An Evaluation of Service Provision and Novel Strength Assessment on Patient Outcomes in a UK based Pulmonary Rehabilitation Setting

[1]Ruth Barlow, [2]Ben Jones, [2]Mike Rogerson, [1]Hannah Bannister, [1]Rebecca Stuart, Iqbal [3]Jawadh, [3]Leanne Andrews, [2]Izzie Easton

[1]*Provide UK.*

[2]*School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, UK.*

[3]*School of Health and Social Care, University of Essex, Colchester, UK.*

School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, UK. CO4 3SQ. Email: bjonesa@essex.ac.uk

An Evaluation of Service Provision and Novel Strength Assessment on Patient Outcomes in a UK based Pulmonary Rehabilitation Setting

This study's purpose was to (i) assess the impact of a 7-week Pulmonary Rehabilitation (PR) programme upon patient outcomes; incremental shuttle walk test (ISWT), COPD assessment tool (CAT), Clinical COPD Questionnaire (CCQ) and the Hospital Anxiety and Depression Scale (HADS); (ii) assess the impact of COPD severity on ISWT and psychological functioning and quality of life measures following PR; (iii) assess the feasibility of incorporating individually prescribed one repetition maximum (1RM) training loads into the existing strength training programme.

Patients were people with COPD enrolled onto one of three versions (locations A, B & C) of a 7-week PR programme, which consisted of group exercise sessions and a social plus education element. Two locations incorporated individually prescribed training loads.

Minimal Clinically Important Changes (MCIC) are reported for the ISWT across all locations. Statistically significant changes in both CAT and the CCQ were found, with MCIC's evident for CAT score overall and individually at location B. MCIC's were not found for the CCQ. No statistically significant or MCIC were evident for the HADS. MCIC's were present only in patients with mild to moderate severity for the ISWT. For the CAT, moderate, severe and very severe patients with COPD experienced MCIC's. MCIC's and statistically significant increases in 1RM strength were seen at both locations.

These findings evidence an effective PR service. Basic strength exercise programming and assessment are feasible and should be implemented in PR services to maximize patient outcomes.

Keywords: pulmonary rehabilitation; copd; service provision

Introduction

Chronic obstructive pulmonary disease (COPD) is recognised as a leading respiratory disease with three million deaths worldwide each year with increasing mortalities [1]. Pulmonary Rehabilitation (PR), one of the established COPD treatment strategies is considered critical for individuals living with chronic respiratory diseases. It typically includes exercise programs alongside educational elements [2,3]. PR has been shown to be successful in improving exercise tolerance and health-related quality of life, and has been shown to reduce hospital admissions rates in patients with COPD [4,5]. Exercise training is reported as the cornerstone of PR programs [6] and incorporates many types of exercise including aerobic endurance, high intensity interval training, whole body and localized resistance training [7-9]. Patients with COPD are commonly associated with muscular atrophy, peripheral muscle weakness, low levels of activity and comorbidities indicated with inactivity [10]. Studies have shown that exercise interventions [7] and in particular resistance exercise, including free weights and elastic bands [11-13] can improve not only muscle strength and exercise capacity, but also quality of life in patients with COPD [14,15]. Resistance exercise is therefore integral to PR programs [16].

Although shown to be effective PR programs are typified by patient non-completion, low exercise adherence and poor continuance following discharge [17]. Resistance training and exercise prescription in healthy populations are founded upon key programming variables: (1) repetition maximum (RM); (2) number of sets; (3) choice of exercise; (4) order of exercises; and (5) rest periods and are necessary for safe and accurate assessment and progression of training [18]. Assessment of patients and

programme outcomes should be incorporated wherever possible [19]. There is a necessity to identify peripheral muscle weakness prior to PR to prescribe appropriate resistance loads [20], particularly as strength has marked decrements in patients with COPD, especially in severe COPD [21]. Despite knowledge of these fundamental principles, only 27% of current UK PR services implement baseline strength training assessment, with no indication of post training assessment or individual load prescription [22]. Further, the variable application of strength assessment and subsequent prescription indicates the provision of ineffective strength training by clinical experts [23]. The incorporation of pre/post assessment and progressive, individualized strength training in PR settings will aid PR services [24]. This could lead to improved patient outcomes and even promote future exercise adherence. Negative outcomes regarding program adherence, program continuance and the long term benefits of PR programs have been documented [22,25]. Further to this patients have cited a need for programme value and exercise acceptability [26]. Therefore provision of effective, acceptable patient valued programs, i.e. improved exercise-associated confidence and competence, is key. Strength can be measured in patients using a diverse range of methods; however the application of a one repetition maximum (1RM) estimation formula remains a simplistic measurement to implement [20,27,28]. Since individuals living with COPD experience ventilatory limitations during whole-body endurance training [29], designing exercises which isolate specific muscle groups diminishes the ventilatory load and increases the effectiveness of PR. The exercise program and assessment in the current study focusses on isolated upper and lower limb movements, as quadriceps and biceps have been suggested as the muscles group most affected by the patients' low physical activity levels [7,30]. Understanding which patients are most likely to benefit from PR has clinical importance [31]. Investigation of

baseline characteristics such as severity of lung function, skeletal muscle dysfunction and inspiratory muscle strength have produced conflicting findings with regard to predicting patient outcomes and PR effectiveness [32-35].

The primary purpose(s) of this service evaluation, in a cohort of patients with COPD, using only the usual parameters obtained as part of an ongoing PR programme were to: (i) assess the impact of a 7-week PR programme upon patient outcome measures; incremental shuttle walk test (ISWT) distance, and psychological functioning and quality of life measures including the COPD assessment tool (CAT), the Clinical COPD Questionnaire (CCQ) and the Hospital Anxiety and Depression Scale (HADS) respectively; (ii) assess the impact of COPD severity on ISWT, psychological functioning and quality of life measures; and (iii) assess the feasibility of incorporating individually prescribed one repetition maximum (1RM) training loads into the existing strength training programme. A further aim of this study is to contribute to current understanding about factors influence adherence to PR programmes of this kind. The primary hypothesis was that the 7 week PR programme would lead to significant improvements in; ISWT distance, 1RM and all psychological functioning and quality of life measures. The secondary hypothesis was that improvements in ISWT distance, psychological functioning and quality of life outcomes would differ in patient groups.

