

**A mixed-methods evaluation of strength and  
conditioning training to optimise in-season golf  
performance**

Sean Richard White

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School of Sport, Rehabilitation and Exercise Sciences

University of Essex

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## **Impact of COVID-19**

The pandemic had a significant impact on my planned work causing considerable disruptions and delays, especially since much of it was intended to be practical in nature. Restrictions on interpersonal interactions made it impossible at times to carry out interventional research. Even after national restrictions began to ease, social distancing requirements continued to affect recruitment for, and the execution of, studies. It was only when restrictions were fully lifted, that it became possible to resume in-person interventional research. The Covid-19 pandemic should, however, also be discussed as a facilitator for this thesis, particularly with regards to the research motivations and research aims. The pandemic led to a short-term role with the European Tour (DP World Tour) and Challenge Tour during the 2021 season where I provided 'health and wellbeing' support to players, staff members, and caddies across several events due to the imposed restrictions and 'bubble' systems in place during tournaments designed to protect all involved parties. This experience offered valuable insights into the complexities and nuances of implementing effective physical preparation strategies for golfers on a major tour and further reinforced the rationale behind the motivations for this thesis. Specifically, this strengthened the motivation to explore low-risk, flexible, and pragmatic strategies to support physical preparation without compromising performance during competitive periods.

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## **Abstract**

Strength and conditioning (S&C) is increasingly recognised as an important component of golf performance, particularly in relation to clubhead speed and golf shot outcomes. However, touring professional golfers face substantial challenges when implementing S&C strategies during extensive in-season and tournament schedules, making optimal physical development within competitive contexts complex. The purpose of this thesis was therefore to examine what is currently known regarding the role of S&C in supporting golf performance, and how such strategies may be applied within these practical constraints. To address this, the literature relating to physical preparation for golf was first explored, before systematically reviewing evidence examining resistance training (RT) priming interventions performed one to 48 hours prior to performance. This review considered RT priming both as a potential means of eliciting short-term performance enhancement via potentiation, and as a strategy for maintaining RT exposure when training opportunities are limited, without incurring fatigue-related reductions in performance. To provide applied context, survey and observational data were then collected to characterise physical preparation practices and perceived barriers to implementing S&C strategies among elite professional golfers. Although most players reported long-term engagement with RT, engagement in-season and during tournament weeks was commonly reduced due to fatigue, time constraints, and facility access. Two experimental studies subsequently examined strength- and power-oriented RT priming interventions to evaluate their feasibility within competitive schedules and determine whether such strategies could preserve or enhance neuromuscular and golf-specific performance. At the group level, neuromuscular and golf-specific performance were largely preserved following RT priming, supporting its utility as a pragmatic training management strategy for competitive golfers. Both increases and reductions were observed at the individual level, reinforcing the importance of

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individual monitoring when implementing RT priming. Practical recommendations are therefore provided to guide its applied use within golf environments.

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## Acknowledgements

This PhD has taken place over several years, shaped by significant personal and professional changes, as well as the disruption caused by the COVID-19 pandemic. Plans changed, timelines shifted, and much of the work required rethinking and rewriting along the way. At times, it was a challenging process to navigate, and I am very grateful to those who supported me throughout.

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## Research Disseminations

### Journal Articles

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### Conference Proceedings / Presentations from this Thesis:

Conference Poster Presentation: A survey analysis of European Tour Golfers Physical Preparation Practices and Perceptions: Study A (18-19<sup>th</sup> July 2022), 2<sup>nd</sup> International Congress on Golf and Health

Conference Poster Presentation: A survey and observational analysis of European Tour Golfers Physical Preparation Practices and Perceptions: Study B (18-19<sup>th</sup> July 2022), 2<sup>nd</sup> International Congress on Golf and Health

Presentation: In-season and in tournament training in golf (4<sup>th</sup> October 2021), England Golf Performance Conference.

Presentation: In-season and in tournament training in golf (9<sup>th</sup> February 2020), European Tour Performance Institute staff CPD

## Table of Contents

Impact of COVID-19 .....	I
Abstract.....	II
Research Disseminations .....	<b>Error! Bookmark not defined.</b>
List of Tables.....	XI
List of Figures .....	XII
List of Abbreviations.....	XIII
1 Chapter 1: Introduction.....	1
1.1 General Introduction .....	1
1.2 Approaches To Performance Measurement in Golf .....	2
1.3 Physical Preparation, Injury Risk, and Availability.....	4
1.4 The Structure and Challenges of a Golfer’s Schedule .....	5
1.5 Research Motivations and Philosophy .....	8
1.6 Research Purpose .....	10
1.6.1 Research Questions .....	11
1.7 Overview of Chapters .....	12
1.7.1 Chapter 2 - The Role of Physical Preparation for Improving Clubhead Speed and Golf Shot Outcomes: A Literature Review .....	12
1.7.2 Chapter 3 - The Effects of Resistance Training Priming Exercise on Neuromuscular Athletic Performance Tasks: A Systematic Review .....	12
1.7.3 Chapter 4 - Elite Professional Golfers’ Physical Preparation Practices and Perceptions.....	14
1.7.4 Chapter 5 - The Effects of a Low-Volume Morning Power Training Session on Afternoon Golf-Specific and Neuromuscular Performance in Skilled Male Golfers: A Pilot Study 14	
1.7.5 Chapter 6 - The Effects of Resistance Training Priming Methods on Neuromuscular Performance, Golf-Specific Outcomes, and Readiness Perceptions in Skilled Golfers.....	15
2 Chapter 2: The Role of Physical Preparation for Improving Clubhead Speed and Golf Shot Outcomes: A Literature Review .....	18
2.1 Introduction.....	19
2.2 Biomechanical Considerations for Maximising CHS and Golf Shot Outcomes .....	21
2.2.1 The Sequential Summation of Forces Principle.....	23
2.2.2 Ground Reaction Forces and Centre of Pressure .....	24
2.2.3 X-Factor and X-Factor Stretch.....	25
2.2.4 The Effect of S&C Interventions on Swing Biomechanics .....	26
2.3 Physiological Considerations.....	28
2.4 Key Physical Attributes .....	29
2.4.1 Muscular Force Expression Characteristics.....	29

---

2.4.2	Flexibility and Balance Characteristics .....	32
2.5	Strength & Conditioning Training Interventions.....	34
2.5.2	Programming Considerations.....	37
2.6	Swing Speed Training.....	47
2.7	Warm-up Interventions and Practices .....	49
2.8	Conclusion .....	52
2.9	Chapter Perspective .....	53
3	Chapter 3: The Effects of Resistance Training Priming Exercise on Neuromuscular Athletic Performance Tasks: A Systematic Review .....	55
3.1	Abstract.....	56
3.2	Introduction.....	57
3.3	Method.....	59
3.3.1	Search Strategy .....	59
3.3.2	Literature Search.....	61
3.3.3	Inclusion and Exclusion Criteria.....	61
3.3.4	Screening Strategy .....	63
3.3.5	Data Extraction .....	63
3.3.6	Quality Assessment.....	63
3.3.7	Analysis and Interpretation of Results.....	64
3.4	Results.....	65
3.4.1	Study Characteristics .....	65
3.4.2	Participants Characteristics and Session Volume Loads .....	66
3.4.3	Training Intensity.....	67
3.4.4	Study Quality .....	71
3.5	Discussion.....	82
3.5.1	The Influence of Participant Characteristics.....	82
3.5.2	The Influence of Session Volume Loads and the Level of Effort .....	85
3.5.3	The Influence of Exercise Intensity and Time Course of Effects.....	87
3.5.4	The Influence of Exercise specificity .....	93
3.5.5	Limitations and Directions for Future Research.....	95
3.6	Conclusions and Practical Applications.....	98
3.7	Chapter Perspectives.....	99
4	Chapter 4: Elite Professional Golfers' Physical Preparation Practices and Perceptions	102
4.1	Citation:.....	102
4.2	Affiliations: .....	102
4.3	Abstract.....	103
4.4	Introduction.....	103

---

4.5	Method.....	105
4.5.1	Survey Design.....	105
4.5.2	Survey Questions.....	105
4.5.3	Survey Recruitment.....	106
4.5.4	In-tournament Observation.....	106
4.6	Statistical Analysis.....	107
4.6.1	Survey.....	107
4.6.2	In-tournament Observation.....	107
4.7	Results.....	108
4.7.1	General Physical Preparation.....	108
4.7.2	In-season and Off-season Physical Preparation.....	109
4.7.3	In-Tournament Physical Preparation.....	111
4.7.4	In-Tournament Observation.....	113
4.8	Discussion.....	115
4.8.1	General Physical Preparation.....	115
4.8.2	In-season and Off-season Physical Preparation.....	118
4.8.3	In-tournament Physical Preparation.....	120
4.8.4	Strengths and limitations.....	122
4.9	Conclusion.....	123
4.10	Chapter Perspective.....	124
5	Chapter 5: The Effects of a Low-Volume Morning Power Training Session on Afternoon Golf-Specific and Neuromuscular Performance in Skilled Male Golfers: A Pilot Study.....	126
5.1	Abstract.....	127
5.2	Introduction.....	128
5.3	Method.....	131
5.3.1	Participants.....	131
5.3.2	Experimental Design.....	132
5.3.3	Statistical Analysis.....	135
5.4	Results.....	136
5.5	Discussion.....	139
5.6	Conclusion.....	145
5.7	Chapter Perspectives.....	145
6	The Effects of Resistance Training Priming Methods on Neuromuscular Performance, Golf-Specific Outcomes, and Readiness Perceptions in Skilled Golfers.....	148
6.1	Abstract.....	149
6.2	Introduction.....	150
6.3	Method.....	154

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6.3.1	Participants.....	154
6.3.2	Overview.....	154
6.3.3	Familiarisation and Strength Testing.....	155
6.3.4	Experimental Conditions .....	157
6.3.5	Testing Procedures.....	157
6.4	Statistical Analysis.....	161
6.5	Results.....	162
6.5.1	Reliability of Outcome Measures .....	162
6.5.2	Group-level, Neuromuscular, Golf-specific, and Perceptual Outcomes.....	163
6.5.3	Individual-Level Neuromuscular and Golf-Specific Changes.....	164
6.5.4	Correlations.....	166
6.6	Discussion .....	177
6.7	Practical Applications .....	184
6.8	Limitations .....	186
6.9	Conclusion .....	187
7	Chapter 7 Conclusions, Practical Applications, and Directions for Future Research ....	189
7.1	Overall Summary .....	190
7.2	Overall Contribution of the Body of Work.....	192
7.3	Limitations .....	193
7.4	Practical Applications .....	194
7.5	Directions for Future Research .....	197
7.6	Conclusions.....	198
8	References .....	199
	APPENDIX A.....	234
	APPENDIX B.....	235
	APPENDIX C.....	236
	APPENDIX D.....	249
	APPENDIX E .....	- 250 -
	APPENDIX F.....	- 251 -

**List of Tables**

Table 2.1 Example resistance training programming considerations for strength, power, and hypertrophy across different levels of training experience in golfers.....	44
Table 3.1 PEDro criteria .....	65
Table 3.2 Results from the PEDro checklist .....	72

Table 3.3 A summary of the studies investigating the effects of resistance priming type exercise on neuromuscular athletic performance within a 1–48-hour timeframe .....	73
Table 4.1 Surveyed golfers’ general physical preparation practices and perceptions .....	108
Table 4.2 In-season and off-season physical preparation practices and perceptions.....	110
Table 4.3 Self-reported in-tournament physical preparation training practices and perceptions .....	112
Table 4.4 Self-reported in-tournament warm-up practices .....	113
Table 5.1 Group-level within-session reliability data.....	137
Table 5.2 Group differences in performance outcome measures between the intervention and control conditions.....	138
Table 5.3 Individual changes following the intervention and control conditions across neuromuscular and golf-specific outcome measures .....	138
Table 6.1 Reliability of performance outcome metrics for measurements recorded at baseline between conditions.....	163
Table 6.2 Differences in neuromuscular and golf-specific performance outcomes following resistance training priming and control protocols.....	167
Table 6.3 Differences in psychological readiness and self-reported shot quality outcomes following resistance training priming and control protocols .....	169
Table 6.4 Individual neuromuscular and golf-specific changes following the control condition .....	170
Table 6.5 Individual neuromuscular and golf-specific changes following the strength condition .....	171
Table 6.6 Individual neuromuscular and golf-specific changes following the power condition .....	173

## List of Figures

Figure 1.1 Schematic of thesis structure .....	17
Figure 3.1 Flow diagram of search strategy.....	60
Figure 4.1 Recorded gym entries at the 148th Open Championship .....	114
Figure 4.2 Recorded training activities at the 148th Open Championship gym facility.....	114
Figure 6.1 Outline of study procedures.....	155
Figure 6.2 Individual changes in the driver performance outcomes after the different protocols.....	175
Figure 6.3 Individual changes in the neuromuscular outcomes after the different protocols	176

**List of Abbreviations**

AU	Arbitrary units
BS	Ball speed
CD	Carry distance
CHS	Clubhead speed
CMJ	Countermovement jump
CV	Coefficient of variation
DD	Driver distance
EIMD	Exercise-induced muscle damage
ES	Effect size
ETHPI	European Tour Health and Performance Institute
HL/LV	Heavy load / low volume
ICC	Intraclass correlation coefficient
IMTP	Isometric mid-thigh pull
LL/HV	Low load / high volume
PAPE	Postactivation performance enhancement
PGA	Professional Golfers' Association
RIR	Repetitions in reserve
RPE	Rate of perceived exertion
RT	Resistance training
S&C	Strength and conditioning
SRSS	Short Recovery and Stress Scale
SSC	Stretch-shortening cycle

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# 1 Chapter 1: Introduction

## 2 1.1 General Introduction

3 Farrelly et al. [1], in their early twenty-first-century review of Golf Science, noted that elite  
4 golfers have gained and will continue to gain from a deeper understanding of the physiological  
5 factors influencing their performance. Since this point, physical preparation strategies for  
6 enhancing and optimising golf performance have attracted considerable research attention [2–  
7 6]. This in turn has drawn increased attention and led to a greater understanding of the role of  
8 achieving greater clubhead speed and golf shot distances [3], and the positive impact physical  
9 preparation strategies can elicit for such performance outcomes [2,6].

10 Anecdotally, physical preparation is now an integral aspect of many players' routines, but  
11 historically, this has not always been the case with greater emphasis previously placed on  
12 technological advancements, tactical awareness, skill execution, and mental preparedness in  
13 player development strategies [7]. This, coupled with the relative infancy of golf physical  
14 preparation research in comparison to that of other sports, has meant that sports performance  
15 practitioners working within the sport have historically had to rely more heavily on anecdotal  
16 training information, experiences, and the broader body of research pertaining to physical  
17 preparation strategies in sport. As research within this field progresses, it is therefore essential  
18 to determine how such progressions have integrated into the practices and perceptions of  
19 golfers and to determine whether potential misconceptions and sub-optimal practices currently  
20 exist.

21 Professional athletes face a number of factors which confound optimal development strategies,  
22 often at the expense of their competitive schedules, and golf is no exception to this. With the  
23 growing commercialisation in the game over recent years, players are now presented with an  
24 abundance of opportunities to play in tournaments across nearly year-long seasons. In addition,

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25 players can be presented with a degree of uncertainty with tournament entry (i.e. reserve list),  
26 success, playing times, and can face regular air travel and time-zone changes. As such, it is  
27 equally important to consider the barriers which may confound the practical delivery of optimal  
28 physical preparation and consider the means through which advancements in empirical  
29 evidence may facilitate solutions to such problems.

## 30 **1.2 Approaches To Performance Measurement in Golf**

31 In golf, success is largely quantified by the number of strokes required to complete each hole.  
32 On the broader scale of this, performance in amateur golf is measured using the handicap index  
33 system, which provides a golfer with a shot allowance relative to their skill level and the  
34 difficulty of the course being played. In line with the Council of National Golf Unions  
35 handicaps are divided into the following Categories with a lower handicap being indicative of  
36 a higher skilled player: category-1 (plus to 5.4 strokes), category-2 (5.5 to 12.4 strokes),  
37 category-3 (12.5 to 20.4 strokes), category-4 (20.5 to 28.4 strokes), category-5 (28.5 to 36.4  
38 strokes) and category-6 (36.5 to 54 strokes) [8].

39 For professionals, scoring averages during an event and across the season are instead crucial  
40 performance markers, which in turn influence world rankings, tour standings, and the prize  
41 money earned during tournaments [9]. Such measures are useful in providing a broad measure  
42 of golf performance, however it is important to consider that numerous factors combine to  
43 influence these measures including driving, off the tee, approach play, and putting [9]. Thus, a  
44 comprehensive assessment of golf performance requires a detailed analysis of these individual  
45 aspects to gain a clearer understanding of a player's overall skill level, and areas in need of  
46 improvement.

