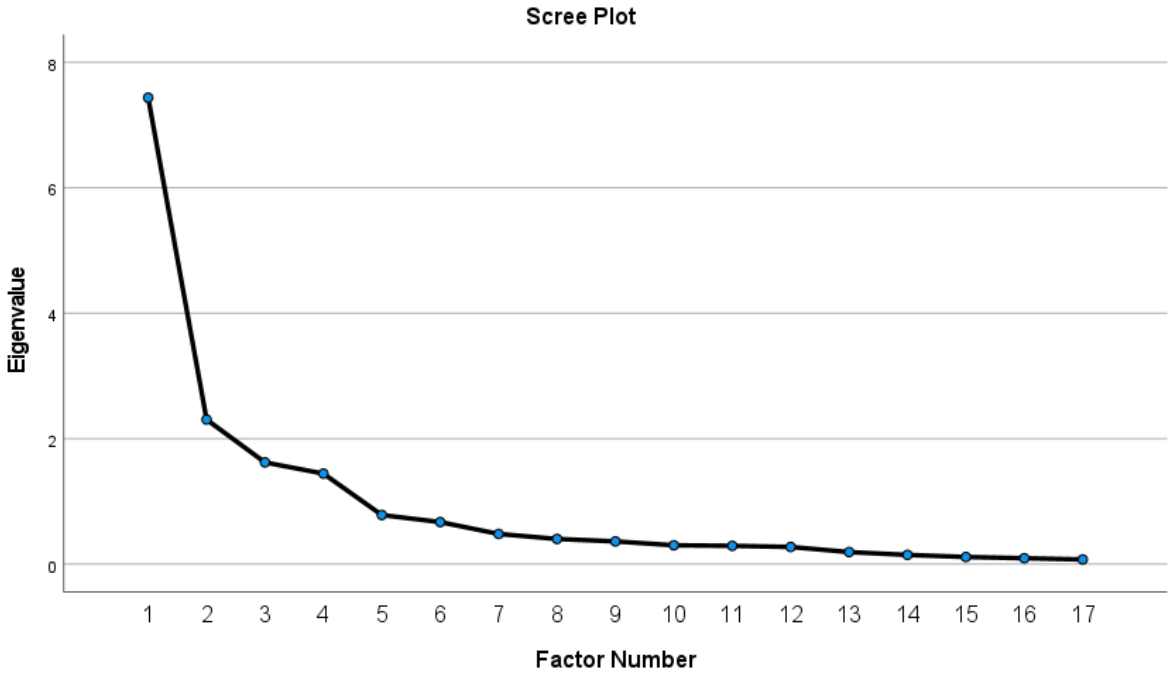
12. I am uncertain about the benefit of strength training for patients	.289**	.327**	.348**	.278**	.182*	.148*	.150*	.241**	.178*	.160**	.581**	1.000					
13. I do not have the training needed to deliver strength training to patients	.321**	.367**	.399**	.295**	.307**	.284**	.251**	.225**	.100	.193**	.492**	.417**	1.000				
14. I do not have the knowledge and understanding needed to deliver strength training to patients	.309**	.329**	.373**	.293**	.214**	.184*	.158*	.244**	.084	.168**	.526*	.490**	.873**	1.000			
15. My colleagues are uncertain about the safety of strength training for patients	.374**	.351**	.368**	.371**	.357**	.358**	.346**	.277**	.139*	.151**	.348**	.197**	.439**	.406**	1.000		
16. My colleagues are uncertain about the benefit of strength training for patients	.347**	.374**	.354**	.361**	.334**	.350**	.345**	.295**	.139*	.181**	.359*	.270**	.382**	.392**	.805**	1.000	
17. My colleagues do not have the training needed to deliver strength training to patients	.396**	.407**	.413**	.361**	.391**	.424**	.371**	.281**	.150*	.186**	.313**	.190**	.489**	.446**	.778**	.730**	1.000
18. My colleagues do not have the knowledge and understanding needed to deliver strength training to patients	.354**	.379**	.391**	.357**	.381**	.406**	.338**	.301**	.166*	.213**	.329**	.236**	.513**	.461**	.768**	.782**	.898**	1.000

Note. * correlation is significant at ≤0.05 level, ** correlation is significant at ≤0.001

Note. Correlations in red are <.3, correlations of items in each factor are highlighted in green