Materials and methods

Patients and design

This between-within design study examined a cohort of patients with COPD, using only outcome measures obtained as a matter of routine practice at the start and end of a PR programme. Participants were patients with COPD who enrolled onto one of three

versions of a 7-week PR programme between September 2016 and November 2017 (patients attended the programme version closest to their home address). Patient diagnosis and classification were based upon Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2017 guidelines [36]. Patients were diagnosed upon spirometry (the presence of a post-bronchodilator FEV1/FVC < 0.70) and symptoms indicating COPD i.e. dyspnea, chronic cough or sputum production. Patients were a real world cohort with a range of comorbidities and accompanying pharmacological treatments.

Programme versions

A local healthcare provider ran three near identical 7-week PR programmes in different geographical locations. In accordance with BTS Guidelines [37], these consisted of group exercise sessions (14 hours) and a 'social plus education' element (14 hours; occurring after each exercise session where patients socialised and talked with invited experts on specific topics e.g. inhaler use).

The group exercise component of the programme comprised a twice-weekly, one hour circuit-style exercise class, whereby patients completed a 10 minute warm up, followed by a 48 minute circuit of 12 exercise 'stations', followed by a short active cool down. Each exercise within the circuit had a duration of 2 minutes, whereby patients completed as many repetitions of the exercise as they were able to. A 2-minute rest period followed each exercise, with continuation of exercise during this rest period when patients felt able and motivated to do so.

Although patients started at different points within the circuit, the order of stations was: walking; wall push-off; heel raises; cycling or step-ups; side arm raises; squats; bicep curls (programme versions A and C) / leg extensions (programme version B); sit to stand; ball throw; star jacks; marching on the spot and upright row. Monitoring

of exercise intensity and exercise progression utilised the Borg scale as per American College of Sports Medicine (ACSM) guidelines [38,39].

The only difference between programmes (A, B, C) was one specific exercise completed within the group exercise sessions. Patients attending version A completed bicep curls, whereby each participant was individually prescribed an optimal training load. At the first PR session the patients completed 2 sets of 6 repetitions at 50% 1RM as per American Thoracic Society (ATS) guidelines [38,39]. Patients were then encouraged to increase repetitions by 1 at the next exercise session until a load difficulty of 10 repetitions per set was completed. The weight was then increased by 0.5-1kg and repetitions reduced back to 2 sets of 6 [40]. Patients attending version B completed leg extension exercise instead of bicep curls, again following an individualised prescribed and progressive training load. Patients attending version C completed bicep curls at self-selected training loads, whereby they were free to choose any resistance theraband (yellow, red or blue), number of reps and sets, within each session.

Predicted 1RM calculation

At locations A (biceps) and B (quadriceps), Epley's prediction protocol and equation was used to calculate patient 1RM in order to reduce the risk of injury or fatigue to the patient [41,42]. The health professional initially estimated a suitable weight for the patient to lift, aiming for 10% of the patient's body weight and taking their overall condition into consideration. The exercise technique was demonstrated and the patient was asked to lift the selected weight as many times as possible. If the patient was able to lift the allocated weight more than 10 times, a heavier weight was then lifted, until this was not possible.

Measures

Both at the start and the end of the 7-week programme, a health professional collected data as described below. The outcome measures used within the analyses were routinely collected by the service. Questionnaires were completed in a random order, either before or after the walking test. Patients completed their own questionnaires, unless in the case of literacy or sight issues, whereby a member of staff would read the questions to the patient. Predicted 1RM (as described above) was additionally measured at these time points.

The Incremental Shuttle Walk test (ISWT)

The ISWT is a validated walking test and is sensitive to changes after PR [43,44]. The test is a maximal externally paced incremental exercise test and assesses exercise capacity. Using instructions standardised from an audio recording, patients walk back and forth between markers paced 10-metres apart, whereby the walking speed is increased slightly each minute. The ISWT score is a record of how far the patient has walked in metres before a participant could no longer complete a shuttle in the time allowed (i.e. more than 0.5 m away from the cone when the beep sounded). Higher scores indicate greater functional capacity, and the minimal clinically important change (MCIC) for the ISWT is between 35.0 and 36.1 metres [45]. A practice test was conducted as recommended [44]. Patients then rested for 30 minutes before repeating the test.

COPD Assessment Tool (CAT)

The CAT is a validated patient-completed questionnaire that assesses the impact of COPD on an individual's health status [46]. Previous PR research has used the CAT to assess health changes associated with PR programmes. Scores range from 0 – 40,

whereby higher scores indicate poorer health status, and the MCIC in the CAT is 2 points [47].

The Clinical COPD Questionnaire (CCQ)

The CCQ is a self-administered10-item questionnaire that measures quality of life in patients with COPD. It is designed to evaluate treatment whilst incorporating both the clinician's and patient's goals [48]. Higher scores indicate worse quality of life, and a score decrease of 0.4 or more is considered to be clinically significant [49].

The Hospital Anxiety and Depression Scale (HADS)

The HADS is a self-administered 14 item questionnaire of which, 7 items assess anxiety and 7 assess depression [50]. The HADS is used to assess anxiety and depression in clinical settings and is recommended for use in PR [41]. Higher scores indicate more severe anxiety or depression, with scores higher than 10 indicating probable presence of disorder [51]. The MCIC in each of the HAD subscales is 1.7 points [52].