47 Regarding the impact of physical preparation on aspects of golf performance, Brearley et al.  
48 [10] present a 'probability of performance impact model' that identifies key performance

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49 elements potentially influenced by physical preparation. This model forms the foundation of  
50 the strength and conditioning (S&C) services provided by the European Tour Health and  
51 Performance Institute (ETHPI). In this model, it is discussed that improving a golfer's driver  
52 distance (DD) represents a direct means through which physical preparation may impact a  
53 golfer's performance.

54 The primary objective when using a driver club is to maximise shot distance while maintaining  
55 accuracy so as to not compromise the follow-up shot. Increasing DD is therefore proposed to  
56 offer a competitive advantage, as it can set up and make it easier to hit a good second shot  
57 which can then lead to lower scoring [11]. Indeed, Hellstrom & Isberg. [11] reported that  
58 Professional Golfers' Association (PGA) tour professional players are likely to achieve a lower  
59 score the closer the ball is to the pin after the tee shot, with significant negative correlation  
60 coefficients observed between striking distance and scoring on long par-4 ( $r = -0.451$ ,  $p <$   
61  $0.001$ ) and par-5 holes ( $r = -0.537$ ,  $p < 0.001$ ). The importance of DD was further highlighted  
62 by Broadie. [12], who related performance to the concept of 'strokes gained'. This metric is  
63 used to analyse how much better or worse a player performs in specific aspects of the game  
64 when compared to the average competing golfer. In line with this, Broadie demonstrated that  
65 PGA Tour professionals who drive the ball an additional 20 yards are likely to save 0.75 strokes  
66 per tournament round (i.e. 3 shots over a four-day tournament). Furthermore, among the 40  
67 highest-ranked players on the PGA Tour, DD was shown to contribute to 28% of strokes  
68 gained, whereas putting accounted for only 15%.

69 Although DD is a key performance indicator in golf, its reliability can be influenced by various  
70 factors, such as environmental conditions (weather conditions like wind and temperature), and  
71 swing technique (centredness of strike, spin rate) [3]. How fast a golfer can swing the club is  
72 directly related to golf shot distance, with greater clubhead speed (CHS) resulting in increases  
73 in shot distance when other factors remain consistent [3]. As such, CHS is commonly used as

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74 a determinant of golf performance particularly in S&C literature [2,5,13], perhaps as it is less  
75 subject to influence by external variables.

76 Further to this, improvements in physical capacities relevant to the golf swing are a method  
77 through which CHS can be increased [2,4]. It is however important that CHS transfers  
78 efficiently to result in longer shot distances, which is governed by the interplay between the  
79 clubhead and ball at impact (impact factors), and the subsequent launch characteristics of the  
80 ball when environmental factors remain consistent [13]. As such, improvements in CHS and  
81 other golf shot outcomes including ball speed and carry distance are commonly sought  
82 following S&C interventions [2,4]. Additionally, commercially available launch monitor  
83 technologies provide highly reliable and valid measurements for these metrics [14], offering  
84 researchers and practitioners an accessible, practical, and relevant means of assessing golf  
85 performance. Accordingly, CHS and related shot outcomes represent relevant and feasible  
86 metrics for assessing golf performance in applied research settings.

### 87 **1.3 Physical Preparation, Injury Risk, and Availability**

88 Brearley et al. [10] also suggest that long-term injury and illness prevention through increased  
89 physical preparedness could have the most notable, albeit indirect, impact on a golfer's  
90 performance by maximising their availability for practice and competition. Sports injuries can  
91 severely affect a golfer's career, leading to reduced performance levels and periods of inactivity  
92 that not only result in a loss of form but also potentially diminish income and can impact tour  
93 card status.

94 Professional golfers have been shown to produce swing speeds in excess of 117 miles per-hour  
95 when using a driver [15], with the entire golf swing typically executed within a fraction of a  
96 second [16]. During a swing with a 5-iron, professional golfers generate spinal compressive  
97 forces of approximately eight times their body weight, with these forces significantly higher

98 than those experienced by amateur golfers (7584 N vs. 6100 N) [17]. For comparison, an  
99 experienced lifter performing the clean exercise with 80kg experiences spinal compressive  
100 forces estimated at  $7979 \pm 443$  N [18]. With a professional golfer performing up to 2000  
101 swings throughout a tournament week in practice and competition [19], it is evident why golf  
102 has been described as a moderate risk factor for musculoskeletal injuries, with annual injury  
103 incidence estimates spanning from 31-90% in professionals [20].

104 While the use of physical preparation strategies for reducing injury risk in golfers is an area  
105 worthy of considerable research attention, prospective epidemiological research in elite  
106 populations presents considerable logistical challenges, particularly due to the need for long-  
107 term access to large cohorts of players. Nevertheless, in a study by Smith and Hillman. [21] a  
108 retrospective audit of injuries documented over 36 tournaments by the mobile physiotherapy  
109 unit on the PGA European Tour was conducted. The results of the study revealed that 80% of  
110 documented injuries were related to overuse. These findings highlight the importance of  
111 managing cumulative load and maintaining physical robustness across the in-season period and  
112 provides a strong rationale for the golfer to be regularly partaking in resistance training. In fact,  
113 a large meta-analysis and systematic review revealed that both acute and overuse injuries could  
114 be significantly reduced with the use of strength-oriented injury prevention programs, with  
115 overuse injury incidence almost being halved [22]. These findings further emphasise the  
116 importance of physical preparation for improving robustness and reducing injury risk, which  
117 may assist in optimising a golfer's ability to train, compete, and maximise performance.

#### 118 **1.4 The Structure and Challenges of a Golfer's Schedule**

119 While there is evidence to support that S&C can enhance golf performance, including CHS and  
120 shot outcomes [4], it is vital that golfers are able to effectively integrate these strategies into  
121 their annual training plans. Accordingly, it is important to first understand the competition

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122 format, the structure of a competitive golfer's season, and the typical schedule of a tournament  
123 week.

124 The PGA Tour, the DP World Tour (formerly the European Tour), and the LIV Golf Tour  
125 represent the pinnacle of competitive men's golf, where the world's top male players compete  
126 for the highest prize money, ranking points, and global recognition. Equivalent structures exist  
127 within women's professional golf, including the LPGA Tour and Ladies European Tour.  
128 Beneath these primary tours, secondary 'feeder' tours operate as progression pathways. For  
129 example, the Korn Ferry Tour feeds into the PGA Tour, and the Challenge Tour feeds into the  
130 DP World Tour. These tours typically feature professional golfers who have either failed to  
131 maintain their status on the major tours or are emerging professionals aiming to secure a spot  
132 on the main tours. Success on these secondary tours often results in opportunities to qualify for  
133 the major tours. Additionally, regional and national tours, such as the Clutch Pro Tour, act as  
134 further feeder systems to secondary tours, serving as developmental platforms for advancement  
135 towards elite professional competition.

136 Major golf tours, including the DP World Tour, now commonly run on a year-round basis, with  
137 the 2022 season featuring 44 tournaments scheduled across all 12 months of the entire calendar  
138 year [23]. Professional golfers generally participate in between 18 and 30 tournaments  
139 annually, although this will vary significantly depending upon several factors [24]. For  
140 instance, higher ranked players may have a greater degree of selection in the events they play,  
141 whereas lower ranked players may be required to play in more tournaments in order to accrue  
142 sufficient ranking points to maintain their tour status. Consequently, back-to-back events are  
143 common, with players frequently travelling directly from one tournament to the next, often  
144 crossing international and intercontinental borders. Although breaks between events are  
145 possible, they are often sporadic and difficult to predict. For example, a golfer might take a  
146 break after a series of back-to-back events to recover, focus on training and skill development,

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147 to rest or prepare for a major event, or celebrate a recent tournament win. This challenge is  
148 exacerbated by the absence of traditional off-season breaks on many tours, such as the 2021  
149 DP World Tour season, which ended on November 21<sup>st</sup>, with the 2022 season starting just four  
150 days later on November 25<sup>th</sup> [23]. These factors contribute to making each golfer's season  
151 schedule unique and challenging to plan for.

152 During a typical tournament week, players will often travel to and arrive at the event on  
153 Monday. Tuesday is typically dedicated to practice, including a practice round to familiarise  
154 themselves with the course. For some players, Wednesdays will feature a Pro-Am event in  
155 which professionals play a round with amateurs or alternatively involve an additional practice  
156 round. The tournament then begins on Thursday and runs until Sunday, with a maximum of  
157 four competitive rounds. A player's participation in the tournament may end early if they miss  
158 "the cut", which typically occurs after the conclusion of the second round. Approximately half  
159 of the field will not advance to the final two rounds, as only those who meet a specific score  
160 threshold are permitted to continue. A unique component of professional golf tournaments is  
161 that only players who make the cut and compete in the final rounds are eligible for prize money,  
162 meaning missing the cut may result in a loss of income, thereby increasing the competitive and  
163 financial jeopardy associated with tournament participation. During tournament weeks, tee-off  
164 times (i.e. a player's tournament round start time) can vary significantly, ranging from early  
165 morning to mid-afternoon, with each round typically lasting four to five hours. Furthermore,  
166 less than 24 hours' notice of tee-off times may be provided, highlighting the need for players  
167 to remain adaptable in their preparation and recovery routines [24]. Beyond on-course play,  
168 players must also manage media commitments, practice sessions, pre-round warm-ups, and  
169 travel, all of which must be carefully accommodated within their schedules. This underscores  
170 the importance of a well-structured S&C programme that can be effectively integrated around  
171 these constraints.

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172 In order to optimise performance during an athlete's season and navigate various constraints,  
173 S&C will often follow a structured approach known as periodisation. Periodisation has been  
174 described as the systematic approach to training which organises an athlete's program into  
175 specific time periods [25], with the goal of optimising performance through the potentiation of  
176 biomotors and the management of fatigue and accommodation [26]. This is primarily achieved  
177 by systematically applying variation to the training methods and volume loads applied in a  
178 logical and, at times, innovative manner [26,27].

179 Variation in training is typically achieved by dividing an annual training plan (macrocycle) into  
180 smaller phases (mesocycles), which usually span four  $\pm$  two weeks [26]. These phases are  
181 commonly used to target specific training adaptations, such as increasing muscular size,  
182 enhancing maximal force production, or developing velocity [25]. Mesocycles can be further  
183 broken down into microcycles, typically lasting a week. In the context of a golfer's season, a  
184 microcycle might correspond to a single tournament week, which, as previously noted, can  
185 vary significantly from one week to the next due to various external and performance-based  
186 factors. Therefore, the careful management, planning, and adjustment of training variables  
187 during these phases are crucial for athletes to progress toward their broader training objectives.  
188 However, evidence on periodisation for golfers is presently limited, particularly regarding the  
189 complexities of scheduling appropriate S&C strategies during the in-season and in-tournament  
190 periods.

## 191 **1.5 Research Motivations and Philosophy**

192 As research in golf progresses, new insights are uncovered in areas such as biomechanics,  
193 equipment, technology, and training methodologies for performance enhancement [1]. Ideally,  
194 these advancements should integrate with golfers' practices and perceptions, ensuring that new  
195 research findings are effectively translated into practice. However, this integration process is  
196 often complex and multifaceted, characterised by challenges in aligning the perceptions of key

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197 stakeholders (golfers, coaches, and researchers) due to varying levels of access to information  
198 and, in some cases, resistance to changing traditional practices. As a result, misconceptions and  
199 suboptimal practices may persist, underscoring the motivation to investigate whether a  
200 practice-research gap exists between golfers' physical preparation practices and the best  
201 available research on using S&C to optimise golf performance while managing fatigue and  
202 performance risk within competitive environments.

203 Equally, practical constraints may prevent golfers and their sports performance practitioners  
204 from implementing optimal practices that align with the best available evidence, even when  
205 they are aware of them. Research findings can be difficult to apply in real-world and high-level  
206 sporting contexts, highlighting the motivation to bridge the research-practice gap. Indeed,  
207 while advancements in S&C for golf performance are gaining recognition, there currently  
208 appears to be a gap in the literature regarding how to effectively incorporate these practices  
209 within the complexities of a golfer's annual training cycle and dense competitive schedules.

210 To address these research and practice challenges, this thesis adopts a pragmatic research  
211 philosophy. Pragmatic research starts with questions and problems that are directly relevant to  
212 practitioners, with the primary intended goal of producing findings that are useful and broadly  
213 applicable in practice [28]. Indeed, researchers using this approach focus on generating results  
214 that can be directly applied by practitioners to enhance their work in real-world settings and in  
215 an actionable manner [28]. Pragmatic research often employs flexible, yet systematic  
216 methodologies to solve research questions rather than adhering to a strict framework.  
217 Consequently, mixed methods (both qualitative and quantitative) are frequently utilised and  
218 adapted to provide the most actionable insights, allowing researchers to address real-world  
219 complexities effectively [29].

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220 Some of the key characteristics of a pragmatic research approach include addressing specific  
221 practice needs and questions, utilising models and frameworks that emphasise relationships  
222 and context, and employing designs that address issues relevant to practitioners, policymakers,  
223 and athletes. Further to this, the measures used in pragmatic research should be both feasible  
224 and actionable in real-world settings [28]. Accordingly, it is recommended that these measures  
225 and metrics be reliable and valid, sensitive to change, feasible, important to practitioners,  
226 actionable, broadly applicable, and non-harmful [28]. In the context of golf, tracking  
227 performance outcomes such as CHS and shot outcomes is a feasible way to assess the  
228 effectiveness of S&C strategies whilst meeting these objectives.

229 Within this context, the central research problem addressed in this thesis is that sub-optimal  
230 implementation, fatigue, or limited adherence to S&C strategies may compromise performance  
231 across their annual training cycle, during a tournament week, or even within a single  
232 tournament round. Accordingly, strategies that allow physical preparation to be maintained  
233 without inducing excessive fatigue-related performance decrements are of particular applied  
234 interest. This highlights the necessity for effective S&C programming to maximise  
235 performance, while mitigating the risk of performance reductions resulting from sub-optimal  
236 training or fatigue.

## 237 **1.6 Research Purpose**

238 The purpose of this thesis was to investigate the role of S&C strategies in supporting golf  
239 performance, and to examine how such strategies can be applied within the practical constraints  
240 of golf competition.

241 More specifically, this thesis aimed to:

- 242 1) Examine the current evidence base relating to the role of S&C strategies in improving golf  
243 performance, including clubhead speed and golf shot outcomes, and to evaluate the

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244 efficacy, limitations, and applied relevance of approaches examined in the literature,  
245 particularly within the context of competitive golf schedules.

246 2) Explore the physical preparation practices and perceptions of golfers competing at the  
247 highest level, and to determine the extent to which current applied practice aligns, or  
248 conflicts with the available evidence.

249 3) Experimentally evaluate the feasibility and applied utility of potential S&C approaches,  
250 informed by both the literature and applied context, with particular emphasis on strategies  
251 that can be implemented practically within a golfer's schedule.

252 In summary, this research aims to bridge the gap between S&C research and its practical  
253 application in golf by identifying what is currently known, what is currently applied, and where  
254 discrepancies exist, before evaluating potential solutions. Accordingly, the value of proposed  
255 strategies is evaluated primarily on their practical utility within the constraints of golf  
256 competition.

### 257 **1.6.1 Research Questions**

258 These aims are addressed through the following research questions:

259 **Question 1:** What is currently known regarding the role of S&C for improving golfers'  
260 clubhead speed and shot outcome performances?

261 **Question 2:** What is the scope of the literature regarding the use of resistance training priming  
262 on neuromuscular athletic performance outcomes within a one- to 48-hour period after  
263 training?

264 **Question 3:** How are S&C practices currently implemented by players competing at the highest  
265 level, and what are the key barriers that may influence engagement during in-season and  
266 tournament periods?

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267 **Question 4:** What are the effects of resistance training priming activities on neuromuscular  
268 and golf-specific performance outcomes in skilled golfers when assessed in the hours following  
269 and on the day after training?

270 These research questions are addressed sequentially across Chapters 2 to 6, as summarised in  
271 Figure 1.1. Chapter 7 then outlines the overarching conclusions and practical implications of  
272 the thesis.

## 273 **1.7 Overview of Chapters**

274 The following section outlines the structure of the thesis and summarises the focus and  
275 progression of each chapter in addressing the stated research questions.

### 276 **1.7.1 Chapter 2 - The Role of Physical Preparation for Improving Clubhead Speed and** 277 **Golf Shot Outcomes: A Literature Review**

278 Chapter 2 addresses Research Question 1 by examining the current evidence base relating to  
279 the role of physical preparation in improving CHS and golf shot outcomes. The chapter  
280 establishes the theoretical and applied foundations of S&C within golf by synthesising key  
281 biomechanical principles, relevant physical attributes, and the effectiveness of longitudinal  
282 (RT) and acute (warm-up) intervention strategies. It also considers the practical challenges  
283 associated with implementing S&C within competitive golf schedules and identifies areas of  
284 consensus and limitation within the literature. Collectively, this chapter provides the contextual  
285 foundation for subsequent chapters, particularly the investigation of strategies that may be  
286 feasible within the competitive constraints of competitive golf.