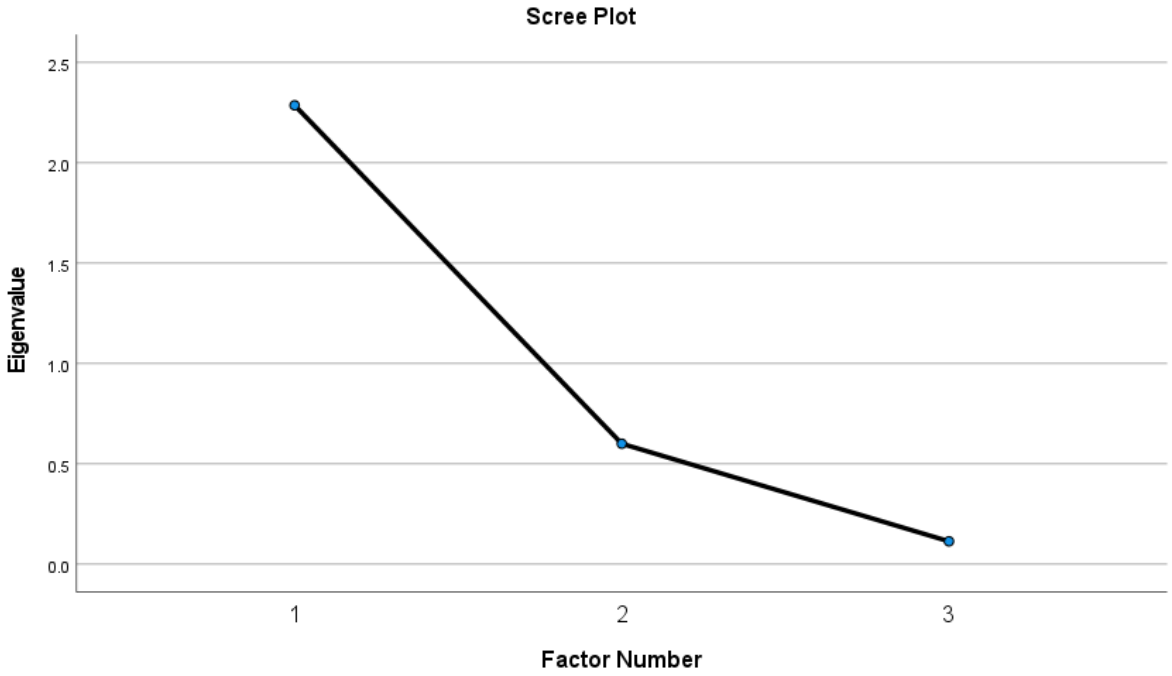
Appendix AM

Strength training barrier EFA scree plot



Appendix AN

Strength training guideline awareness EFA scree plot



Appendix AO

Binary logistic regression coefficients of the model predicting fulfilment of the strength training prescription criteria

	β	SE	Wald's χ^2	*df*	*p*	*OR*	95% CI *OR*	
							Lower	Higher
SA Use	.200	.426	.220	1	.639	1.221	.530	2.814
Number of PR sites	-.063	.081	.614	1	.433	.939	.802	1.099
PR programme length (weeks)	-.272	.236	1.327	1	.249	.762	.479	1.210
ST Attitude Score	.006	.010	.308	1	.579	1.006	.986	1.025
ST Guideline Awareness Score	-.384	.376	1.041	1	.308	.681	.326	1.424
ST Service Barrier Score	.246	.246	1.000	1	.317	1.279	.790	2.070
ST Patient Barrier Score	.083	.194	.183	1	.669	1.087	.742	1.591
ST Practitioner Barrier Score	.104	.177	.347	1	.556	1.110	.784	1.571
ST Colleague Barrier Score	-.466	.295	2.497	1	.114	.627	.352	1.119
ST Practitioner Training	-.142	.199	.505	1	.477	.868	.587	1.283
ST Confidence			2.070	2	.355			
ST Confidence – Disagree (1)	-1.165	.815	2.044	1	.153	.312	.063	1.540
ST Confidence – Neither Disagree Nor Agree (2)	-.208	.563	.136	1	.712	.812	.269	2.450
Constant	3.098	3.575	.751	1	.386	22.159		

Note. 'ST Confidence' categorical comparison group was 'Agree' (3)

Appendix AP

Information received from enquiry to the BTS about their offered courses

From: Bookings <Bookings@brit-thoracic.org.uk>
Sent: 28 February 2024 12:58
To: Pittaccio, Kate F
Subject: RE: BTS PR Advanced Course

Dear Kate,

Thank you for your email.