Statistical analyses

Data from all patients was included for analyses of adherence to the programmes. A series of Mann-Whitney U tests (as data was non-normally distributed; for interval scale variables at the start of the programmes: Age; CAT; CCQ; ISWT; HADS Anxiety; HADS Depression) and chi-square tests (for nominal variables: Gender; COPD severity status; Smoking status; Programme Location) were used to examine potential differences in baseline characteristics between adherers (patients who attended at least 75% of the exercise component of the programmes) and non-adherers. To additionally explore the possibility that baseline characteristics might statistically *predict* adherence,

a series of binary logistic regressions were performed (a series of single regressions was used in order to avoid potential suppressor effects within a single, multiple logistic regression model).

Only data from adherers was included for analysis of outcomes. For each variable other than 1RM (ISWT, CAT, CCQ & HADS), changes from start to end of the programme across each location were first assessed though interpreting magnitudes of change as indicated by descriptive statistics, in relation to MCIC values.

Presence of statistically significant effects of time and of time-by-location interactions were then tested for using a series of two-way mixed (between, within) ANOVA tests.

The factor of 'programme location' was then collapsed and data was grouped by severity status of COPD. First, magnitudes of change (as indicated by descriptive statistics) were assessed in relation to MCIC values. Presence of statistically significant effects of COPD severity categories were then tested for via a series of one-way ANCOVAs on end of programme values, whereby start values were included as the covariates.

As most of the psychological and quality of life measures (ISWT, CAT, CCQ & HADS) were not normally distributed across all levels, median values are given in Tables 2 and 3, in addition to mean values. However, parametric tests were used to examine the data, as ANOVA tests are relatively robust to violations of the assumption of normal distributions, particularly with sample sizes over 20 [53], and because there are not adequate non-parametric equivalent tests to ANCOVA.

For the measure of 1RM, descriptive values were assessed in relation to MCIC values, and Wilcoxon ranked sign tests were used to assess the statistical significance of changes from start to end of programme at each of locations A (biceps) and B

(quadriceps). MCIC were calculated using an distribution based approach according to Vaidya et al. [54]. The calculated 1RM MCICs within the current study were 0.324kg for biceps (location A) and 2.47kg for quadriceps (location B).

An alpha level of 0.05 was used to indicate statistical significance. As not all patients completed all measures at each time-point, sample size analysed varies between measures.

All analyses were performed using SPSS (Version 25.0 Armonk, NY: IBM CORP).

Results

Patients

Data was recorded for 322 patients. Table 1 presents mean and frequency descriptive statistics for age, sex and severity of COPD by programme version (detail about the programmes is given in 'The Programmes' section). Severity of COPD condition was only recorded for 106 patients. The proportion of patients of differing COPD severity did not significantly differ between locations (X^2 (6) = 8.90, p = 0.18).

Table 1. HERE

Adherence

233 patients (72%) successfully adhered to the programmes (79% adherence at location A; 79% at location B; 62% at location C). At the start of the programmes there were small but statistically significant differences between adherers and non-adherers for the variables of smoking status (X^2 (2) = 7.442, p= 0.024, Cramer's V= 0.16),

whereby 81% of non-smokers adhered, compared to only 66% of smokers and 59% of ex-smokers; and programme location status as reported on above (X^2 (2) = 10.818, p= 0.004, Cramer's V= 0.18). There were no statistically significant differences for the variables of Age, CAT, CCQ, ISWT, HADS Anxiety, HADS Depression, COPD status and gender (p> 0.05).

Smoking status predicted 2.9% (Cox & Snell R^2= 0.029) – 4.1% (Nagelkerke R^2= 0.041) of adherence likelihood, and this was statistically significant (X^2 (2, n= 262) = 7.642, Wald = 7.255, p= 0.027). Smokers were only 47% (95% CI for Exp. B [0.259, 0.859]) as likely, and ex-smokers were only 34% (95% CI or Exp. B [0.117, 1.016]) as likely as non-smokers to adhere to the programme.

Programme location also predicted 3.3% – 4.7% of adherence likelihood to a statistically significant extent (X^2 (2, n= 326) = 10.663, Wald = 10.579, p= 0.005). On average, patients at Locations A (95% CI for Exp. B [1.26, 4.24]) and B (95% CI [1.24, 4.12]) were twice as likely to adhere compared to patients at location C.

Finally, HADS Anxiety at the start of the programme predicted 1.9% – 4.7% of adherence likelihood to a statistically significant extent (X^2 (1, n= 225) = 4.317, Wald = 4.492, p= 0.038). For each one-point increase in HADS Anxiety score was associated with a 12% decreased likelihood (95% CI for Exp. B [0.779, 0.99]) of adhering to the programme.

No other variables (age, COPD status, gender, and each of CAT, CCQ, HADS depression and ISWT as measured at the start of the programme) predicted adherence to a statistically significant extent (p> 0.05).

1RM

Both biceps (location A) and quadriceps (location B) surpassed the calculated MCICs. Wilcoxon ranked sign tests found that at each of location A ($Z= -4.540$, $p<0.001$, $n= 47$) and location B ($Z= -4.245$, $p<0.001$, $n= 42$) there were statistically significant trends of increased Epley's 1RM scores from the start to end of PR.

ISWT, quality of life and psychological functioning measures

Inspection of the mean values shown in Table 2 indicates that the changes in ISWT were clinically important across all locations. A nearly clinically important change in CAT was found across the total sample (only 0.1 short of the critical change value), with a clinically important change reported at programme location B. Overall reported changes in CCQ were 75% of the magnitude considered clinically important. Changes in HADS anxiety and depression scores were negligible, with little variation between programmes.

A series of mixed two-way ANOVAs found statistically significant improvements from start to end of the PR programmes for the measures of ISWT ($F_{1,168}= 81.93$, $p< 0.001$, $\eta^2 = 0.33$), CCQ ($F_{1,198}= 6.80$, $p= 0.01$, $\eta^2 = 0.03$), CAT ($F_{1,203}= 20.55$, $p< 0.001$, $\eta^2 = 0.09$). There were no statistically significant effects for time for HADS anxiety and depression, ($p> 0.05$). There were no statistically significant time by location interactions effects across the outcome measures ($p> 0.05$).