### 287 **1.7.2 Chapter 3 - The Effects of Resistance Training Priming Exercise on** 288 **Neuromuscular Athletic Performance Tasks: A Systematic Review**

289 Building on the broader application of S&C within golf established in Chapter 2, Chapter 3  
290 addresses Research Question 2 by systematically reviewing the literature on RT priming

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291 interventions and their effects on measures of neuromuscular performance. RT priming has  
292 been examined primarily as a short-duration, low-volume, high-intensity resistance training  
293 stimulus performed within one to 48 hours prior to competition, with the primary aim of  
294 eliciting acute performance enhancement via delayed potentiation mechanisms. However, this  
295 review also considers its potential application as a micro-dosing training strategy, whereby  
296 resistance training may be applied within such timeframes without inducing prolonged  
297 reductions in neuromuscular performance. The findings demonstrate that RT priming can result  
298 in performance improvements across tasks such as jumping, sprinting, strength-based  
299 assessments, throwing, and select sport-specific outcomes. However, these changes were  
300 heterogeneous, with several studies reporting no change or transient declines in performance.  
301 The direction and magnitude of performance changes were influenced by multiple factors,  
302 including exercise selection, training intensity, volume, effort, recovery interval duration, and  
303 individual participant characteristics, with stronger and more resistance-trained individuals  
304 generally demonstrating a greater likelihood of positive or preserved performance changes than  
305 weaker participants.

306 Beyond the pursuit of acute performance enhancement, the current evidence more consistently  
307 supports the use of RT priming as a low-risk strategy for implementing resistance training prior  
308 to competition without inducing prolonged reductions in neuromuscular performance. This is  
309 of substantial applied relevance, particularly for athletes such as golfers during congested in-  
310 season periods where opportunities to engage in resistance training may be limited.  
311 Collectively, this chapter establishes the broader evidence base underpinning RT priming and  
312 provides the rationale for investigating its applied relevance and feasibility within golf-specific  
313 populations and performance outcomes in subsequent chapters.

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314 **1.7.3 Chapter 4 - Elite Professional Golfers' Physical Preparation Practices and**  
315 **Perceptions**

316 Chapter 4 addresses Research Question 3 by examining how S&C practices are currently  
317 implemented within elite professional golf and identifying the key barriers influencing  
318 engagement throughout the annual training cycle. While Chapters 2 and 3 established the  
319 theoretical foundations and broader athletic evidence supporting physical preparation and RT  
320 priming, it remains unclear how such strategies are applied within real-world elite golf  
321 environments. Accordingly, this chapter provides applied context through survey data collected  
322 from players competing on the European and Challenge Tours, in addition to observational  
323 data gathered from the gym facility during the 148th Open Championship.

324 The findings indicate that while the majority of players reported long-term engagement with  
325 structured RT plans, players face challenges in incorporating physical preparation consistently  
326 throughout a tournament year. In turn, the development of physical attributes such as muscular  
327 strength, power, and muscle mass known to underpin clubhead speed and driver distance, along  
328 with the training methods typically required to stimulate such adaptations, were often not  
329 prioritised during the in-season and tournament periods. These patterns appeared to be most  
330 commonly explained by fatigue-related concerns, time constraints, and equipment and facility  
331 limitations. Collectively, these findings reinforce the practical challenges of implementing  
332 optimal S&C strategies within competitive golf and provide the applied rationale for  
333 experimentally evaluating RT priming interventions as a potential solution to these barriers in  
334 Chapters 5 and 6.

335 **1.7.4 Chapter 5 - The Effects of a Low-Volume Morning Power Training Session on**  
336 **Afternoon Golf-Specific and Neuromuscular Performance in Skilled Male**  
337 **Golfers: A Pilot Study**

338

339 Chapter 5 presents the first experimental investigation and addresses Research Question 4 by  
340 examining the short-term effects of a low-volume, power-oriented RT priming intervention on  
341 neuromuscular and golf-specific performance in skilled male golfers. Using a randomised  
342 crossover design, the study evaluated whether a morning RT priming session influenced  
343 performance outcomes when measured in the afternoon, four and a half hours after training.  
344 This represented a practically feasible window of opportunity in which golfers could perform  
345 RT prior to an afternoon tournament round.

346 The results indicated that, at the group level, no consistent change was observed, suggesting  
347 that the protocol was neither reliably beneficial nor detrimental to performance. Inspection of  
348 the individual data revealed variability in performance changes, most commonly reflected in  
349 reductions in neuromuscular jump performance. Importantly, these reductions did not typically  
350 correspond with decreases in golf-specific driver performance outcomes. Collectively, the  
351 findings do not support the protocol as a reliable method for eliciting acute performance  
352 enhancement within this cohort of skilled male golfers. Instead, the intervention appears to  
353 function as a feasible low-volume micro-dosing strategy for implementing RT without  
354 compromising golf-specific performance. The observed variability further emphasises that the  
355 effects of RT priming are not uniform and that such strategies should therefore be applied  
356 cautiously and considered on an individual basis. This variability informed the refinement of  
357 protocol design and outcome assessment in the subsequent experimental investigation.

#### 358 **1.7.5 Chapter 6 - The Effects of Resistance Training Priming Methods on** 359 **Neuromuscular Performance, Golf-Specific Outcomes, and Readiness Perceptions** 360 **in Skilled Golfers**

361 Chapter 6 further addresses Research Question 4 by examining the short-term effects of two  
362 RT priming interventions, strength- and power-oriented, on neuromuscular performance, golf-  
363 specific outcomes, and perceptual readiness in skilled male golfers. Building on the feasibility

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364 insights gained in Chapter 5, this study evaluated performance changes at two hours and 24  
365 hours following each intervention, representing same-day and next-day performance windows  
366 relevant to implementing RT during golf competitions. The investigation also expanded the  
367 scope of assessment to include a broader range of golf-specific shot outcomes, a wider battery  
368 of neuromuscular performance measures, and perceptual readiness outcomes, providing a more  
369 comprehensive evaluation of RT priming within golf. In addition, maximal strength  
370 characteristics were examined as a potential factor influencing the individual variability  
371 observed in Chapter 5.

372 At the group level, no consistent performance enhancement was observed following either RT  
373 priming protocol at either time point. However, neuromuscular and golf-specific performance  
374 were largely preserved across conditions, with no meaningful decrements evident at two or 24  
375 hours. Individual analyses revealed variability in individual responses, with both increases and  
376 reductions observed across outcome measures, which were not consistently explained by  
377 maximal strength characteristics. These findings reinforce the need for individualised  
378 implementation and monitoring and informed the development of practical guidance to support  
379 the applied use of RT priming in competitive golf. Collectively, the results support the  
380 application of RT priming as a low-risk training-management strategy rather than a guaranteed  
381 acute performance enhancer. Within congested competitive schedules, RT priming may  
382 provide a feasible means of maintaining exposure to RT during the in-season without  
383 compromising same-day or next-day performance or readiness.

## Chapter 2: Literature Review

(Research Question 1)

**Aim:** To provide a broad overview of the literature examining physical preparation strategies for improving golf performance, particularly clubhead speed (CHS) and shot outcomes

**Key Findings:**

- Muscular force-producing qualities (strength, power, and force-velocity characteristics) demonstrate the strongest associations with CHS and shot performance.
- These qualities can be developed through appropriately programmed strength and conditioning strategies, leading to improvements in CHS and shot distance.
- However, implementing optimal training within competitive schedules is challenging, particularly during the in-season period.

**Contribution:** A research–practice gap was identified, highlighting the need for physical preparation strategies that align with the practical constraints of competitive golf.



## Chapter 3: Systematic Review

(Research Question 2)

**Aim:** To examine the effects of resistance training (RT) priming performed one to 48 hours prior to athletic performance.

**Key Findings:**

- Under specific conditions, RT priming has been shown to improve neuromuscular performance in tasks such as sprinting, jumping, throwing, and strength-based assessments.
- Performance increases were most evident following low-volume, higher-intensity interventions including heavily loaded or ballistic exercise.
- Changes in performance were heterogeneous and influenced by exercise selection, intensity, volume, recovery duration, and participant characteristics.
- Across studies, RT priming more consistently maintained neuromuscular performance than impaired it.
- Sport-specific performance outcomes, particularly in golf, remain under-investigated.

**Contribution:** Established RT priming as a potentially low-risk strategy for both eliciting performance enhancement under specific conditions and maintaining RT exposure prior to competition, justifying applied investigation within golf-specific contexts.



## Chapter 4: Survey / Observation

(Research Question 3)

**Aim:** To examine physical preparation practices and perceived barriers to engagement among elite professional golfers.

**Key Findings:**

- The majority of golfers reported long-term engagement with and positive perceptions of RT for performance and health.
- Training priorities shifted between off-season and in-season periods, with higher-intensity RT methods more frequently implemented during the off-season.
- In-season and tournament-week engagement with higher-intensity RT was reduced, primarily due to concerns regarding fatigue, time constraints, and facility or equipment availability.

**Contribution:** Provided applied evidence of a gap between evidence-based RT recommendations and real-world implementation, reinforcing the need for pragmatic training strategies within elite golf.



## Chapter 5: Intervention 1 (Pilot)

(Research Question 4)

**Aim:** To examine the effects of a morning power-oriented RT priming session on afternoon neuromuscular and golf-specific performance in skilled male golfers.

**Key Findings:**

- No consistent group-level performance enhancement was observed.
- Neuromuscular and golf-specific outcomes were largely preserved following the intervention.
- Individual variability in performance changes was evident, with some reductions in neuromuscular measures not consistently reflected in golf-specific outcomes.

**Contribution:** Demonstrated the practical feasibility of implementing RT priming prior to golf competition as a micro-dosing strategy for maintaining training exposure without impairing performance. The observed individual variability informed refinement of protocol design and outcome selection in the subsequent investigation.



## Chapter 6: Intervention 2

(Research Question 4)

**Aim:** To examine the effects of strength- and power-oriented RT priming on neuromuscular performance, golf-specific outcomes, and perceptual readiness at two and 24 hours post-training.

**Key Findings:**

- No consistent group-level performance enhancement was observed at either time point.
- Neuromuscular, golf-specific, and perceptual outcomes were largely preserved following both interventions.
- Individual increases and reductions were evident and were not consistently explained by baseline strength characteristics.

**Contribution:** Positioned RT priming as a low-risk, individualised training-management strategy rather than a guaranteed acute performance enhancer, informing the development of practical monitoring guidance for applied implementation.

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385 **2 Chapter 2: The Role of Physical Preparation for Improving**  
386 **Clubhead Speed and Golf Shot Outcomes: A Literature Review**

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## 387 2.1 Introduction

388 Golf is a sport in which the primary objective is to complete a round (18 holes) or tournament  
389 (rounds over consecutive days) in as few shots as possible. Lower scores will typically result  
390 in better outcomes in tournament play, and are indicative of higher levels of skill and ability  
391 [7]. For professional golfers and competitive amateurs, a total score is provided for a round  
392 relative to the par of the course played, and a player's scores during an event and scoring  
393 averages over the course of the season represent key performance indicators. Amateur and  
394 recreational golfers will instead receive a handicap index which provides them with a shot  
395 allowance relative to the difficulty of the course and representative of their ability, with a lower  
396 handicap being indicative of a higher skilled player [8]. Technical skill execution, tactical  
397 awareness, and mental preparation are well established as central components of player  
398 development strategies, and are key determinants of success in the sport [7]. However, with  
399 recent developments in the understandings of the physical demands of the sport [3], in the  
400 absence of well-developed physical fitness, it now appears that the development of such  
401 attributes alone will not allow for a player's potential to be fully realised [1]. Consequently,  
402 greater emphasis has been placed on the modern golfer to engage with physical preparation  
403 strategies and develop attributes such as muscular strength, power, flexibility, and balance to  
404 improve their performance and reduce injury risk [1,5,30,31].

405 Improving a golfer's DD is a key area of performance that can be influenced by enhancements  
406 in physical capacities [2]. DD primarily contributes to golf performance by reducing the  
407 distance remaining to the pin following the tee shot, a factor that is significantly associated  
408 with lower scores on par-4 and par-5 holes in PGA professional golfers [11]. The importance  
409 of DD for golf performance is further supported by Broadie. [12], who demonstrated that a 20-  
410 yard increase in DD can save 0.75 strokes per round, amounting to a reduction of three strokes  
411 over a typical four-day tournament. This, in turn, could have a significant impact on broader

412 aspects of golf performance, such as tournament rankings and prize earnings, especially given  
413 the fine margins of success at the elite level of the sport. Achieving greater DD is governed by  
414 the complex interplay between impact factors such as a golfers CHS, and launch characteristics  
415 including ball speed (BS), and carry distance (CD) [13]. CHS refers to the velocity at which  
416 the clubhead impacts the golf ball [32], and is amongst the most commonly reported  
417 performance outcome metrics in golf S&C research [2,5,13]. Indeed, CHS has been described  
418 as the most important modifiable factor for increasing shot distance [3], with 75% of the  
419 variance in a players BS having shown to be determined by their CHS alone [33]. However, a  
420 golfer's CHS must also effectively transfer to BS to ensure maximal displacement of the ball  
421 is obtained, with each 1mph increase in BS having shown to result in an additional 1.83-yards  
422 in CD [34]. As such, both CHS and other shot outcome measures are regarded as important  
423 metrics for analysing golf performance, and are thus commonly referred to in the literature  
424 [2,5,13].

425 In a systematic review and meta-analysis, Brennan et al. [35] investigated the associations  
426 between golfers' physical characteristics and CHS, reporting that pooled correlation  
427 coefficients for muscular force expression showed the strongest relationships with CHS ( $r =$   
428  $0.47-0.82$ ). Anthropometric measures showed moderate associations ( $r = 0.43$ ), whereas  
429 muscle 'capacity' ( $r = 0.17$ ), flexibility ( $r = -0.06$ ), and balance ( $r = -0.04$ ) demonstrated  
430 weaker relationships. While correlational findings cannot establish causality, they can highlight  
431 meaningful associations and offer context and rationale for identifying which physical qualities  
432 may be most effectively targeted through strength and conditioning (S&C) interventions to  
433 enhance golf performance. Indeed, several interventional studies have demonstrated that  
434 resistance training (RT) programmes targeting muscular force-producing capabilities can lead  
435 to improvements in CHS and other golf shot outcomes [36-38]. Additionally, several studies  
436 have reported acute improvements in CHS and shot outcomes following S&C-based warm-up

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437 strategies [39,40], highlighting the utility of varied S&C approaches for enhancing elements of  
438 a golfer's performance.

439 At the highest level of professional golf, male players compete on the PGA Tour, DP World  
440 Tour (formerly known as the European Tour), and the LIV Golf Tour. There are also feeder  
441 development tours such as the Challenge Tour to the DP World Tour, as well as senior tours.  
442 This makes golf a unique sport in which players can continue to compete at the highest level  
443 as they age. The structure of an elite golfer's schedule, often characterized by near-weekly  
444 tournaments that span four consecutive days (typically Thursday to Sunday), poses a significant  
445 challenge to the delivery of optimal physical preparation strategies. Although several reviews  
446 have investigated the key biomechanical and physiological factors for maximising golf shot  
447 distance [3,5,7], as well as the use of physical preparation strategies including S&C  
448 interventions and warm-up protocols for improving golf performance [4,6,41], less attention  
449 has been afforded to the practical application of such strategies within these constraints of a  
450 golfer's schedule. The aim of this review is therefore to collate and summarise the key concepts  
451 pertaining to the role of physical preparation for improving CHS and golf shot outcomes, before  
452 providing recommendations for the practical application of such strategies in real-world  
453 settings.

## 454 **2.2 Biomechanical Considerations for Maximising CHS and Golf Shot Outcomes**

455 To understand the biomechanical principles underpinning increases in CHS and shot distance,  
456 it is first important to understand the phases of the golf swing. Broadly, most researchers have  
457 agreed upon four distinct phases of the golf swing, comprised of the set-up (address), the  
458 backswing, the downswing, and follow-through [42]. Movement is first initiated by the golfer  
459 during the backswing whereby the club is rotated upwards and back away from the ball. The  
460 purpose of the backswing is to allow for the correct positioning of the clubhead, setting up ideal  
461 sequencing during the downswing, and to provide a stretch on the key muscles and joint

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462 structures responsible for producing an accurate and powerful downswing [3]. The downswing  
463 involves the golfer accelerating the club forwards and downwards utilising predominantly  
464 concentric muscle actions until striking the ball, with the purpose being to deliver the clubhead  
465 to the ball in the correct plane and with maximum velocity [3]. The duration of the downswing  
466 has been stated to take less than 0.3 seconds for the professional golfer, with the entire duration  
467 of the swing generally being performed within 0.89 seconds [16]. This highlights not only the  
468 importance of developing force producing capabilities, but also how quickly force can be  
469 produced relative to the time constraints of the golf swing [31]. The follow through will then  
470 begin after the club head impacts the ball, with the aim being to stop the movement and  
471 decelerate the club, using predominantly eccentric muscle actions [3].