If the clinicians have no experience at all then they need to attend the fundamentals before they do the advanced course:

Advanced Pulmonary Rehabilitation
The advanced course will appeal to a multi-disciplinary audience with some years' experience of working in pulmonary rehabilitation. As you might have seen on our website, this course will take place 6 – 7 November 2024, though the booking isn't open yet nor has the programme been set. I've added the learning points from the 2023 course below as they will most likely be similar in 2024:

This two-day virtual course aims to provide the following learning objectives:

- *Demonstrate your understanding of alternative models of pulmonary rehabilitation.*
- *Demonstrate your understanding of strategies to augment the benefits of pulmonary rehabilitation including ambulatory oxygen therapy, balance retraining and intermittent exercise.*
- *Demonstrate your understanding of post-COVID-19 assessment and rehabilitation.*
- *Demonstrate your understanding of how to effectively deliver formal education sessions remotely.*

The two-day course will include a combination of pre-course recorded content, live presentations and group-based case studies and discussions.

Fundamentals of Pulmonary Rehabilitation
If the clinicians have no experience at all then they need to attend the fundamentals before they do the advanced course. The fundamentals course will appeal to a multi-disciplinary audience delivering or involved in the management of Pulmonary Rehabilitation and as an introduction for new members of staff delivering rehabilitation. The 2024 short course is fully booked, and the waitlist is closed. Another course will take place in 2025, however the booking page for this course is not yet available.

It will also be useful for teams who will be applying for accreditation of their PR service.

Non-BTS members will need to keep an eye out for updates on the course page. BTS members incl. international BTS members will receive a newsletter when the booking opens. We recommend people booking as soon as either of these courses open for bookings as they are very popular.

I hope the above was useful,

Best wishes,

[redacted]

Appendix AQ

BTS fundamentals of pulmonary rehabilitation 2024 online course schedule (557)

The Fundamentals of Pulmonary Rehabilitation

Wednesday 6 & Thursday 7 March 2024

Online Programme

	WEDNESDAY 6 MARCH 2024
SESSION 1	
09.00am – 09.10am	Welcome & objectives
09.10am – 09.30am	Patient experience of PR
09.30am – 10.00am	Pulmonary Rehabilitation as part of the management of COPD (overview)
10.00am – 10.30am	Patient selection and initial assessment
10.30am – 10.40am	COMFORT BREAK
10.40am – 11.10am	Properties, conduct and practice of the 6MWT and ISWT
11.10am – 11.55am	Case study on pulmonary rehabilitation assessment (Break-out groups)
11.55am – 12.00pm	Review of content from Session 1
12.00pm	End of Session 1
12.00pm – 1.00pm	LUNCH BREAK
SESSION 2	
1.00pm – 1.05pm	Welcome back & session objectives
1.05pm – 1.55pm	The fundamentals of aerobic exercise prescription
1.55pm – 2.25pm	The fundamentals of resistance exercise prescription
2.25pm – 3.00pm	Case study on exercise prescription (Break-out groups)
3.00pm – 3.15pm	Review of content in Session 2
3.15pm	End of Session 2 & Close for day 1

	THURSDAY 7 MARCH 2024
SESSION 3	
09.00am – 09.05am	Welcome and session objectives
09.05am – 09.35am	Overview of the educational component
09.35am – 10.15am	Group exercise on delivering education (Break-out groups)
10.15am – 10.30am	COMFORT BREAK
10.30am – 11.30am	Clinical Dilemmas for complex patients
11.30am – 12.15pm	Q&A Session
12.15pm	End of Session 3
12.15pm – 1.00pm	LUNCH BREAK
SESSION 4	
1.00pm – 1.05pm	Welcome back & session objectives
1.05pm – 1.45pm	Rehabilitation in non-COPD
1.45pm – 2.15pm	Considerations for remote delivery of pulmonary rehabilitation: evidence, safety, assessment
2.15pm – 2.50pm	Ask the experts (All faculty members)
2.50pm – 3.00pm	Review of session & closing remarks