COPD severity status

Inspection of the mean change values in Table 3 indicates that clinically important improvements were seen for the mild and moderate severity patients for the ISWT. For CAT, mild and severe and very severe COPD patients experienced clinically important

improvements. For CCQ, HADS anxiety and HADS depression none of the COPD categories showed clinically important mean improvement.

A series of one-way ANCOVAs found that after controlling for start of the programme scores, there was not a statistically significant effect for starting COPD severity status on end of programme values for ISWT (p= 0.061), CAT (p= 0.263), CCQ (p= 0.651), HADS anxiety (p= 0.938) or HADS depression (p= 0.692).

Table 2 HERE

Table 3 HERE

Discussion

Overall the findings from the current study indicate the provision of an effective PR service as evidenced by statistical and clinically important changes in both incremental shuttle walk test (ISWT) distance and quality of life outcomes. Further the feasibility of incorporating individualised load prescription based off a 1RM assessment was possible and effective.

Contextually the findings from this service evaluation are consistent with a recent national audit within the UK [22]; that PR programmes are effective at improving outcomes measures such as the ISWT. Statistically significant and Minimally Clinically Important Changes (MCIC) are reported for the incremental shuttle walk test (ISWT) across all locations. These findings are similar to those seen following similar length PR programmes for the ISWT and provide evidence for an effective PR service [45,55]. Secondary findings show that MCIC's were present only in patients with mild to moderate severity for the ISWT. It is perhaps intuitive that mild to moderate COPD patients experienced the greatest improvement in ISWT as physical activity and

capacity levels decline with severity of disease [56] and in part may be related to a reduced capacity for improvement within the severe to very severe patient categories. However, Altenburg and colleagues demonstrated a better response in exercise capacity in more severe patients following an intensity tailored PR programme [32], suggesting that with correct exercise prescription, improvements can be experienced by all.

Evaluation of psychological functioning, health status, quality of life and depressive symptoms is common place within National Health Service (NHS) practice and important to establish the benefit or treatment and practice upon a patient. For the CAT, moderate, severe and very severe patients with COPD experienced clinically important improvements. MCIC's were not evident for the CCQ and HADS anxiety and depression scores for any COPD classification. The CAT and CCQ are tools that evaluate health status and quality of life respectively, and positive changes would be expected following an improvement in exercise capacity, which is consistent with the findings of others [55,57-59]. Higher rates of depression and anxiety have been found in patients with COPD compared to the normal population and so it has been postulated that PR may improve anxiety and depression [60,61]. This service evaluation saw no changes within HADS score, which is in contrast to other studies, which have evidenced improvements [61-63], albeit differences between studies including; in-patient rehabilitation, length of rehabilitation and specific tool to measure the construct may account for this. The simplest explanation however, may be, that patients initially reported low levels of anxiety and depression, nearly as much as half as those reported by Garuit et al. [61]. Given the 'ceiling' effect for initial values, effective PR service and opportunity to socialize with other patients, improved depressive scores were unlikely. It is suggested that a more disease specific patient reported outcome measure

(PROMs) be used as an alternative, or potentially measures to assess exercise enjoyment or exercise self-efficacy - both predictors of continuance [64]. This may hold more value for behavior change, programme adherence and exercise / activity continuance. Similarly, the use of focus groups or individual questioning of existing patient may better inform effective PROMs use and should form part of a patient programme exit process.

Tertiary findings were that across both implemented locations (A: biceps and B: quadriceps), there were clinically important and statistically significant increases in one repetition maximum (1RM) strength. Increases at both locations was not unexpected as theraband (elastic) resistance training has previously been shown to be as effective as free weights for improving strength in various populations including patients with COPD [12,65].

There is a growing body of evidence to support the application of strength training and its effectiveness in PR programs [7,11,13]. Here we have shown that it is possible to use a simplistic clinically appropriate methodology [66-68] to establish 1RM and incorporate this within a PR programme. This in itself holds value for the service and others that wish to implement such an approach. This small 'pilot' application can be used as the basis for both structured upper and lower limb strength training programs that would lead to improved isolated limb strength. The use of basic programming principals [18] will impact upon service outcome measures (strength and functionality), but could also help combat the major issue of programme continuance [17]. Based on the findings of Cook et al. that patients need to see the value within a programme to 'buy in' and adhere [26], value will arguably most easily be seen through personally experienced improvement. Stone and colleagues also 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 their PR programme [69]. Additionally strength training has been shown to be an effective therapy for depressive symptoms [70], which may hold importance due to the common relationship between depression and COPD [71,72]. In order to fully quantify the benefits of individually prescribed training loads (a limitation here) robust, patient preference-based MCIC's need to be established for upper and lower limb strength in COPD. As such we calculated 1RM MCIC's using a distribution based approach in order to facilitate this for future clinicians and researchers. In context, the improvements in 1RM leg strength seen in the current study are comparable to those seen by Daabis et al. [59], who utilised an 8 week 3x per week combined resistance and endurance training programme. It would have been valuable to have also evaluated the impact of COPD severity upon strength improvement, as this could potentially enable a much needed targeted approach for PR services [31]. This was not however possible due to incomplete data collection and is a requirement for further assessment and evaluation.

Although only predicting small percentages of adherence likelihood, the findings that HADS Anxiety, smoking status and programme location influenced the likelihood of adherence within the current study alludes to the potential importance of targeting future interventions more efficiently, so to reduce dropout rates and wasted resource. For example, perhaps amendments can be made to align some programmes more closely with the needs of patients who experience greater anxiety. The findings that smoking status [73-76] and anxiety [75,77] influenced adherence are consistent with many other studies. Future research and programmes should continue to collect data that enables analyses of factors that influence adherence, so to increase understanding and useful guidance across the sector.

Conclusion

This service evaluation evidences an effective PR service that leads to positive physiological and quality of life outcomes that are evidenced by MCIC's. Basic exercise programming and assessment are feasible, led to significant improvements in 1RM strength and should be implemented in PR services to maximize patient outcomes. This may have further reaching effects upon patient adherence and continuance, which requires further study. Where time effective and economically viable approaches to PR services are key to both patient and provider, correctly administered strength training may benefit all.