472 Electromyography research has shown that much of the body's musculature is active  
473 throughout the various phases of the golf swing [43]. More specifically, at the lower limb, the  
474 semimembranosus and biceps femoris have been stated to play a crucial role in maintaining  
475 knee flexion during the backswing, thus allowing for a larger range of motion to be obtained  
476 at the trunk [43]. The contraction of the trail leg musculature (gluteus maximus, gluteus medius,  
477 biceps femoris, and semimembranosus) initiates the downswing, with the adductor magnus  
478 facilitating rotation at the pelvis on the lead leg [43–45]. The knee extensors assist to resist  
479 knee flexion, providing a stable base for the pelvis and trunk to rotate upon during the  
480 downswing [46]. During the follow-through, the gluteus medius, biceps femoris, and vastus  
481 medialis continue to be active, ensuring stability for effective rotation to occur [46,47]. At the  
482 trunk, the internal and external obliques are highly active and responsible for facilitating  
483 rotation, while the erector spinae group assist with stabilisation of the spine throughout the  
484 phases of the swing [19,48]. In the upper-limb, the shoulder internal rotators, and latissimus  
485 dorsi are active, and the pectoralis major reaches maximal activation prior to impact during the  
486 downswing [43,45]. While this is not an exhaustive overview, this provides practitioners with

487 insights into the key muscles likely to influence swing performance, guiding the focus of S&C  
488 strategies to muscle groups such as the hip extensors, trunk rotators, spinal extensors, and  
489 pectoralis major. For a more extensive review of the Electromyography activity during the golf  
490 swing readers are directed to Cole & Grimshaw. [43].

491 Several biomechanical considerations have been proposed to underpin developments in a  
492 golfer's CHS. Linear clubhead velocity is a function of the angular clubhead velocity and the  
493 length of the arm-club lever at impact with the ball [3]. The length of the arm-club lever is  
494 stated to have limited potential for improvements, as it is largely governed by a player's  
495 anthropometrics [31]. In contrast, angular clubhead velocity may be influenced by several  
496 modifiable factors including ground reaction force, centre of pressure, the sequential  
497 summation of forces principle, and x-factor variables [49]. These principles are explored in the  
498 following sections to examine how they may contribute to increases in CHS.

### 499 **2.2.1 The Sequential Summation of Forces Principle**

500 It is well established that improving a golfer's ability to transfer energy effectively through the  
501 kinetic chain can contribute to increases in CHS [49]. During the downswing, force production  
502 is ideally sequenced in a proximal-to-distal pattern, progressing from the ground upward  
503 [42,50]. This process allows for maximum speed at the clubhead to occur through the timed  
504 acceleration of each segment, with the more distal segments accelerating later to build upon  
505 the momentum generated by proximal ones [42]. In support of this, Fujimoto and Kanatani.  
506 [51] investigated the kinematic sequence of 13 male professional golfers, reporting that their  
507 knee, hip, and shoulder segments reached peak angular velocity in order at 93.5%, 94.5%, and  
508 97.0% of the downswing, respectively. Similarly, Nesbit and Serrano. [52] reported that the  
509 generation of mechanical work (forces and torques responsible for moving the club) occurs in  
510 a bottom-up fashion, generally peaking in order from the legs to the hips, lower-back, upper-  
511 back, shoulders, arms, and then wrists. EMG studies further support this sequence, showing

512 that muscle activation during the golf swing typically progresses from the lower limbs upward  
513 through the trunk and upper body [42,49].

514 It is recommended that effective S&C programmes for CHS development include whole-body,  
515 multi-joint exercises that promote the transfer of force throughout the kinetic chain [10,31].  
516 For instance, as the lower limb represents the foundation for force generation, exercises such  
517 as the squat, deadlift, and lunge can assist in establishing a strong foundation for subsequent  
518 force transmission [31]. Building on this, it is also important to develop the trunk musculature  
519 to minimise the loss of energy generated by the lower limb [10]. To achieve this, coaches may  
520 consider the use of anti-motion control exercises to enhance the stability of the trunk  
521 musculature [31,53], or dynamic movements like medicine ball throws to enhance the transfer  
522 of force through the trunk and kinetic chain in a high-velocity manner [54].

### 523 **2.2.2 Ground Reaction Forces and Centre of Pressure**

524 The use of the kinetic chain links to the importance of ground reaction forces, as the transition  
525 from the top of the backswing to the beginning of the downswing is ideally initiated by the legs  
526 with large ground reaction forces being produced [52,55]. Consequently, in order to maximise  
527 CHS, large ground reaction forces must be produced, and transferred effectively to the  
528 clubhead [3]. The relationship between ground reaction forces and CHS was explored by Han  
529 et al. [56], who reported significant correlation coefficients between skilled players' (handicap  
530  $\leq 3$  strokes) bilateral vertical ground reaction forces and CHS. More specifically, the  
531 correlations were observed when using a driver ( $r = 0.33$ ), 5-iron ( $r = 0.33$ ), and pitching wedge  
532 ( $r = 0.35$ ), indicating a consistent moderate relationship with CHS across all the club types.

533 Studies have demonstrated that golfers may adopt different approaches to weight shift during  
534 the golf swing, which can be classified by the differences in centre of pressure (the average  
535 location of vertical ground reaction forces) movement patterns [57,58]. For instance, two main

536 styles of weight transfer (front foot/reversed) were identified within a cohort of 62 golfers  
537 ranging from professional, to high handicap ( $11 \pm 8$ ), and recreational golfers [57]. Both styles  
538 were initiated with the centre of pressure moving to the rear foot during the backswing and  
539 shifting to the lead foot during the downswing. Front-foot-styled players continued to move  
540 their centre of pressure toward the target until impact, whereas reversed-style players would  
541 instead move their centre of pressure back towards the trail foot during the downswing.  
542 Notably, both movement strategies were observed across performance levels, and as such the  
543 authors suggest that neither style was considered as a technical fault.

544 Despite their contrasting mechanisms, both front foot and reverse style golf swings have been  
545 associated with greater CHS, with the rate and magnitude of changes in centre of pressure  
546 appearing to be more important than the specific direction of the movement. In front foot  
547 players, CHS has been shown to correlate with a larger range of centre of pressure displacement  
548 ( $r = 0.53$ ), and a more rapid centre of pressure movement towards the front foot in the  
549 downswing ( $r = 0.46$ ) [58]. For reverse style players, CHS was correlated with centre of  
550 pressure positions further from the back foot during the late backswing ( $r = 0.75$ ), and a more  
551 rapid transfer towards the back foot at ball contact ( $r = 0.69$ ) [58]. More broadly, it has been  
552 suggested that the initial loading of the back foot during the backswing, followed by an earlier  
553 and more rapid transfer of weight onto the front foot during the downswing, may assist a golfer  
554 in achieving greater CHS [3,57]. Collectively, these findings highlight that while golfers may  
555 adopt individual variations in styles of centre of pressure changes, optimising the timing and  
556 rate at which centre of pressure shifts occur may be important considerations for maximising  
557 CHS.

### 558 **2.2.3 X-Factor and X-Factor Stretch**

559 The X-factor refers to the relative rotation of the shoulders in comparison to the hips at the top  
560 of the backswing prior to the downswing, with a greater degree of separation believed to enable

561 higher CHS to be achieved [59]. In support of this, Meister et al. [16] reported a strong  
562 relationship between peak X-factor and CHS in professional male golfers ( $r = 0.90$ ). The X-  
563 factor stretch, in contrast, refers to the maximal X-factor occurring at the start of the  
564 downswing, where the upper body remains stationary while the pelvis begins to rotate toward  
565 the target, creating a stretch across the torso [59]. Cheetham et al. [59] found that highly skilled  
566 golfers (handicap  $\leq 0$ ) demonstrated significantly greater X-factor stretch values (19%) than  
567 less skilled golfers (handicap  $\geq 15$ ; 13%), whereas no significant difference was observed  
568 between groups in X-factor ( $p = 0.326$ ). These results indicate that X-factor stretch may be  
569 more important in facilitating greater CHS., rather than X-factor. This may be explained by the  
570 theoretical advantage of the X-factor stretch in engaging the stretch-shortening cycle (SSC) in  
571 the trunk musculature, potentially enhancing CHS through stored elastic energy and increased  
572 muscular force output [42,60]. Alternatively, it has been suggested that increases in force  
573 resulting from eccentric muscle actions could be responsible, as there is a greater time in which  
574 force can be applied before the downswing begins, thus allowing for greater levels of work to  
575 be performed [49]. Additionally, the X-factor stretch may enhance proximal-to-distal  
576 sequencing, thereby improving the sequential summation of forces throughout the kinetic chain  
577 [3].

#### 578 **2.2.4 The Effect of S&C Interventions on Swing Biomechanics**

579 Few studies to date have investigated the effects of longitudinal S&C interventions on golf  
580 swing kinematics [54,61–64]. From the available evidence, improvements in swing kinematics,  
581 such as rotational and segmental sequencing variables have been reported. However, the  
582 magnitude of such changes and translation to CHS and golf shot performance outcomes appear  
583 inconsistent and, at times, unclear. Parker et al. [62] investigated the effects of nine weeks of  
584 ‘isokinetic power’ (constant speed) training, involving an externally loaded standing rotation  
585 and a loaded squat exercise in pre-elite golfers. Within group changes revealed small increases

586 in peak lead arm acceleration (ES = 0.48) and lead arm speed (ES = 0.49), alongside increases  
587 in shoulder stretch rate (the rate at which the shoulder was stretched during the backswing, ES  
588 = 0.30). While CHS did not improve, both BS (ES = 0.32) and CD (ES = 0.59) increased. The  
589 authors suggested that these changes may have been influenced by alterations in swing  
590 mechanics, including lead arm acceleration, which could have resulted in a more centred strike,  
591 improved clubhead path, or more favourable clubface orientation at impact [62]. Lastly, only  
592 a trivial within-group increase in X-factor stretch (ES = 0.15) was observed, with no  
593 corresponding improvement in X-factor.

594 Comparatively, Sorbie et al. [63] demonstrated that a six-week yoga intervention led to  
595 moderate increases in X-factor (ES = 0.50) and pelvis rotation at the top of the backswing (ES  
596 = 0.38), but not in X-factor stretch, in skilled single-handicap golfers ( $5.0 \pm 3.0$  strokes) [4].  
597 Similarly, Bull and Bridge. [46] reported significant improvements in X-factor, X-factor recoil,  
598 and peak arm and hand speed following eight weeks of plyometric training in skilled golfers  
599 (< 5 handicap). These measures reflect rotational separation and proximal-to-distal segment  
600 velocity contributions, which are considered important contributors to CHS. However, as these  
601 studies did not include performance outcomes such as CHS, BS, or CD, it remains unclear  
602 whether the observed kinematic changes translated into enhanced shot performance.

603 In contrast, Choi et al.[54] investigated the effects of eight weeks of medicine-ball-throwing  
604 training performed prior to golf practice sessions. The intervention elicited large increases in  
605 the percentage of weight shift at the lower limb (+34.3%, ES = 1.77) which also corresponded  
606 with large increases in CHS (+15.9%, ES = 1.60) and DD (+7.1%, ES = 0.82) in novice golfers.  
607 These findings indicate that enhanced lower-body weight transfer may represent an important  
608 kinetic mechanism underpinning the improvements in CHS and subsequent DD. However, the  
609 applicability of these findings to higher skilled players remains uncertain, as the large effect  
610 sizes observed may in part be explained by the greater trainability and lower proficiency of the

611 novice golfers. Accordingly, while the outlined research demonstrates the potential for S&C  
612 programmes to significantly improve a golfer's swing kinematics, further research would be of  
613 value to better understand the kinematic and kinetic changes underpinning improvements in  
614 CHS and shot outcomes resulting from S&C interventions.

### 615 **2.3 Physiological Considerations**

616 Evidence has shown the sport of golf to impose relatively low energetic and cardiorespiratory  
617 demands during play [7]. For instance, the intensity demands are low, with players' average  
618 heart rate reported at  $103.5 \pm 13.2$  beats per minute during play [65]. McKay et al. [66] reported  
619 that elite golfers experienced a 17% increase in heart rate during competitive rounds when  
620 compared to practice rounds, indicating that heart rate may be elevated by high pressure  
621 situations and stress during tournament play as opposed to the physiological demand of the  
622 sport. Additionally, lactate responses following the completion of a full 18-hole round have  
623 been shown to be similar to those found at typical resting levels (0.8-1.1 mmol/L) [67]. To  
624 date, measures of cardiorespiratory fitness have not been consistently associated with any  
625 objective indicators of golf performance [68,69]. Exceptionally, Wells et al. [70] reported  
626 significant associations between cardiovascular fitness ( $VO_{2max}$ ) and measures of golf  
627 performance. However, the authors did not provide the correlation coefficient results and  
628 attributed these findings to the participants' general athletic ability rather than the importance  
629 of a player's aerobic capacity for generating force in the golf swing.

630 While cardiorespiratory fitness may not be considered as a direct performance determinant in  
631 golf, it may still be relevant in supporting certain aspects of preparation and tournament play.  
632 For instance, greater cardiorespiratory health may assist a golfer in tolerating the varying  
633 terrain and weather conditions, which potentially stress the decision-making and concentration  
634 processes throughout tournament play [9]. This could be a particularly relevant factor on  
635 undulating surfaces or in hot weather or high-altitude conditions. Cardiovascular fitness may

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636 also support recovery from training and competition load [71,72], enabling players to sustain  
637 high levels of performance throughout four-day tournaments and back-to-back events.  
638 Individuals with greater cardiorespiratory health have also demonstrated the ability to cope  
639 with the high cardiovascular stress and allostatic load associated with regular air travel [73], a  
640 relevant factor with the extensive travel commitments and time zone changes faced by touring  
641 golfers.

## 642 **2.4 Key Physical Attributes**

643 To optimise the delivery of S&C, it is important to understand the relationship between  
644 physical attributes and performance measures to inform appropriate training strategies, monitor  
645 training progress, and address individual requirements [2,74]. Researchers have extensively  
646 analysed the physical attributes associated with CHS and golf shot outcomes, commonly  
647 focusing on muscular strength and power, flexibility, balance, and anthropometric  
648 characteristics, identifying the key areas to target in S&C interventions [15,55,70,75–77].

### 649 **2.4.1 Muscular Force Expression Characteristics**

650 Force is generated in the golf swing from the ground up [3], and measures of lower-limb force  
651 expression have consistently been associated with CHS [35], indicating that they should  
652 represent a key component of training and monitoring for golf athletes. Brennan et al. [35], in  
653 their meta-analysis, reported that pooled measures of jump impulse ( $r = 0.82$ , 95% CI: 0.63–  
654 1.02), jumping peak power ( $r = 0.66$ , 95% CI: 0.53–0.79), jump displacement ( $r = 0.53$ , 95%  
655 CI: 0.28–0.78), and lower-body strength ( $r = 0.47$ , 95% CI: 0.24–0.69) were among the  
656 physical characteristics most strongly associated with CHS. Once force has been generated  
657 from the lower body, it must then be effectively transferred through the trunk and to the upper  
658 limb [42]. In line with this kinetic sequence, Brennan et al. [35] also reported moderate and  
659 large correlation coefficients for upper body strength ( $r = 0.48$  [95% CI 0.28–0.68]), and upper

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660 body explosive strength ( $r = 0.67$  [95% CI 0.53–0.80]) with CHS, highlighting that upper-limb  
661 force expression should be a consideration in targeted S&C interventions.

662 Individual studies provide further clarity on the force-time characteristics that underpin the  
663 associations between lower-limb performance and CHS. For instance, Wells et al. [15,55] gave  
664 evidence that countermovement jump (CMJ) positive impulse accounted for 37.9% of the  
665 variance in European Challenge Tour Golfers' CHS [15], and showed a very large correlation  
666 with highly skilled golfers CHS (handicap  $\leq 5$ ,  $r = 0.79$ ) [55]. Moreover, qualities reflecting a  
667 slow stretch–shortening cycle (SSC) action (i.e., CMJ) were more strongly correlated with CHS  
668 than those reflecting a fast SSC action (i.e., drop jump positive impulse,  $r = 0.56$ ) [55]. SSC  
669 utilisation has been described as slow or fast based upon a classification of ground contact  
670 times of above or below 250 ms [78]. Rather than reflecting a fast SSC action ( $<250$  ms), taking  
671 advantage of stored elastic energy utilisation and stretch reflex properties, the golf swing may  
672 therefore instead reflect a slow SSC action ( $>250$  ms) which draws more upon contractile  
673 elements, with increased time for muscle cross-bridge formation to occur and for high threshold  
674 motor unit recruitment [55,76,79]. As a result, it has been suggested that golf training programs  
675 may benefit from exercises aimed at increasing impulse during slow SSC exercises [55].

676 Some researchers have suggested that the downswing, referenced as lasting between 230 to  
677 283 ms [50,80], could reflect a fast SSC action. However, Wells et al. [15] highlighted a  
678 limitation in these findings, noting that the duration of the downswing was measured from the  
679 time that the club was stationary at the top of the backswing until the moment of impact. In  
680 contrast to this, highly skilled golfers have been shown to apply force into the ground with the  
681 lower limb while the upper body is still rotating away from the ball [81], thus initiating the  
682 downswing with the legs earlier. In support of this, Nesbit and Serrano [52] reported that skilled  
683 golfers (scratch and 5-handicap) generated hip and spine work earlier in the downswing and  
684 maintained higher joint torques, whereas less-skilled golfers (13- and 18-handicap) produced

685 work later and at lower torque levels. This sequencing may extend the timeframe for force  
686 generation in the lower body, and explain why slow SSC actions have been shown to correlate  
687 more strongly with CHS than fast SSC measures in the lower-limb [55]. However, once that  
688 force is transferred up through the kinetic chain, different types of SSC actions may emerge  
689 and thus should not be discounted entirely. For example, a fast SSC in the upper limb that has  
690 been potentiated by slower SSC actions in the lower limb may occur, especially given that the  
691 time from the top of the backswing to impact could be less than 250 ms [50,80].

692 When isolating measures of ‘upper-body explosive strength’, Ehlert et al. [5]. in a separate  
693 systematic review with quantitative analysis reported large, pooled correlations between CHS  
694 and both rotational medicine ball throw performance ( $r = 0.60$ ; 95% CI: 0.50–0.70) and seated  
695 medicine ball throw performance ( $r = 0.60$ ; 95% CI: 0.32–0.81). In contrast, isokinetic trunk  
696 rotation has not been shown to correlate with CHS, with Suhara et al. [82] reporting only trivial-  
697 to-small, non-significant associations in elite golfers ( $\leq 3$  handicap,  $r = -0.29$  to 0.26). This  
698 likely reflects the role of the trunk as a transmitter of force between the lower and upper limbs  
699 during the golf swing, facilitating kinetic sequencing rather than generating force  
700 independently [31]. Medicine ball throws, comparatively, involve sequential contributions  
701 from the legs, trunk, and arms, which may explain their stronger relationship with CHS [31].  
702 However, seated medicine ball throws also demonstrated large correlations despite reducing  
703 lower-limb and trunk contributions [5]. This may be explained by the high levels of activation  
704 of the pectoralis major during the downswing, reaching up to 93% maximal voluntary isometric  
705 contraction on both the trail and lead arm in the late downswing [83]. This is also reflected in  
706 upper-limb strength measures such as the bench press, where moderate correlations with CHS  
707 ( $r = 0.50$ ) [84], and large correlations with ball speed ( $r = 0.62$ ) have been reported [76], further  
708 supporting the role of upper-limb force production in maximising golf performance.

709 Given that it can take up to 0.9 seconds to reach peak force [85], previous authors have  
710 questioned the relevance of training modalities aimed at developing maximal force, as the  
711 duration of the downswing has been speculated be too short to be influenced [31]. However,  
712 as previously highlighted, activities less constrained by time have shown to have the greatest  
713 relationships with golfers CHS (i.e. slow SCC actions) [55], which may afford golfers more  
714 time to recruit higher threshold motor units, and achieve greater force production [55]. In  
715 support of this, Brennan et al. [15], reported moderate correlations between CHS and measures  
716 of maximal strength in both the lower body ( $r = 0.47$ ; 95% CI: 0.24–0.69) and the upper body  
717 ( $r = 0.48$ ; 95% CI: 0.28–0.68). When isolating individual measures of lower-limb strength,  
718 Ehlert et al. [5] also reported large, pooled correlations between golfers' squat strength and  
719 CHS ( $r = 0.63$ ; 95% CI: 0.45, 0.82). However, while the squat represents a valuable measure,  
720 the isometric mid-thigh pull (IMTP) may offer a safer and more easily administered alternative  
721 for golfers, particularly if force plates are available for use. At the individual study level, Wells  
722 et al. [55] reported significant moderate correlations between IMTP peak force and CHS ( $r =$   
723 0.48) in Challenge Tour Professional golfers. Collectively, these findings suggest that the  
724 development and monitoring of maximal strength in both the lower and upper body is an  
725 important consideration, with traditional lifts such as the squat and bench press, alongside  
726 isometric measures such as the IMTP, offering valid and practical assessment options.

#### 727 **2.4.2 Flexibility and Balance Characteristics**

728 It is commonly believed that increasing flexibility is an important consideration for improving  
729 a golfer's performance [2,86]. More specifically, increases in range of motion, particularly  
730 around the hip, shoulder, and trunk joints, have been suggested to enhance X-factor/X-factor  
731 stretch [3,60,84], which may in turn contribute to increases in CHS. Contrary to this belief,  
732 Joyce. [87] stated that axial rotation flexibility was not significantly correlated with X-factor  
733 variables, indicating that golfers with a greater range of motion may not necessarily utilise this

734 to increase their X-factor. This may be explained by evidence indicating that measures of  
735 passive flexibility do not reflect the dynamic nature of the golf swing [5,35]. Brennan et al.  
736 [35] reported trivial, non-significant associations between flexibility and CHS ( $r = -0.04$ , 95%  
737 CI  $-0.33$  to  $0.26$ ). While the relevance of commonly employed tests of flexibility included in  
738 this analysis may be questioned, such as the sit-and-reach test, Ehlert. [5] also reported only  
739 trivial, and non-significant associations when isolating trunk rotation flexibility and CHS ( $r =$   
740  $0.17$ , 95% CI  $-0.26$  to  $0.60$ ). As such, while flexibility is commonly considered to be an  
741 essential component in optimising golf performance and CHS [31], this notion is not well  
742 supported by current empirical evidence.

743 Notably, some evidence indicates an inverse relationship between some measures of flexibility  
744 and CHS. For example, Sheehan et al. [88] reported a large negative relationship with internal  
745 rotation of the lead hip and CHS ( $r = -0.54$ ). Reduced hip internal rotation range of motion  
746 may therefore be desirable in assisting the shoulders and torso to rotate around a relatively  
747 stable base with increased opposing forces, thereby enhancing X-factor/X-factor stretch  
748 [84,88]. More broadly, several studies have shown that S&C interventions can lead to  
749 improvements in golfers' flexibility [89–92]. For example, Kim [89] investigated the effects of  
750 a 12-week combined strength, flexibility, and endurance programme in female professional  
751 golfers. The intervention group achieved a 9.0% increase in forward flexion, and a significant  
752 9.4% improvement in back flexion, compared with declines in the control group ( $-2.5\%$  and  $-$   
753  $1.9\%$ ). These improvements were accompanied by a significant increase in CHS ( $+3.5\%$ )  
754 compared with a  $-2.0\%$  decline in the control group. However, as flexibility training was  
755 delivered in conjunction with other exercise modalities, it is difficult to determine the isolated  
756 effects on swing performance. This limitation has also been observed across the wider research  
757 [89–92]. As such, further research on the effects of isolated flexibility training on golf

758 performance would be of benefit to establish the importance of flexibility training for golf  
759 performance.

760 It has been speculated that balance and proprioceptive qualities may support golfers by  
761 improving consistency of shot outcomes in difficult stance positions, and by improving the  
762 ability to handle the significant weight shift that occurs during the swing [93]. However, to  
763 date, balance has not been an area that has been researched in great depth. From the available  
764 evidence, Loock et al. [69] reported non-significant correlations between balance and CHS ( $r$   
765 = 0.43,  $p = 0.448$ ), and carry distance ( $r = 0.10$ ,  $p = 0.880$ ) in a cohort of 101 male recreational  
766 golfers. More broadly, Brennan et al. [35] also supported these findings with only trivial, non-  
767 significant associations between pooled measures of balance and CHS ( $r = -0.08$ , 95% CI –  
768 0.33 to 0.18). These findings may be explained in that the single-leg balance assessments  
769 commonly used may not reflect the dynamic, task-specific demands of the golf swing. At the  
770 individual study level, Green et al. [68] reported significant positive correlations between  
771 single-leg balance duration and DD in male golfers ( $n = 18$ , handicap  $11 \pm 6$  strokes), with  
772 average balance across both legs ( $r = 0.563$ ), left leg ( $r = 0.620$ ), and right leg ( $r = 0.488$ )  
773 balance scores. However, as there is currently no supporting evidence solely assessing the  
774 effects of longitudinal balance training on golf performance outcomes [44], the development  
775 of balance for maximising a golfer's CHS and shot outcomes currently appears to be poorly  
776 supported by empirical evidence.

## 777 **2.5 Strength & Conditioning Training Interventions**

778 To optimise the delivery of S&C, it is necessary to build on correlational evidence by  
779 examining whether improvements in physical capacities can lead to measurable changes in golf  
780 performance outcomes over time. Recent systematic reviews confirm that S&C interventions  
781 can lead to enhancements in CHS and other shot outcomes [2,4,41]. For example, Ehlert. [4]  
782 reported that a range of training approaches including strength, plyometric, core, and flexibility

783 exercises led to mean increases of 4.1% (ES = 0.45) in CHS, 5.3% (ES = 1.13) in BS, 6.3%  
784 (ES = 0.59) in CD, and 6.4% (ES = 1.12) in TD. While these results highlight the effectiveness  
785 of S&C interventions, varied effects were observed, with improvements ranging from 1.6% to  
786 15.9% and effect sizes from trivial to very large (ES = 0.11–4.26). Several methodological and  
787 participant characteristics may influence the relative magnitude of effects of training  
788 interventions on golf performance outcomes, which will be explored in the following sections.

789 Concurrent with improvements in golf performance, several physical attributes previously  
790 highlighted to correlate with CHS, such as maximal strength, vertical jump, and medicine-ball-  
791 throw performances [35], have also improved following longitudinal strength and power-  
792 oriented S&C interventions [36–38,89,94,95]. For example, Oranchuck et al. [36] reported that  
793 eight weeks of multi-joint barbell and weightlifting training increased CHS (+3.2%, ES = 0.38),  
794 1RM back squat strength (+17.3%, ES = 0.39), and CMJ height (+11.5%, ES = 0.56) in  
795 collegiate golfers, with significantly greater gains than a bodyweight training control group  
796 (CHS: ES = 2.02; 1RM squat: ES = 1.11; CMJ: ES = 1.42). Similarly, Bliss et al.[94] reported  
797 that eight weeks of plyometric training improved golfers CHS (+3.9 ± 3.0%) and CD  
798 (+4.9±3.3%), alongside vertical jump, broad jump, kneeling chest throw, and kneeling  
799 rotational throw performances (+10.2 - 22.9%), with these changes being significantly greater  
800 than a golf-practice-only control group. Collectively, these findings indicate that improvements  
801 in physical capacities such as maximal strength, jump ability, and rotational power can  
802 meaningfully contribute to golf-specific performance outcomes.

803 It is a common perception that S&C training exercises should replicate the golf swing under  
804 load. Indeed, Wells et al.[86] in a survey of 430 PGA Assistant Professionals, reported that  
805 35.6% “somewhat agreed,” 20.9% “agreed,” and 6.7% “strongly agreed” that gym training  
806 should replicate the movements of the golf swing as closely as possible. However, this  
807 perception is unfounded, as no evidence supports that specific interventions utilising exercises

808 that replicate the swing provide enhancements in golf performance over traditional RT methods  
809 [96]. Several studies, including Oranchuk et al. [36], have demonstrated that improvements in  
810 CHS or shot outcomes can be achieved via ‘conventional’ RT exercises such as squat, bench  
811 press, deadlift, and lunge variations [37,96–99], as well as through muscle power and  
812 plyometric focused training methods such as jumps and medicine ball throws, as shown by  
813 Bliss et al. [94]. With that being said, Choi et al. [54] demonstrated that eight weeks of weighted  
814 ball throw training, performed in a pattern similar to the golf swing, led to significant  
815 improvements in CHS (+15.9%) and DD (+7.1%) in male amateur golfers (handicap  $\geq 15$ ). As  
816 such, specific development exercises may, at times be appropriate, particularly once  
817 foundational strength and power qualities have been established.

#### 818 ***2.5.1.1 Strength, Power, and Hypertrophy***

819 From a broader perspective, weaker and previously untrained individuals will typically benefit  
820 from increased power output as a result of conventional strength training [100], which may  
821 enhance swing performance. This is largely because they start with a lower baseline and thus  
822 have a greater potential for rapid improvements when exposed to novel training methods  
823 [100,101]. Muscular strength is closely related to both velocity and power, as stronger muscles  
824 typically have the potential to generate force more rapidly [100]. However, stronger individuals  
825 may require alternative and more advanced methods, such as ballistic and/or plyometric  
826 training [102], to elicit further improvements [103], as their higher training age and reduced  
827 potential for adaptation following conventional strength training necessitate more novel stimuli  
828 to ensure continued development [102]. Ballistic and plyometric training methods are known  
829 to enhance neuromuscular adaptations, including inter- and intramuscular coordination [102],  
830 which may positively impact golf swing performance [41,104]. In support of this,  
831 improvements in golf swing performance metrics have been observed after eight weeks of  
832 focused power training involving jumps, bounds, medicine-ball-throws, and golf-swing

833 derivatives [61,94]. Consequently, golfers are advised to incorporate ballistic and plyometric  
834 exercises into their routines after establishing a foundation of strength training  
835 [102,103].Consequently, information regarding an individual's RT status, experience, and  
836 current strength levels is therefore essential to discerning the appropriateness of RT  
837 interventions and exercise prescription.

838 Increases in a golfer's muscle mass may be considered as desirable for enhancing CHS, as  
839 increases in muscular cross-sectional area can positively impact the ability to generate high  
840 levels of force and express power [100]. While limited evidence is currently available, in  
841 support of this, Keogh et al. [84] reported that fat free mass had a moderate correlation  
842 coefficient with CHS ( $r = 0.43$ ), whereas only a small correlation was found for total body mass  
843 ( $r = 0.27$ ). Significant increases in muscle mass (+3.7%, ES = 1.0) and decreases in body fat  
844 percentages (-14.0%, ES = 1.8) were also reported by Alvarez et al. [38] following an 18-week  
845 periodised RT programme, with the authors speculating that muscle hypertrophy may have  
846 contributed to improvements in CHS (+11.5%, ES = 1.0) and BS (+10.4%, ES = 1.9) achieved  
847 following the training intervention, in addition to neural adaptations. However, further research  
848 is required to determine the respective roles in performance enhancement during the golf swing  
849 [38]. While some authors have previously speculated that excessive increases in a golfer's  
850 muscle mass may negatively impact the swing by restricting range of motion [84], this claim  
851 has yet to be substantiated in the literature. In fact, evidence suggests that provided multi-joint  
852 RT exercises are performed through a full range of motion, flexibility can be preserved or even  
853 increased following S&C interventions [105,106].

## 854 **2.5.2 Programming Considerations**

### 855 **2.5.2.1 Periodisation**

856 For high performance sports athletes, RT will typically follow some form of periodisation  
857 wherein peak performance is sought through the systemic planning and structuring of training

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858 variables (volumes, intensity, frequency, and rest) during specific training timeframes, aimed  
859 at maximising performance gains and minimising the potential for overtraining and reductions  
860 in performance [26,27,107]. In sports with long in-season periods such as soccer and rugby,  
861 the approach in-which physical qualities are developed over the off-season is typically  
862 preferred, with focus shifting to the maintenance of previously developed biomotor abilities  
863 during the in-season period [108]. However, this approach is not without issues when applied  
864 in the context of a professional golfer's season. For the most part, professionals performing at  
865 the highest level do not benefit from extended periods outside of competitive tournament  
866 fixtures in which they can develop their physical attributes. Consequently, strategies allowing  
867 for players to develop during the in-season, or at least throughout certain identified periods in  
868 the season would be advantageous for optimising performance. With the limited time to train  
869 during individual tournaments, the importance of optimising programme design perhaps  
870 becomes even more important so as to progressively overload the athlete sufficiently, without  
871 detracting from sports practice and competitive performance.

872 To date only one study has investigated the effects of a full periodised training cycle (18-  
873 weeks), transitioning from maximal strength, to power, to golf- specific strength training [38].  
874 This study resulted in the largest improvements in BS (10.4%; ES: 1.94) of any currently  
875 available S&C interventions for golf swing performance [38]. This may in-part be explained  
876 by the length of the training intervention, with long duration (more than eight weeks)  
877 interventions typically having shown to elicit greater mean changes in BS than short duration  
878 interventions (3.6% [3.0 to 4.5%] vs 6.9% [3.2 to 10.4%]) [38]. However, the periodised  
879 training intervention also elicited significantly greater improvements in CHS and BS when  
880 compared to a control intervention of core stability, and general strength training exercises  
881 [38]. Notwithstanding the lack of periodised training interventions for golf performance,  
882 external literature advocates and recommends the use of several types of periodised training

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883 structures for maximising strength and power adaptations [26,109,110], which can in turn  
884 contribute to improvements in CHS and golf shot outcomes. Alvarez et al. [38] employed a  
885 block style periodisation model, emphasising the logical sequential progress of biomotor  
886 development. Due to the little variation and deviation in exercise selection, and relatively flat  
887 workload progressions this type of model may be most appropriate for the golf athlete with  
888 limited training experience, as an introduction to S&C [26].