Acknowledgements

We would like to thank Alan Gooding for the early discussions relating to strength assessment and training in PR.

Disclosure statement

In accordance with Taylor & Francis policy and my ethical obligation as a researcher, I am reporting that Ruth Barlow, Hannah Bannister and Rebecca Stuart, have a potential personal conflict as they are employed by Provide, the provider of the pulmonary rehabilitation service, in which the evaluation took place. I have disclosed those interests fully to Taylor & Francis, and I have in place an approved plan for managing any potential conflicts arising from that employment.

References

1. Forum of International Respiratory Societies. The Global Impact of Respiratory Disease. Second ed. Sheffield: European Respiratory Society; 2017.

2. Andrews L, Barlow R, Easton I. Differences in patient outcomes between a 6, 7 and 8-week pulmonary rehabilitation programme: A service evaluation. Physiotherapy. 2015;101(1):62 68.
3. Marques A, Jácome C, Cruz J, et al. Effects of a pulmonary rehabilitation program with balance training on patients with COPD. J Cardiopulm Rehabil Prev. 2015;35(2):154-158.
4. Puhan MA, Gimeno - Santos E, Cates CJ, et al. Pulmonary rehabilitation following exacerbations of chronic obstructive pulmonary disease. Cochrane Database Syst Rev. 2016;12.
5. Chen Y, Niu ME, Zhang X, et al. Effects of home-based lower limb resistance training on muscle strength and functional status in stable Chronic obstructive pulmonary disease patients. J. Clin. Nurs. 2018;27(5-6):e1022-37.
6. Bolton CE, Bevan-Smith EF, Blakey JD, et al. British Thoracic Society guideline on pulmonary rehabilitation in adults: accredited by NICE. Thorax. 2013;68:ii1-ii30.
7. Armstrong M, Vogiatzis I. Personalized exercise training in chronic lung diseases. Respirology. 2019.
8. Troosters T, Gosselink R, Janssens W, et al. Exercise training and pulmonary rehabilitation: new insights and remaining challenges. Eur Respir Rev. 2010;19(115):24-29.
9. Almeida P, Rodrigues F. Exercise training modalities and strategies to improve exercise performance in patients with respiratory disease. Rev Port Pneumol *(English Edition)*. 2014;20(1):36-41.
10. Zwerink M, van der Palen J, van der Valk P, et al. Relationship between daily physical activity and exercise capacity in patients with COPD. Respir. Med. 2013;102(2):242-248.
11. Latimer LE, Constantin D, Greening NJ, et al. Latimer LE, Constantin D, Greening NJ, Calvert L, Menon MK, Steiner MC, Greenhaff PL. Impact of transcutaneous neuromuscular electrical stimulation or resistance exercise on skeletal muscle mRNA expression in COPD. Int J Chron Obstruct Pulmon Dis. 2019;14:1355-1364.
12. Ramos EMC, de Toledo-Arruda AC, Fosco LC, et al. The effects of elastic tubing-based resistance training compared with conventional resistance training in patients with moderate chronic obstructive pulmonary disease: a randomized clinical trial. Clin Rehabil. 2014;28(11):1096-1106.
13. Daabis R, Hassan M, Zidan M. Daabis R, Hassan M, Zidan M. Endurance and strength training in pulmonary rehabilitation for COPD patients. Egypt J Chest Dis Tuberc. 2017;66(2):231-236.
14. Vonbank K, Strasser B, Mondrzyk J, et al. Strength training increases maximum working capacity in patients with COPD–randomized clinical trial comparing three training modalities. Respir. Med. 2012;106(4):557-563.
15. Lacasse Y, Martin S, Lasserson TJ, et al. Lacasse Y, Martin S, Lasserson TJ, Goldstein RS. Meta-analysis of respiratory rehabilitation in chronic obstructive pulmonary disease. Cochrane Database Syst. Rev. 2007:475-485.
16. Man WD, Polkey MI, Donaldson N, et al. Community pulmonary rehabilitation after hospitalisation for acute exacerbations of chronic obstructive pulmonary disease: randomised controlled study. BMJ. 2004;329(7476):1209.
17. Lopez-Campos JL, Gallego EQ, Hernandez LC. Status of and strategies for improving adherence to COPD treatment. Int J Chron Obstruct Pulmon Dis. 2019;14:1503-1515.

18. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness. Sports Med. 2005;35(10):841-851.
19. Peno-Green L, Verrill D, Vitcenda M, et al. Patient and program outcome assessment in pulmonary rehabilitation: an AACVPR statement. J Cardiopulm Rehabil Prev. 2009;29(6):402-410.
20. Zeng Y, Jiang F, Chen Y, et al. Exercise assessments and trainings of pulmonary rehabilitation in COPD: a literature review. Int J Chron Obstruct Pulmon Dis. 2018;13:2013-2023.
21. McCarthy B, Casey D, Devane D, et al. McCarthy B, Casey D, Devane D, Murphy K, Murphy E, Lacasse Y. Pulmonary rehabilitation for chronic obstructive pulmonary disease. Cochrane Database Syst Rev. 2015 (2).
22. Steiner M, McMillan V, Lowe D, et al. Pulmonary rehabilitation: an exercise in improvement. National chronic obstructive pulmonary disease (COPD) audit programme. 2017; clinical and organisational audits of pulmonary rehabilitation services in England and Wales.
23. Schultz K, Jelusic D, Wittmann M, et al. Inspiratory muscle training does not improve clinical outcomes in 3-week COPD rehabilitation: results from a randomised controlled trial. Eur Respir J. 2018;51(1):1702000.
24. McLay R, O'hoski S, Beauchamp MK. Role of muscle strength in balance assessment and treatment in chronic obstructive pulmonary disease. Cardiopulm Phys Ther J. l. 2019;30(1):35-43.
25. Jones SE, Green SA, Clark AL, et al. Pulmonary rehabilitation following hospitalisation for acute exacerbation of COPD: referrals, uptake and adherence. Thorax. 2014;69(2):181-182.
26. Cook H, Reilly CC, Rafferty GF. A home-based lower limb-specific resistance training programme for patients with COPD: an explorative feasibility study. ERJ Open Res. 2019;5(2):00126-2018.
27. Zeren M, Demir R, Yigit Z, et al. Effects of inspiratory muscle training on pulmonary function, respiratory muscle strength and functional capacity in patients with atrial fibrillation: a randomized controlled trial. Clin Rehabil. 2016; 30(12):1165-1174.
28. Mathur S, Dechman G, Bui KL, et al. Evaluation of limb muscle strength and function in people with chronic obstructive pulmonary disease. Cardiopulm Phys Ther J. 2019;30(1):24-34.
29. Robles P, Araujo T, Brooks D, et al. Cardiorespiratory responses to short bouts of resistance training exercises in individuals with chronic obstructive pulmonary disease. J Cardiopulm Rehabil Prev. 2017;37(5):356-362.
30. Spencer L. Pulmonary rehabilitation for patients with acute chronic obstructive pulmonary disease exacerbations: is the evidence strengthening? Curr Opin Pulm Med. 2018;24(2):147-151.
31. Rochester CL. Patient assessment and selection for pulmonary rehabilitation. Respirology. 2019;24(9):844-853.
32. Altenburg WA, de Greef MH, Ten Hacken NH, et al. A better response in exercise capacity after pulmonary rehabilitation in more severe COPD patients. Respir. Med. 2012;106(5):694-700.
33. Plankeel JF, McMullen B, MacIntyre NR. Exercise outcomes after pulmonary rehabilitation depend on the initial mechanism of exercise limitation among non-oxygen-dependent COPD patients. Chest. 2005;127(1):110-116.
34. Garrod R, Marshall J, Barley E, et al. Predictors of success and failure in pulmonary rehabilitation. Eur Respir J. 2006;27(4):788-794.

35. Walsh JR, Morris NR, McKeough ZJ, et al. A simple clinical measure of quadriceps muscle strength identifies responders to pulmonary rehabilitation. Pulm Med. 2014;2014.
36. Vogelmeier CF, Criner GJ, Martinez FJ, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease 2017 report. GOLD executive summary. Am J Respir Crit Care Med. 2017;195(5):557-582.
37. Bolton CE, Bevan-Smith EF, Blakey JD, et al. British Thoracic Society guideline on pulmonary rehabilitation in adults. Thorax. 2013 Sep; 68 Suppl 2(Suppl 2): ii1-30.
38. Garvey C, Bayles MP, Hamm LF, et al. Pulmonary rehabilitation exercise prescription in chronic obstructive pulmonary disease: Review of selected guidelines. J Cardiopulm Rehabil Prev. 2016;36(2):75-83.
39. American College of Sports Medicine. ACSM Guidelines for Exercise Testing and Prescription. 9th ed. Philadelphia, PA:2013. p. 334–338.
40. O'Shea SD, Taylor NF, Paratz J. Peripheral muscle strength training in COPD: a systematic review. Chest. 2004;126(3):903-914.
41. Nici L, Donner C, Wouters E, et al. American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. Am J Respir Crit Care Med. 2006 Jun 15;173(12):1390-413.
42. Epley B. Poundage chart. Boyd Epley Workout Lincoln, NE: Body Enterprises. 1985;86.
43. Emtner MI, Arnardottir HR, Hallin R, et al. Walking distance is a predictor of exacerbations in patients with chronic obstructive pulmonary disease. Respir. Med. 2007;101(5):1037-1040.
44. Singh SJ, Morgan M, Scott S, et al. Development of a shuttle walking test of disability in patients with chronic airways obstruction. Thorax. 1992;47(12):1019-1024.
45. Evans RA, Singh SJ. Minimum important difference of the incremental shuttle walk test distance in patients with COPD. Thorax. 2019;74(10):994-995.
46. Jones PW, Harding G, Berry P, et al. Development and first validation of the COPD Assessment Test. Eur Respir J. 2009;34(3):648-654.
47. Kon SS, Canavan JL, Jones SE, et al. Minimum clinically important difference for the COPD Assessment Test: a prospective analysis. Lancet Respir Med. 2014;2(3):195-203.
48. Van der Molen T, Willemse BW, Schokker S, et al. Development, validity and responsiveness of the Clinical COPD Questionnaire. Health Qual Life Outcomes. 2003;1(1):13.
49. Kon SS, Dilaver D, Mittal M, et al. The Clinical COPD Questionnaire: response to pulmonary rehabilitation and minimal clinically important difference. Thorax. 2014;69(9):793-798.
50. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand. 1983;67(6):361-370.
51. Snaith RP. The hospital anxiety and depression scale. Health Qual Life Outcomes. 2003;1(1):29.
52. Lemay KR, Tulloch HE, Pipe AL, et al. Establishing the Minimal Clinically Important Difference for the Hospital Anxiety and Depression Scale in Patients With Cardiovascular Disease. J Cardiopulm Rehabil Prev. 2018.
53. Norman GR, Streiner DL. Biostatistics: the bare essentials. Bc Decker Hamilton; 2008.