889 For the more experienced athlete, non-traditional forms of periodisation are suggested to be  
890 effective strategies during the in-season period. This is often necessitated due to competitive  
891 schedules, and the ease of administration of such strategies within long seasons, with regular  
892 changes in exercise volumes, loads, and biomotor emphasis which may occur on a session-to-  
893 session basis [26]. Undulating periodisation has been described as more frequent, daily,  
894 weekly, or biweekly variation in exercise intensity and volumes [107], and as such may be  
895 suited to the golfers schedule due to the flexibility in programming. For instance, the golfer  
896 may be able to prioritise higher volume loads earlier in the week, before competition which  
897 typically begins on a Thursday, with lighter sessions performed around tournament  
898 commitments later in the week (Thursday-Sunday) so as to minimise the potential for  
899 detriments in competitive performances. Further to this, if the athlete were to miss the  
900 tournament “cut” (thereby having an abbreviated involvement in the competition), they may  
901 be presented with an opportunity to switch from a light to a heavier volume and/or load training  
902 session. With the variable and unpredictable availability of equipment at each tournament  
903 venue, players may also be forced to switch the biomotor focus of a session in order to make  
904 best use of the equipment they have available on-site. Lastly, were the golfer to take a break  
905 from competition, for instance after tournament success or a long run of back-to-back events,  
906 they would be able to adapt their training accordingly. While evidence indicates that providing  
907 the work performed is equal, periodisation strategies such as undulating and linear yield no

908 significant differences in their effectiveness for strength development [107], an undulating  
909 model may enhance the likelihood of positive training adaptations for the golf athlete.

### 910 *2.5.2.2 Programming Variables*

911 The large disparities in exercise selection, programme design, and participant characteristics  
912 across golf-specific S&C interventions make it difficult to determine the optimal methods for  
913 enhancing golf performance [4,41]. Consequently, exercise programming variables such as  
914 intensity, volume, and frequency should be considered on an individual basis, as the dose-  
915 response relationship to RT is influenced by an athlete's training experience and athletic status  
916 [101]. Indeed, almost any training could represent a novel stimulus to an untrained  
917 neuromuscular system, whereas trained athletes will tend to be less responsive and require  
918 more specific training modalities and parameters to ensure their continued progression [101].  
919 In line with these principles, Table 2.1 provides a practical framework of suggested  
920 programming considerations for novice, intermediate, and experienced resistance trained  
921 golfers, based upon their likely responsiveness to different RT variables.

922 Training load refers to the interaction between training volume and intensity and is a key metric  
923 guiding RT prescription and influencing subsequent training adaptations. Across the golf-  
924 specific S&C literature, studies have employed a wide range of set and repetition schemes,  
925 from one to six sets of two to 25 repetitions, with prescriptions typically aligning to the desired  
926 training outcome such as strength, power, or hypertrophy. The results of a systematic review  
927 revealed that RT programmes using lower repetition schemes (<12 repetitions) produced  
928 greater average improvements in CHS (+3.3%,  $d = 0.11-1.53$ ) compared with higher repetition  
929 training (>15 repetitions), which led to substantially smaller average improvements (+0.9%,  $d$   
930  $= 0.25-0.56$ ) [41]. Lower repetition training may be seen as preferential due to the potential for  
931 greater intensities to be used and maintained (e.g. one to six repetitions at 85-100% 1RM),  
932 allowing for greater developments in muscular strength, power, and speed which are

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933 considered essential components to a players physical development [111]. This is further  
934 substantiated in external literature [112–114], with Schonefeld et al. [112] in a systematic  
935 review and meta-analysis indicating that gains in 1RM strength were significantly greater  
936 following high-load RT ( $\geq 60\%$  1RM; ES = 1.69, 95% CI 1.25-2.14) in comparison to low-  
937 load ( $\leq 60\%$  1RM; ES = 1.32, 95% CI 0.87-1.76), and with hypertrophy adaptations also being  
938 similar between conditions.

939 While lower-repetition, higher-intensity RT appears to provide greater transfer to CHS,  
940 exercises and their respective intensities should also be considered on an individual basis and  
941 in-line with the individual's training age and training status. Less experienced golfers can  
942 typically benefit from higher volume training (e.g. 8-12 repetitions at 60-80% 1RM) to develop  
943 skill and competency in specific training exercises, before being introduced to more complex  
944 and heavily loaded exercises [4,100]. As training experience increases, golfers generally  
945 require progressively higher intensity training and more targeted exercise selection and loading  
946 strategies to continue stimulating training adaptations [4].

947 Percentage 1RM loading is a commonly used method for prescribing and individualising  
948 external load during RT and is frequently employed within the golf S&C intervention literature  
949 [4,41]. However, in practical settings, this method is not without limitations. Specifically,  
950 golfers' training demands, competitive schedules, and accumulated fatigue can fluctuate  
951 greatly during the in-season period, influencing 1RM values and making frequent testing or  
952 training to failure unfeasible due to the potential emergence of excessive fatigue and injury  
953 risk. Further to this, day-to-day variability in readiness and fatigue can result in the prescribed  
954 percentage 1RM loads being too high or too low, reducing the accuracy of training prescription.  
955 Autoregulatory methods such as rate of perceived exertion (RPE) and repetitions-in-reserve  
956 (RIR) offer a practically feasible solution to these fluctuations while still supporting continued  
957 progress towards training goals [115,116]. RPE-based loading describes the perceived effort

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958 of a set on a scale of 1-10, whereby the external load is adjusted to maintain the level of effort  
959 exerted by the athlete and can therefore be valuable when aiming to maintain training volume  
960 without inducing excessive fatigue [117]. RIR instead refers to the perception of how many  
961 repetitions can be performed prior to muscle failure, allowing for changes in load or repetition  
962 number to be adjusted without inducing maximal fatigue [117]. Empirical evidence supports  
963 the use of such autoregulatory methods for mitigating the risk of training to failure, whilst  
964 ensuring accurate training prescription and maintaining training volume when compared with  
965 percentage 1RM loads [118].

966 Consistent with the earlier observations that longer training interventions have been shown to  
967 elicit greater improvements in golf performance outcomes [4], evidence from individual studies  
968 further highlights the importance of considering training duration when evaluating both  
969 physical and golf-specific performance changes. Alvarez et al. [38] indicated that while six-  
970 weeks of strength training was sufficient to improve skilled golfers' ( $\leq 5$  handicap) maximal  
971 strength and power qualities, a further six-weeks of power training was required to realise  
972 improvements in CHS (+6.9%, ES = 0.6) and BS (+7.3%, ES =1.4). This suggests that the  
973 golfers may require more time to fully adapt their swing technique to their enhanced physical  
974 capabilities, or that optimal training adaptations required a longer duration to occur [38].  
975 Further to this, golfers of a lower skill have been shown to realise greater average  
976 improvements in CHS (nine interventions; ES = 0.5 [0.15 to 1.60]) when compared with higher  
977 skilled golfers (five interventions; ES = 0.38 [0.18 to 0.63]) following S&C interventions [4].  
978 This indicates that skilled golfers may require more specific, longer duration, higher intensity  
979 and/or more frequent training to elicit large improvements in CHS [4]. The differences in  
980 outcomes to training could be related to the players' RT experience and baseline strength levels,  
981 as less skilled golfers may have had limited exposure to RT, giving them a higher potential for

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982 improvement [101]. However, as many studies have not adequately reported on these  
983 characteristics, this remains speculative.

984 Regarding weekly training frequencies, RT frequencies ranging from one to six weekly  
985 sessions have been shown to be effective in improving measures of golf performance with an  
986 average of  $2.8 \pm 1.0$  sessions per week across studies [4]. While there is little consensus on  
987 which training frequencies may be optimal, strength and power training interventions have  
988 typically shown to be effective following two to three weekly training sessions [36–38]. In line  
989 with this, current American College of Sports Medicine guidelines recommend training  
990 frequencies of two to three days per week with at least 48 hours' recovery between sessions for  
991 “general muscular fitness” [119]. Comparatively, The National Strength and Conditioning  
992 Association allow for a slight reduction during the in-season period of between one to three RT  
993 sessions per week [120]. However, external literature indicates that exercise volumes and loads  
994 are more influential than training frequency for strength development. Cuthbert et al. [108] in  
995 a systematic review and meta-analysis, reported that no clear differences between RT  
996 frequencies when weekly training volume was equated in well-trained populations. Practically,  
997 these findings may offer golfers greater flexibility in weekly RT programming. For instance,  
998 during tournament weeks, golfers can follow a more traditional training approach prior to the  
999 tournament commencing, or instead administer shorter, more frequent sessions that are  
1000 potentially less fatiguing and more easily scheduled around tournament commitments [108].

1001 **Table 2.1 Example resistance training programming considerations for strength, power, and hypertrophy across different levels of**  
 1002 **training experience in golfers**

<b>Training Adaptation</b>	<b>Training Status</b>	<b>Intensity (%1RM)</b>	<b>Alternative Intensity Prescription</b>	<b>Sets</b>	<b>Reps</b>	<b>Rest</b>	<b>Frequency</b>	<b>Example Exercises</b>	<b>Training Focus</b>
<b>Strength</b>	Novice	60-80%	RPE 6-7 / RIR 3-4	2-4	8-12	1-2 min	2-3x/week	Goblet squat, leg press, hip thrust, back extension, push-up, BB inverted row, assisted pull-up	Foundational strength and movement competency
	Intermediate	75-90%	RPE 7-8 / RIR 2-3	3-5	3-8	2-3 min	2-3x/week	Hexagonal bar deadlift, DB bench press, BB back squat, BB bent over row, DB overhead press, pull-up	Progressive overload, increases in movement complexity, and development of maximal strength and force producing capabilities
	Experienced	80-100%	RPE 8-10 / RIR ≤ 2	3-5	1-6	3-5 min	2-3x/week	Romanian deadlift, Anderson/pin squat, BB overhead press, BB bench press, Pendley row, weighted pull-up	Maximal strength development, increases in neuromuscular efficiency, and integration with complex and contrast methods
<b>Power</b>	Novice	N/A - Light implements only i.e. medicine ball / light DB or KB	RPE 5-6 / RIR 4-5	2-4	6-10	2-4 min	2-3x/week	Box jump, box land, medicine ball chest throw, medicine ball slam	Develop fundamental movement competency, improve co-ordination, and the ability to safely apply and absorb force
	Intermediate	Strength-Speed: 50-70% Speed-strength: 30-50%	RPE 6-7 / RIR 3-4	3-5	3-6	3-5 min	2-3x/week	DB CMJ, kettlebell swing, push press, rotational medicine ball throw, ballistic press-up, rotational box jump (90 degree)	Introduce loaded ballistic/plyometrics, improve rate of force development, enhance force transfer through the kinetic chain, and encourage high intent

<b>Training Adaptation</b>	<b>Training Status</b>	<b>Intensity (%1RM)</b>	<b>Alternative Intensity Prescription</b>	<b>Sets</b>	<b>Reps</b>	<b>Rest</b>	<b>Frequency</b>	<b>Example Exercises</b>	<b>Training Focus</b>
	Experienced	Strength-Speed: 50-80% Speed-strength: 20-50%	RPE 6-7 / RIR 3-4	3-5	2-5	3-5 min	2-3x/week	Hexagonal bar deadlift jump, ballistic bench press throw, BB jump squat, dynamic effort/ band resisted lifts	High-velocity force expression, increases in impulse during slow SSC actions, kinetic chain efficiency, maximal intent and velocity focus
<b>Hypertrophy</b>	Novice	60-75%	RPE 6-8, RIR 2-4	2-4	8-12	1-1.5 min	2-3x/week	Deficit push-up, TRX row, plank, plank shoulder touch, landmine press, DB step-up, single leg hip thrust	Foundational increases in muscle cross-sectional area, and development of movement competency
	Intermediate	65-80%	RPE 7-9, RIR 1-3	3-5	6-12	1-2 min	2-4x/week	DB incline BP, s/a 3-point DB row, ab-wheel roll-out, cable woodchop, half kneeling DB shoulder press, Bulgarian split squat, weighted single leg RDL /hip thrust	Progressive overload to increase muscle cross-sectional area, support strength and power development, and introduce greater movement complexity and unilateral demands to support joint stability
	Experienced	70-85%	RPE 8-9, RIR 1-2	3-6	6-10	1.5-3 min	2-5x/week (in-season/off-season dependent)	BB incline BP, Seated DB shoulder press, half kneeling cable row, BB roll-out, Landmine rotation, , BB split squat, staggered stance RDL	Higher-intensity, lower-volume to support both hypertrophy and strength development, with stable and mechanically advantageous exercises to maximise force output

*RIR = reps in reserve, RPE = rate of perceived exertion, BB = barbell, DB = dumbbell, BP = bench press, CMJ = countermovement jump, RDL = Romanian deadlift, s/a = single arm,*

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### 1004 2.5.2.3 *Micro-Dosing*

1005 Given the density of golfers' in-season schedules, potentially competing up to four times per  
1006 week over consecutive days (often Thursday to Sunday), with back-to-back tournaments,  
1007 regular air travel, and time zone changes, flexibility in weekly RT organisation is important.  
1008 The high-intensity nature of traditional RT methods can impose substantial neuromuscular  
1009 demands and contribute to fatigue [121]. As a result, it is commonly recommended that such  
1010 training be avoided within 48 hours of competition [110]. This recommendation limits the  
1011 available window for implementing RT prior to competitive play, particularly during congested  
1012 tournament schedules. As previously highlighted, when weekly RT volume is matched, similar  
1013 adaptations can be achieved irrespective of training frequency [108]. Accordingly, shorter,  
1014 more frequent sessions may offer a practical advantage over traditional programming during  
1015 tournaments, enabling golfers to maintain or develop important physical qualities while  
1016 reducing accumulated fatigue that may disrupt practice and performance. This concept aligns  
1017 with the 'micro-dosing' approach, defined in S&C literature as "the division of total volume  
1018 within a micro-cycle across frequent, short duration, repeated bouts" [108].

1019 A related strategy which could be a potentially efficacious tool in the use of micro-dosing, is  
1020 resistance training priming [108]. This refers to the use of short-duration, low-volume RT  
1021 sessions performed within 1-48 hours of competition, with the potential to improve subsequent  
1022 neuromuscular readiness and performance via a delayed potentiation response; a form of post  
1023 activation performance enhancement (PAPE) that exerts over a longer timeframe [122]. These  
1024 sessions typically involve low volumes of strength and/or power exercises performed at  
1025 moderate to high-intensities [122]. For example, Tsoukos et al. [123] reported that a session  
1026 involving 5x4 squat jumps at 40% 1RM led to small but significant increases in CMJ height  
1027 (+5.1%, Hedges'  $g = 0.46$ ) and drop jump reactive strength index (+10.7%, Hedges'  $g = 0.40$ )  
1028 when measured 24 hours post training, with CMJ height remaining elevated 48 hours post

1029 training (+3.0%, Hedges'  $g = 0.31$ ). Given the relationship previously outlined between lower-  
1030 limb muscular force expression characteristics (e.g., CMJ performance) and CHS [35], it is  
1031 plausible that such enhancements could extend to golf-specific performance outcomes.

1032 In practice, these sessions could align well with the demands of a golfer's in-season schedule,  
1033 allowing for short duration RT sessions to be completed on the day of, or the day prior to,  
1034 competition. This may enable golfers to maintain and/or develop key muscular force qualities  
1035 during the in-season period, minimise the risk of fatigue affecting performance levels, and  
1036 potentially elicit transient improvements in neuromuscular performances. However, despite the  
1037 potential compatibility of such micro-dosing strategies within a golfer's schedule, there is little  
1038 consensus on the optimal methods of administering resistance training priming, particularly  
1039 within golf populations and in relation to golf-specific performance outcomes.

## 1040 **2.6 Swing Speed Training**

1041 Anecdotally, swing speed training methods involving overspeed or weighted implements such  
1042 as speed sticks are popular and implemented in practice. This is somewhat supported by  
1043 evidence indicating that 73.2% of 430 PGA Assistant Professionals reported including 'golf  
1044 swings with a resistance', and 62.1% reported including 'speed training' methods as part of  
1045 their S&C practices year-round [86]. However, there is limited evidence investigating the  
1046 effectiveness of these strategies for enhancing CHS and golf shot outcomes. Predominantly,  
1047 researchers have investigated the short-term application of these methods as part of a warm-up  
1048 routine. Bliss et al. [124] reported that an overspeed warm-up involving swings with light  
1049 (20% lighter than a standard driver), medium (10% lighter), and heavy (standard weight or up  
1050 to 5% heavier) speed sticks led to significant small increases in CHS ( $110.1 \pm 5.5$  vs  $111.6 \pm$   
1051  $5.2$  mph;  $\eta^2 = 0.28$ ) and medium increases in CD ( $261.5 \pm 16.4$  vs  $268.2 \pm 16.0$  yards;  $\eta^2 =$   
1052  $0.41$ ) compared with a traditional warm-up control condition, with comparable results to a  
1053 ballistic potentiation strategy involving jumps and plyometric press-ups ( $p = 1.000$ ). However,

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1054 no significant improvements were observed for BS or TD ( $p > 0.05$ ). Similarly, Hébert-Losier  
1055 and Wardell [125] reported that a warm-up involving SuperSpeed Golf™ weighted clubs  
1056 elicited small but significant increases in peak CHS when compared to a control condition  
1057 ( $110.0 \pm 9.7$  vs  $102.5 \pm 3.5$  mph;  $d = 0.24$ ). However, no significant change in BS was observed,  
1058 resulting in a large reduction in smash factor ( $d = -0.82$ ). Furthermore, the effects of the warm-  
1059 up on CHS became trivial and non-significant beyond the first set of swings (out of 5 measured  
1060 sets). As such, this may limit the practical usefulness of such strategies for enhancing golf  
1061 performance across an 18-hole round, potentially limiting performance benefits to the opening  
1062 actions of a round. Collectively, these results indicate that CHS may be acutely enhanced, but  
1063 the translation to other performance outcomes such as BS, CD and TD appears limited.

1064 This limitation indicates that players may require a degree of skill development to effectively  
1065 translate gains in CHS to BS and ultimately CD. In line with this, Coughlan et al.[24] proposed  
1066 a learning-based approach to speed training, whereby players engage in progressively  
1067 representative training drills and environments to apply newfound increases in physical  
1068 capacities prior to transferring these gains into tournament settings. For instance, players may  
1069 begin in a controlled training environment with high intent practice swings, before progressing  
1070 to on-course practice including dispersion control (i.e. the accuracy and consistency of shots),  
1071 and, lastly, competitive pressures. In support of this, Sergio and Boatwright [126] demonstrated  
1072 that significant increases in baseball swing velocity (+8.8%) were achieved following a six-  
1073 week intervention involving increased swing volume using a standard bat (100 additional  
1074 swings three times weekly), with comparable results with weighted implement conditions  
1075 (+8.0 - 8.2%) and no significant differences between groups. These findings highlight that  
1076 increasing the volume in intentional practice alone can lead to improvements in swing velocity,  
1077 supporting the notion of skill integration in translating physical capacities into performance  
1078 outcomes. However, it should be noted that this framework is currently conceptual and is not

1079 supported by empirical research in golf. It has therefore been recommended that sessions be  
1080 carefully designed in collaboration between the golfer, golf coach, and S&C coach, with  
1081 consideration of the player's individual needs [24].

1082 Evidence on the longitudinal effects of overspeed or weighted-implement strategies in golf is  
1083 currently lacking. The wider body of research has demonstrated that in sports such as baseball,  
1084 overspeed and weighted implement training has been shown to lead to increases in bat velocity  
1085 [127]. For instance, DeRenne et al.[128] reported that a combination of overweight and  
1086 underweight implement training led to significant increases in bat swing velocity ( $34.6 \pm 2.1$   
1087 to  $38.0 \pm 2.3 \text{ m}\cdot\text{s}^{-1}$ , +9.8%;  $35.8 \pm 3.4$  to  $37.8 \pm 2.9 \text{ m}\cdot\text{s}^{-1}$ , +5.6%) over a 12-week training  
1088 period, consisting of four training sessions per week and 150 additional swings weekly. Further  
1089 to this, both protocols produced significantly greater improvements in bat velocity than the  
1090 control condition. This highlights the potential utility of such training methods in the context  
1091 of improving golf performance. However, further research is required to evaluate both the acute  
1092 and longitudinal effectiveness of swing speed training methods in golf, using standard clubs as  
1093 well as overspeed or weighted implements. Additionally, researchers and practitioners should  
1094 apply caution regarding the increased training volumes associated with such methods, given  
1095 that overuse injuries are the most frequently reported mechanism of injury in professional golf  
1096 [129].

## 1097 **2.7 Warm-up Interventions and Practices**

1098 Effective warm-ups are crucial for an athlete's physical and mental preparation for exercise and  
1099 competition and can also support long-term training goals [130]. Modern warm-ups typically  
1100 incorporate elements of the RAMP model ("Raise, Activate, Mobilise, Potentiate"), which  
1101 aims to sequentially raise body temperature and heart rate, activate key muscles, mobilise  
1102 joints, and potentiate muscular performance [130]. Warm-up interventions featuring various  
1103 RAMP components have been shown to improve acute golf performance, as demonstrated in

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1104 a recent systematic review [6]. Notably, dynamic warm-ups have shown to outperform control  
1105 and/or club-only warm-up conditions [39,131,132]. For instance, Moran et al. [132] reported  
1106 that a dynamic stretching protocol led to significantly greater increases in CHS and BS, and  
1107 straighter swing paths than both a control condition, and a static stretching condition.

1108 Comparatively, static stretching appears to be a sub-optimal warm-up strategy and can  
1109 substantially impair measures of golf performance [133,134]. For example, the addition of  
1110 static stretching to an active dynamic warm-up led to immediate significant declines in CHS (-  
1111 4.92%), DD (-7.26%), accuracy (-1.99%), and self-reported shot quality (-31.29%) when  
1112 compared to an active dynamic warm-up in low handicap male golfers (Handicap  $3.2 \pm 1.6$ ).  
1113 Furthermore, CHS remained significantly impaired until 45 minutes post-warm-up (-2.59% at  
1114 15 minutes; -2.19% at 30 minutes). DD was also significantly impaired across all time points  
1115 measured post warm-up (-5.19% at 15 minutes; -5.47% at 30 minutes; -3.30% at 45 minutes; -  
1116 3.53% at 60 minutes). These findings align with the broader literature, supporting that static  
1117 stretching can negatively impact muscular compliance by affecting the length-tension  
1118 relationship, which may result in detrimental effects on performance when performed before  
1119 physical activity [135]. Accordingly, dynamic stretching appears to be preferable to static  
1120 stretching when the goal is to maximise subsequent golf performance.

1121 In addition to dynamic stretching, warm-ups including light RT and resistance-band exercises  
1122 have shown to be effective for enhancing golf performance measures [39,40]. Indeed, Tilley &  
1123 Macfarlane. [40] reported that a combined resistance-band and dynamic warm-up resulted in  
1124 greater DD (+5.59%), smash factor ratio (+1.47%), and BS (+13.36%) than a dynamic-only  
1125 warm-up. Notably, resistance-bands offer a versatile, and easily transportable option when RT  
1126 equipment is not available [40]. Potentiation strategies, whereby exercises are selected to  
1127 achieve a super-maximal effect through the PAPE effect [136], can also improve a golfer's  
1128 driver performance beyond that of a regular warm-up [124,137]. For example, Read et al.[137]

1129 demonstrated that a PAPE warm-up involving three maximal CMJ elicited trivial but  
1130 significant improvements in driver CHS (+2.15%, ES = 0.16) compared to a control condition  
1131 of a standard dynamic stretching only warm-up in low handicap male golfers (handicap  $5.8 \pm$   
1132  $2.2$ ). Similarly, Bliss et al. [124] found that both a CMJ and plyometric press-up protocol ( $110.1$   
1133  $\pm 5.5$  vs  $111.6 \pm 5.1$  mph, ES = 0.28) and overspeed training with speed sticks ( $110.1 \pm 5.5$  vs  
1134  $111.6 \pm 5.2$  mph, ES = 0.28) produced significantly greater CHS than a dynamic only warm-  
1135 up in low handicap golfers (handicap  $1.0 \pm 2.1$ ).

1136 Taken together, these findings suggest that warm-ups for golfers should aim to raise body  
1137 temperature, activate key muscles, and mobilise the joints required for the golf swing, through  
1138 dynamic stretching and light RT or resistance-band exercises. In-addition, warm-ups that  
1139 incorporate bodyweight ballistic exercises or golf-specific swings to potentiate performance,  
1140 may offer additional short-term performance benefits beyond standard warm-up effects.  
1141 Collectively, such approaches represent current best practice, whereas static stretching should  
1142 be avoided when the aim is to maximise CHS and driver performance. In theory, these  
1143 strategies may enhance competitive performance and support a golfer's longer-term training  
1144 goals. However, the duration of these performance benefits is not well understood, and future  
1145 research should explore the effects of warm-ups over longer periods of time and the potential  
1146 utility of re-warm-up strategies [6,124].

1147 Despite the benefits associated with warm-ups, historical evidence has shown golfers' attitudes  
1148 and behaviours towards the practice to be poor. In a study in 2003, Fradkin et al. [138] reported  
1149 70% of 1040 surveyed golfers "never or seldom" warmed up, with only 3.8% doing so on every  
1150 occasion. The most common reasons for not warming up were the perceptions that they "don't  
1151 need to" (38.7%), "don't have enough time" (36.4%) and "can't be bothered" (33.7%). In a  
1152 separate observational study, Fradkin et al. [139] reported that only 54.3% of 1040 amateur  
1153 golfers performed any form of warm-up, with air swings on the tee being the most common

1154 activity (88.7%). Furthermore, most golfers who did warm up performed only one type of  
1155 activity (77.0%), with only 17.8% performing two or more warm-up elements.

1156 It should be noted that higher-skilled golfers may hold different attitudes and behaviours, with  
1157 only 5.8% of the surveyed golfers having a handicap between 0-10 [139]. In support of this,  
1158 more recent evidence from Wells et al. [86] demonstrated more positive attitudes towards  
1159 warm-ups among PGA professionals (n = 430), with 56.51% “strongly agreeing” that warming  
1160 up can “help increase golf performance”. Participation rates were also high, with 91.86%-  
1161 96.74% reporting that they warm-up prior to practice rounds, range sessions and tournament  
1162 rounds. However, little is known of whether the practices of golfers competing at the highest  
1163 level align with current scientific recommendations for warming-up within the sport of golf.

## 1164 **2.8 Conclusion**

1165 This review summarises the relevant concepts relating to the use of physical preparation for  
1166 maximising golfers’ CHS and shot outcomes, as well as practical considerations for the  
1167 application of such strategies in practice. From a biomechanical standpoint, factors including  
1168 ground reaction forces, centre of pressure, the sequential summation of forces principle, and  
1169 X-factor variables are thought to underpin changes in CHS. Physiologically, golf imposes  
1170 relatively low energetic and cardiorespiratory demands. However, a general base of  
1171 cardiorespiratory fitness may benefit golfers in sustaining high levels of performance over four-  
1172 day tournaments and back-to-back events, and in tolerating the lifestyle demands of the sport.  
1173 Muscular force expression characteristics including upper- and lower-limb strength and power,  
1174 and rotational power have the strongest correlations with CHS. In contrast, measures of  
1175 flexibility, muscular endurance, and balance appear to be less important. This is supported by  
1176 research showing that strength- and power-oriented training interventions can improve CHS,  
1177 shot outcomes, and related physical capacities. Dynamic and resistance-based warm-ups can  
1178 also improve CHS and shot performance, whereas static stretching is detrimental and represents

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1179 a sub-optimal warm-up strategy. Although strength and power training should be the primary  
1180 focus for golfers aiming to maximise their CHS, competition schedules can confound optimal  
1181 development strategies. Therefore, this chapter offers practical recommendations for  
1182 implementing effective player development strategies. Further evidence would be of value in  
1183 designing increasingly relevant S&C programmes that support physical development without  
1184 compromising golf practice and competitive performances.

## 1185 **2.9 Chapter Perspective**

1186 Chapter 2 outlined the currently available literature regarding the biomechanical,  
1187 physiological, and neuromuscular considerations underpinning golf performance. A recurring  
1188 theme that emerged throughout the chapter was the importance of muscular force-expression  
1189 qualities for improving CHS, as evidenced in both correlational and longitudinal research.  
1190 Consequently, S&C, particularly the development of strength and power qualities, is  
1191 highlighted as a key avenue through which meaningful improvements in golf shot-performance  
1192 outcomes may be achieved. However, the chapter also identified the considerable barriers  
1193 associated with implementing S&C strategies within professional golf. Dense tournament  
1194 schedules, prolonged in-season periods, extensive travel demands, variability in training  
1195 environments, and limited opportunities for recovery collectively restrict the feasibility of  
1196 traditional S&C programming during competitive periods. Accordingly, the chapter also  
1197 considered practical strategies through which existing evidence might be translated into applied  
1198 settings.

1199 As a result of these constraints, alternative training strategies that could support physical  
1200 development, or at least maintenance, without imposing excessive fatigue or interfering with  
1201 tournament preparation are of interest. Micro-dosing sessions were therefore proposed as a  
1202 potential solution to this problem. More specifically, resistance training priming may offer  
1203 benefits through short-term increases in neuromuscular readiness while also contributing to

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1204 longer-term training goals. However, despite the theoretical compatibility with the demands of  
1205 competitive golf, there appears to be a lack of supporting empirical evidence.

1206 To address this gap, Chapter 3 presents a systematic review of RT priming interventions and  
1207 their effects on neuromuscular athletic performance outcomes. By collating and critically  
1208 evaluating the available literature, the review highlights the potential utility of priming  
1209 strategies within golf, both for acute performance enhancement and for supporting longer-term  
1210 physical development without compromising performance. Furthermore, by examining the  
1211 magnitude and time-course of performance changes reported across studies, the review  
1212 provides insights that may inform the design and scheduling of training strategies suitable for  
1213 use during the in-season period. In doing so, Chapter 3 extends the conceptual foundation  
1214 outlined in Chapter 2 and contextualises the evidence base underpinning the intervention  
1215 studies presented later in the thesis.

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1216 **3 Chapter 3: The Effects of Resistance Training Priming Exercise**  
1217 **on Neuromuscular Athletic Performance Tasks: A Systematic**  
1218 **Review**

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### 1219 3.1 Abstract

1220 Intense RT is commonly avoided in the hours or days preceding sport competition due to  
1221 concerns that fatigue may impair performance. However, emerging evidence suggests that low-  
1222 volume, short-duration RT sessions, termed ‘RT priming’, may preserve or, under certain  
1223 conditions enhance performance within a one- to 48-hour window post-training. A systematic  
1224 review was conducted to examine the effects of RT priming on neuromuscular athletic  
1225 performance outcomes, with thirty studies meeting eligibility criteria. Collectively, the findings  
1226 indicate that RT priming interventions can result in improvements in neuromuscular athletic  
1227 performance tasks, although changes in performance were heterogeneous. Increases in  
1228 performance were most consistently observed following high-intensity, low-volume load  
1229 (arbitrary units (AU) sessions) RT priming sessions involving multi-joint compound  
1230 movements ( $\geq 80\%$  1RM; 780–2155 AU) when assessed four to eight hours post-exercise, and  
1231 low-intensity ballistic interventions (30–40% 1RM; 450–800 AU) assessed six to 24 hours  
1232 post-exercise. Outcomes were influenced by exercise selection, intensity, volume, recovery  
1233 duration, and participant characteristics, with stronger and more resistance-trained individuals  
1234 typically demonstrating more favourable changes in performance. Beyond acute enhancement,  
1235 the evidence more consistently supports RT priming as a low-risk strategy for implementing  
1236 RT prior to competition without inducing prolonged neuromuscular impairment. However,  
1237 higher-volume protocols (1500-5600 AU), particularly in weaker individuals or when sets are  
1238 performed to failure, appear to increase the risk of performance reductions. Accordingly,  
1239 individual monitoring is recommended when employing RT priming strategies to minimise  
1240 performance decrements and support longer-term training objectives.

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## 1241 3.2 Introduction

1242 The demands of numerous sports require athletes to rapidly produce large forces to accelerate  
1243 or decelerate external objects [74,140], manipulate their own mass against gravity, or an  
1244 opponent's mass [74]. These demands rely heavily on the neuromuscular system's ability to  
1245 produce large outputs of force, and high-velocity movements [141]. RT is implemented by  
1246 S&C professionals to improve muscular force expression through improvements in skeletal  
1247 muscle function, architecture, and activation [74,108]. While appropriately planned RT  
1248 supports these adaptations, its high-intensity nature can be taxing on the neuromuscular system  
1249 and may require up to 72 hours for full recovery [121]. As a result, scheduling RT can be  
1250 challenging during busy competition periods, as it is commonly avoided in the 48 hours prior  
1251 to competition due to the potential for impaired sporting performance levels [110]. Indeed, a  
1252 common feature consistent across the many proposed definitions of fatigue, is an exercise-  
1253 induced transient decline in muscular force-generating capabilities [142]. Fatigue has also been  
1254 shown to limit the maximum velocity of muscle fibre shortening, in addition to slowing  
1255 relaxation [143], negatively impacting muscular power output. Consequently, neuromuscular  
1256 athletic performance tests are commonly used as non-invasive markers of fatigue, to track  
1257 recovery and guide training decisions [144].