54. Vaidya T, Beaumont M, de Bisschop C, et al. Determining the minimally important difference in quadriceps strength in individuals with COPD using a fixed dynamometer. Int J Chron Obstruct Pulmon Dis. 2018;13:2685.
55. Egan C, Deering BM, Blake C, et al. Short term and long term effects of pulmonary rehabilitation on physical activity in COPD. Respir. Med. 2012;106(12):1671-1679.
56. Zwerink M, van der Palen J, van der Valk P, et al. Relationship between daily physical activity and exercise capacity in patients with COPD. Respir. Med. 2013;107(2):242-248.
57. Foglio K, Bianchi L, Bruletti G, et al. Seven-year time course of lung function, symptoms, health-related quality of life, and exercise tolerance in COPD patients undergoing pulmonary rehabilitation programs. Respir. Med. 2007;101(9):1961-1970.
58. Chen Y, Niu Me, Zhang X, et al. Effects of home-based lower limb resistance training on muscle strength and functional status in stable Chronic obstructive pulmonary disease patients. J Clin Nurs. 2018;27(5-6):e1022-e1037.
59. Daabis R, Hassan M, Zidan M. Endurance and strength training in pulmonary rehabilitation for COPD patients. Egypt J Chest Dis Tuberc. 2017;66(2):231-236.
60. Lacasse Y, Rousseau L, Maltais F. Prevalence of depressive symptoms and depression in patients with severe oxygen-dependent chronic obstructive pulmonary disease. J Cardiopulm Rehabil Prev. 2001;21(2):80-86.
61. Garuti G, Cilione C, Dell Orso D, et al. Impact of comprehensive pulmonary rehabilitation on anxiety and depression in hospitalized COPD patients. Monaldi Arch Chest Dis. 2003;59(1):56-61.
62. von Leupoldt A, Taube K, Lehmann K, et al. The impact of anxiety and depression on outcomes of pulmonary rehabilitation in patients with COPD. Chest. 2011;140(3):730-736.
63. Paz-Díaz H, De Oca MM, López JM, et al. Pulmonary rehabilitation improves depression, anxiety, dyspnea and health status in patients with COPD. Am J Phys Med Rehabil. 2007;86(1):30-36.
64. Sherwood NE, Jeffery RW. The behavioral determinants of exercise: implications for physical activity interventions. Annu. Rev. Nutr. 2000;20(1):21-44.
65. Lopes JSS, Machado AF, Micheletti JK, et al. Effects of training with elastic resistance versus conventional resistance on muscular strength: A systematic review and meta-analysis. SAGE open medicine. 2019;7:2050312119831116.
66. Mathur S, Dechman G, Bui K-L, et al. Evaluation of limb muscle strength and function in people with chronic obstructive pulmonary disease. Cardiopulm Phys Ther J. 2019;30(1):24-34.
67. Zeren M, Demir R, Yigit Z, et al. Effects of inspiratory muscle training on pulmonary function, respiratory muscle strength and functional capacity in patients with atrial fibrillation: a randomized controlled trial. Clin Rehabil. 2016;30(12):1165-1174.
68. Zeng Y, Jiang F, Chen Y, et al. Exercise assessments and trainings of pulmonary rehabilitation in COPD: a literature review. Int J Chron Obstruct Pulmon Dis. 2018;13:2013.
69. Stone P, Steiner M, McMillan V, et al. Predictors of Pulmonary Rehabilitation Completion in the Chronic Obstructive Pulmonary Disease Population: National Audit Data from the United Kingdom. C106. PULMONARY REHABILITATION: American Thoracic Society; 2019. p. A5737-A5737.

70. Gordon BR, McDowell CP, Hallgren M, et al. Association of Efficacy of resistance exercise training with depressive symptoms: meta-analysis and meta-regression analysis of randomized clinical trials. JAMA psychiatry. 2018;75(6):566-576.
71. Maurer J, Rebbapragada V, Borson S, et al. Anxiety and depression in COPD: current understanding, unanswered questions, and research needs. Chest. 2008;134(4):43S-56S.
72. Schneider C, Jick SS, Bothner U, et al. COPD and the risk of depression. Chest. 2010;137(2):341-347.
73. Brown AT, Hitchcock J, Schumann C, et al. Determinants of successful completion of pulmonary rehabilitation in COPD. Int J Chron Obstruct Pulmon Dis. 2016;11:391.
74. Oates GR, Hamby BW, Stepanikova I, et al. Social determinants of adherence to pulmonary rehabilitation for chronic obstructive pulmonary disease. COPD: Chronic Obstr Pulm Dis. 2017;14(6):610-617.
75. Jordan RE, Adab P, Enocson A, et al. Interventions to promote referral, uptake and adherence to pulmonary rehabilitation for people with chronic obstructive pulmonary disease (COPD). Cochrane Database Syst Rev. 2017;2017(10).
76. Keating A, Lee A, Holland AE. What prevents people with chronic obstructive pulmonary disease from attending pulmonary rehabilitation? A systematic review. Chron Respir Dis. 2011;8(2):89-99.
77. Heerema-Poelman A, Stuive I, Wempe JB. Adherence to a maintenance exercise program 1 year after pulmonary rehabilitation: what are the predictors of dropout? J Cardiopulm Rehabil Prev. 2013;33(6):419-426.

Tables

Table 1. Descriptive statistics of sample by programme version

	Programme version A	**Programme version B**	**Programme version C**	**Total**
n	76	79	78	233
Sex	44 males; 32 females	35 males; 44 females	55 males; 23 females	134 males 99 females
Mean Age (years) ± SD	70.1 ± 8.7	72.3 ± 7.4	72.7 ± 8.2	71.7 ± 8.1 Range: 45 – 90
COPD Severity	n= 43 Mild: 8 Moderate: 13 Severe: 19 Very severe: 3	n= 21 Mild: 5 Moderate: 8 Severe: 5 Very severe: 3	n= 42 Mild: 2 Moderate: 14 Severe: 18 Very severe: 8	n= 106 Mild: 15 Moderate: 35 Severe: 42 Very severe: 14

	Programme version A	Programme version B	Programme version C	Total
n	76	79	78	233
Sex	44 males; 32 females	35 males; 44 females	55 males; 23 females	134 males 99 females
Mean Age (years) ± SD	70.1 ± 8.7	72.3 ± 7.4	72.7 ± 8.2	71.7 ± 8.1 Range: 45 – 90
COPD Severity	n= 43 Mild: 8 Moderate: 13 Severe: 19 Very severe: 3	n= 21 Mild: 5 Moderate: 8 Severe: 5 Very severe: 3	n= 42 Mild: 2 Moderate: 14 Severe: 18 Very severe: 8	n= 106 Mild: 15 Moderate: 35 Severe: 42 Very severe: 14

Table 2. Mean ± SD values by location and time-point

Measure		Location and time-point							
		Location A		Location B		Location C		Total	
		Start	***End***	***Start***	***End***	***Start***	***End***	***Start***	***End***
1RM (kg)	*Mean ± SD*	8.7 ± 3.1 (biceps)	10.5 ± 3.8	11.5 ± 5.7 (quadriceps)	17.0 ± 10.9				
	***Median** (IQR)*	8.0 (4.5)	10.1 (4.7) **	9.7 (9.2)	15.0 (19.4) **				
	n	47		42					
ISWT (m)	*Mean ± SD*	199.8 ± 131.7	246.6 ± 127.3	172.61 ± 98.4	210.7 ± 115.1	211.1 ± 129.6	254.8 ± 139.1	196.7 ± 123.2	239.9 ± 129.3
	***Median** (IQR)*	185.0 (150.0)	250.0 (122.0) **	155.0 (110.0)	200.0 (132.5) **	180 (180.0)	250.0 (210.0) **	180.0 (150.0)	230.0 (150.0) **
	n	62		46		63		171	
CAT §	***Mean** ± SD*	21.5 ± 7.6	20.1 ± 8.2	21.4 ± 7.6	19.0 ± 7.4 **	17.6 ± 7.7	15.9 ± 6.5	20.2 ± 7.8	18.3 ± 7.6
	Median (IQR)	21.5 (11.0)	19.5 (12.8)	22.0 (11.3)	19.5 (11.3)	18.0 (9.0)	16.5 (8.8)	20.0 (11.0)	18.0 (11.0)
	n	68		70		68		206	
CCQ	*Mean ± SD*	2.70 ± 1.21	2.50 ± 1.12	3.00 ± 1.43	2.61 ± 1.26	2.23 ± 1.00	2.08 ± 1.15	2.64 ± 1.25	2.40 ± 1.20
	***Median** (IQR)*	2.75 (1.58)	2.50 (1.50)	2.7 (1.70)	2.50 (1.70)	2.20 (1.20)	2.10 (1.30)	2.50 (1.50)	2.20 (1.60)
	n	64		69		68		201	
HADS Anxiety	*Mean ± SD*	5.90 ± 3.57	5.78 ± 3.63	6.00 ± 4.14	5.56 ± 3.79	4.10 ± 3.22	3.84 ± 3.14	5.33 ± 3.75	5.06 ± 3.62
	***Median** (IQR)*	5.00 (5.00)	5.78 (5.00)	6.00 (6.00)	5.56 (6.25)	3.00 (5.00)	3.00 (5.00)	5.00 (5.00)	5.00 (6.00)
	n	69		70		70		209	
HADS Depression	*Mean ± SD*	6.86 ± 3.45	6.81 ± 3.53	6.09 ± 3.74	6.20 ± 3.59	4.76 ± 2.92	4.53 ± 3.25	5.89 ± 3.48	5.84 ± 3.58

	***Median** (IQR)*	7.00 (5.00)	7.00 (6.00)	5.50 (5.25)	6.00 (6.00)	4.00 (4.00)	4.00 (5.00)	5.00 (5.00)	6.00 (6.00)
	n	69		70		70		209	

§ indicates variable was normally distributed

Mean / Median in **bold** text indicates the appropriate value to assess in relation to minimal clinically important change.

** Indicates clinically important change from start to end of programme

Table 3. Mean ± SD Changes in outcomes measures by COPD severity classification

Measure		**COPD Severity**			
		Mild	**Moderate**	**Severe**	**Very Severe**
Δ ISWT (m) §	***Mean*** *± SD*	49.0 ± 46.5 **	60.7 ± 67.3 **	19.3 ± 64.1	30.0 ± 35.7
	95% CI	15.7, 82.3	34.6, 86.8	-5.1, 43.7	7.3, 52.7
	Median (IQR)	45.0 (87.5)	50.0 (80.0)	25.0 (57.5)	20.0 (50.0)
	n	10	28	29	12
Δ CAT	*Mean ± SD*	-2.5 ± 5.6	-1.7 ± 5.5	-2.0 ± 6.1	1.9 ± 4.9
	95% CI	-6.0, 1.1	-3.8, 0.5	-4.0, 0.0	-1.0, 4.7
	Median *(IQR)*	-1.5 (12.5)	-2.0 (5.5) **	2.5 (7.0) **	2.0 (10.0) **
	n	13	28	37	14
Δ CCQ	*Mean ± SD*	-0.01 ± 0.46	-0.17 ± 0.84	0.04 ± 1.40	-0.11 ± 0.69
	95% CI	0-0.28, 0.27	-0.50, 0.17	0.04, 0.53	-0.53, 0.31
	Median *(IQR)*	-0.20 (0.97)	-0.10 (0.90)	-0.20 (0.83)	0.00 (1.50)
	n	13	26	34	13
Δ HADS Anxiety	*Mean ± SD*	-0.64 ± 2.92	-0.82 ± 3.21	-0.38 ± 2.99	0.36 ± 1.65
	95% CI	-2.33, 1.05	-2.07, 0.42	-1.38, 0.62	-0.59, 1.31
	Median *(IQR)*	0.00 (2.50)	0.00 (3.50)	0.00 (2.50)	1.00 (2.00)
	n	14	28	37	14
Δ HADS Depression §	***Mean*** *± SD*	-0.29 ± 2.61	-0.64 ± 2.26	-0.05 ± 2.77	0.43 ± 1.50
	95% CI	-1.80, 1.22	1.52, 0.24	-0.98, 0.87	-0.44, 1.30
	Median (IQR)	-0.50 (3.75)	-1.00 (3.50)	0.00 (3.00)	0.00 (2.00)
	n	14	28	37	14

§ indicates variable was normally distributed

Mean / Median in **bold** text indicates the appropriate value to assess in relation to minimal clinically important change.

** Indicates clinically important change from start to end of programme