1258 Alternatively, the idea that RT can induce significant short-term enhancements in  
1259 neuromuscular performance has garnered considerable research attention, particularly in  
1260 relation to PAPE strategies [136,145–147]. While athletic performance tasks have been shown  
1261 to be significantly improved following PAPE strategies [147], these benefits are short-lived  
1262 and typically subside within minutes (<20 minutes) of application, limiting the practical  
1263 feasibility and usefulness of such strategies in pre-competition settings. More recently, studies  
1264 have demonstrated that measures of neuromuscular performance may improve at longer  
1265 intervals of between one and 48 hours following low-volume RT sessions [122]. This approach,

1266 termed ‘RT priming’, is proposed to elicit a delayed potentiation response, conceptually similar  
1267 to PAPE but exerting over a longer timeframe. The suggested mechanisms include increases  
1268 in high-frequency motor neuron activation, muscle temperature, mechanical stiffness [148],  
1269 muscle fibre sensitivity to calcium ions [122], and/or changes in diurnal testosterone and  
1270 cortisol hormone concentrations following RT [149]. However, the direct mechanisms  
1271 underpinning these responses currently remain unclear.

1272 Despite evidence that RT priming can enhance athletic performance measures including, sprint,  
1273 jump, throwing, and strength tasks [123,149–153], several studies have also reported no  
1274 improvements or even reductions in performance levels [154–158]. Much like PAPE,  
1275 potentiation and fatigue appear to co-exist following RT priming activities, with the magnitude  
1276 of performance effects being influenced by the net balance between these two states [159]. This  
1277 hypothetical interaction has been modelled as an acute interpretation of Bannister’s fitness-  
1278 fatigue model [122,160]. In summary, performance is impaired when fatigue is prominent,  
1279 remains unchanged when these states are balanced, and is enhanced when potentiation  
1280 outweighs fatigue [159]. Accordingly, researchers have sought to explain the lack of agreement  
1281 between studies by identifying the methodological, participant, programming, and time-course  
1282 factors that may moderate the effects of RT priming [122,161,162].

1283 Despite the mixed evidence, RT priming strategies have been implemented in competitive sport  
1284 environments. A recent survey of 69 sports performance practitioners reported that 51%  
1285 applied priming strategies before competition with high-performance athletes, and 84%  
1286 believed it enhanced performance [163]. This highlights the clear need for synthesised, high-  
1287 quality evidence to guide practitioners on best practice. Beyond the primary aim of acute  
1288 performance enhancement, RT priming has also briefly been discussed as a means of  
1289 supporting longer-term training objectives, such as the development or maintenance of  
1290 maximal strength-power adaptations through a ‘micro-dosing’ training effect. Within this

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1291 context, athletes with extended in-season periods and limited opportunities for traditional RT  
1292 methods, such as competitive golfers, may particularly benefit from such strategies. As  
1293 highlighted in Chapter 2, golfers' neuromuscular force-producing capabilities are a key  
1294 determinant of CHS and shot performance [35], and can therefore have a substantial influence  
1295 on competitive performance outcomes across a season. Accordingly, RT priming may offer a  
1296 practical means of administering short-duration sessions within 48 hours of competition while  
1297 minimising residual fatigue, in contrast to traditional RT methods, which are typically avoided  
1298 in the days preceding competition [110].

### 1299 **3.3 Method**

#### 1300 **3.3.1 Search Strategy**

1301 This Systematic review was conducted in accordance with the Preferred Reporting Items for  
1302 Systematic Reviews and Meta-Analysis (PRISMA) guidelines [164], with the search strategy  
1303 outlined in Figure 3.1.

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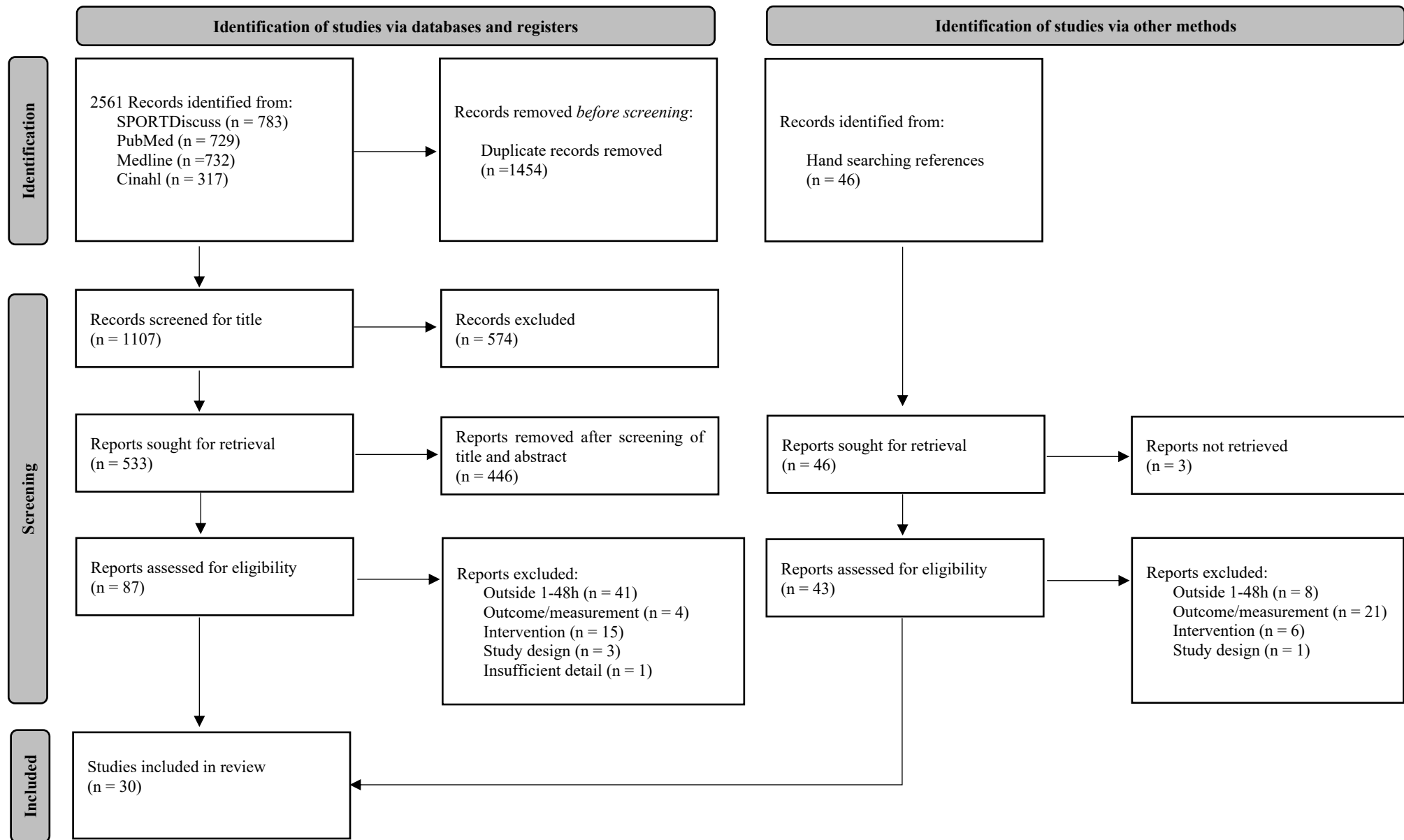


Figure 3.1 Flow diagram of search strategy

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### 1336 3.3.2 Literature Search

1337 The online library databases including PubMed, CINAHL Complete, SPORTDiscus and  
1338 MEDLINE were searched. Preliminary searches of databases were conducted throughout  
1339 March and April 2022 to identify key word combinations, with combinations of search terms  
1340 piloted across each database. The following combinations of keyword search terms were used  
1341 in finding the relevant studies using Boolean operators (AND/OR): Resistance-training OR  
1342 Resistance-exercise OR Strength-training OR Power-training OR Weightlifting OR Jump\* OR  
1343 Morning-exercise OR Morning training AND Priming OR Prior-exercise OR Warm-up OR  
1344 Pre-conditioning OR Pre-activation OR Pre-competition OR PAP OR Postactivation-  
1345 potentiation OR PAPE OR Postactivation-performance-enhancement. Database searches  
1346 occurred in April 2022, with search restrictions to studies published or translated to English,  
1347 and peer-reviewed articles. Following this, manual searches were performed up to 24th May  
1348 2022 with additional screening of reference lists from relevant included articles.

### 1349 3.3.3 Inclusion and Exclusion Criteria

1350 Studies were deemed eligible for inclusion if they satisfied the following criteria:

1351 Inclusion:

- 1352 1. Participants were healthy, and free from injury or illness.
- 1353 2. Studies were published in peer reviewed journals, published in or translated to English.
- 1354 3. Studies were randomised control trials, or counter-balanced crossover comparative  
1355 studies reporting on pre-post intervention outcomes, or post-intervention performance  
1356 outcomes
- 1357 4. Exercise interventions consisted of RT and/or plyometric/ballistic training exercises
- 1358 5. Studies measured neuromuscular athletic performance such as jump, sprint, throw,  
1359 strength, or sports specific performance tasks.

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1360 6. Outcomes were measured between one and 48 hours following the initial exercise  
1361 intervention.

1362 Exclusion:

1363 1. Studies which investigated the effects of treatments/modalities such as electrically  
1364 elicited stimuli, massage, mobilisation, passive stretching, hot/cold therapy, vibration  
1365 therapy, or blood flow restriction

1366 2. Studies which investigated the use of nutritional supplementation or drugs

1367 3. Studies which investigated or including the use of aerobic exercise/endurance exercise,  
1368 sprinting or stretching as the exercise intervention

1369 The outlined criteria were detailed to qualify studies for inclusion in this systematic review  
1370 investigating the effects of RT and/or plyometric or ballistic training exercises , characterised  
1371 by the intention to perform movement with maximal velocity and with the acceleration of mass  
1372 throughout the entire movement [165], on measures of neuromuscular athletic performance.

1373 Studies investigating performance outcomes within a one hour to 48-hour time period were  
1374 considered as prior research indicates that neuromuscular performance may be enhanced as a  
1375 result of RT priming within this timeframe [122]. Further to this, >48 hours is often the  
1376 recommended time-course for recovery from RT [110], allowing for the balance between

1377 fatigue and potentiation following an exercise stimulus to be examined. A minimum of one  
1378 hour separating the exercise intervention and subsequent performance assessment was required  
1379 due to the confounding influence acute strategies such as warm-ups [166], and post activation  
1380 potentiation/PAPE may pose on performance outcomes [147]. Measures of neuromuscular

1381 athletic performance were the primary outcome measures assessed, as RT priming is a  
1382 proposed method of enhancing neuromuscular performance [122]. Likewise, neuromuscular  
1383 athletic performance tasks are often used as non-invasive markers of fatigue [144], and are  
1384 therefore useful in predicting the influence of both fatigue and potentiation following an

1385 exercise stimulus. As a result of this, studies which do not explicitly investigate the use of RT  
1386 interventions as a means of enhancing performance were also included in this review (i.e.  
1387 studies investigating the recovery response to RT within a one-to-48-hour period after training).  
1388 Studies were excluded if they involved nutritional or drug interventions, to exclusively  
1389 investigate the response to the training stimulus.

### 1390 **3.3.4 Screening Strategy**

1391 In selecting studies for inclusion, a four-stage screening process was undertaken in accordance  
1392 with the PRISMA guidelines. Duplicates were removed, followed by title screening and  
1393 abstract review. Full-text articles extracted were then screened against the inclusion and  
1394 exclusion criteria by the primary reviewer. Any uncertainties were resolved through  
1395 consultation with the supervisory team (JM, CW).

### 1396 **3.3.5 Data Extraction**

1397 A customised Microsoft Excel spreadsheet was created and used for data extraction. The data  
1398 extracted from each article included the sample size, participant characteristics, outcome  
1399 measures, details regarding the exercise stimulus, recovery interval durations, and a summary  
1400 of the key findings.

### 1401 **3.3.6 Quality Assessment**

1402 The Physiotherapy Evidence Database (PEDro) scale was used to assess the risk of bias and  
1403 methodological quality of studies included in this Systematic Review [167]. This scale  
1404 evaluates internal study validity on a scale from 0 (high risk of bias) to 10 (low risk of bias). A  
1405 total of 11 criterion measures is assessed (Table 3.1), to identify internal validity (criteria 2-9),  
1406 to identify whether studies could have sufficient statistical information to make their results  
1407 interpretable (criteria 10-11), and external validity (criteria 1). However, criterion 1 is not  
1408 included in the total PEDro score. Scores of 0–3 were regarded as poor, 4–6 were considered

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1409 as fair, 7–8 to be good, and 9–10 as excellent [168]. Studies were not excluded based on quality  
1410 scores. Studies were not evaluated if they were crossover studies including only post-  
1411 intervention outcomes. Accordingly, seven of the 30 included articles were not analysed using  
1412 the PEDro scale [153,156,169–173].

### 1413 **3.3.7 Analysis and Interpretation of Results**

1414 Due to the heterogeneity in study designs, intervention types, and outcome measures, a meta-  
1415 analysis of the results was not performed, and a narrative synthesis was conducted. The  
1416 included studies were grouped according to classifications of intervention type and the  
1417 performance outcome measures assessed.

1418 When possible, percentage change and Hedges' *g* effect sizes were calculated to provide  
1419 standardised measures of the magnitude of change following the interventions. Hedges' *g*,  
1420 which is an extension of Cohen's *d*, was selected due to the small sample sizes of included  
1421 studies, as it provides a correction for small-sample bias [174]. Effect size calculations were  
1422 calculated and reported when appropriate for both between-group, and within group pre-post  
1423 changes. Estimated magnitudes were interpreted in accordance with suggestions from Cohen  
1424 and classified as:  $\leq 0.2$  trivial, 0.2–0.49 small, 0.5–0.79 moderate,  $\geq 0.8$  large [175]. In addition,  
1425 total RT session volume loads were calculated using arbitrary units ([AU] = sets X % RM  
1426 [176]), and, when possible, reported in Table 3.3.

1427

**Table 3.1 PEDro Criteria**

<b>Number</b>	<b>Criteria</b>
1	Eligibility criteria were specified
2	Participants were randomly allocated to groups (in crossover study, participants were randomly allocated an order in which treatments were received)
3	Allocation was concealed
4	The groups were similar at baseline
5	There was blinding of all participants
6	There was blinding of all therapists who administered the therapy
7	There was blinding of all assessors who measured at least one key outcome
8	Measures of at least one key outcome were obtained from more than 85% of the participants initially allocated to groups
9	All participants for whom outcome measures were available received the treatment or control condition as allocated or, were this was not the case, data for at least one key outcome was analysed by 'intention to treat'
10	The results of between-group statistical comparisons are reported for at least one key outcome

1428

## 1429 **3.4 Results**

### 1430 **3.4.1 Study Characteristics**

1431 Thirty studies were deemed eligible for inclusion in this systematic review (Figure 3.1). The  
 1432 majority of studies adopted counterbalanced crossover designs reporting pre- and post-  
 1433 intervention outcomes, with seven studies reporting post-intervention outcomes only  
 1434 [153,156,169–173] and two studies assigning participants to a specific intervention group  
 1435 [151,177]. A total of 61 RT interventions were analysed in this review, with fifteen studies  
 1436 investigating a single intervention, and fifteen examining multiple exercise interventions  
 1437 within the same study. A single exercise was adopted in 30 of the interventions, with 31  
 1438 including multiple exercises. Squat-based exercises were the most utilised modality (22  
 1439 interventions), followed by a combination of squat and bench-press (18 interventions), and  
 1440 bodyweight or externally loaded jump-based exercises (seven interventions).

1441 Jump performance outcomes were most frequently assessed (29 studies), with CMJ  
 1442 performances reported in 26 studies, followed by drop jump (six studies) and squat jump (four

1443 studies). Strength-based outcomes were reported in ten studies, sprint performance in six  
1444 studies, throwing performance in two studies, and Olympic weightlifting performance in one  
1445 study. Performance outcomes were commonly measured at a single post-intervention time  
1446 point, although twelve studies assessed outcomes at multiple time points. Of the included  
1447 studies, 18 explicitly investigated RT interventions with the primary aim of enhancing  
1448 performance. Performance improvements were reported following 16 interventions, decreases  
1449 in at least one outcome measure were observed in 20, and no significant changes in 25  
1450 interventions (Table 3.3).

### 1451 **3.4.2 Participants Characteristics and Session Volume Loads**

1452 Participants were predominantly male (23 studies) or included a combination of male and  
1453 female participants (five studies). Mean participant age ranged from 14.6 to 28 years, with  
1454 sample sizes ranging from eight to 41 participants. Studies including both male and female  
1455 participants reported no differences in performance outcomes between genders [171–  
1456 173,178,179]. Three studies included participants under 18 years of age, all of which  
1457 demonstrated performance improvements following the intervention [151,169,172].

1458 Several studies demonstrated inter-individual variability in performance effects. Gonzalez  
1459 Garcia et al. [178] reported no group-level changes following two sets of parallel back squats  
1460 (80% 1RM); however, individual outcomes varied, with performance improvements observed  
1461 in four participants and performance decrements observed in a further four participants within  
1462 a cohort of fourteen. Absolute 1RM strength was moderately correlated with changes in CMJ  
1463 height, concentric peak velocity, and impulse ( $r = 0.47-0.50$ ), whereas relative strength to body  
1464 mass was not significantly associated. Similarly, Nishioka & Okada [152] reported significant  
1465 improvements in CMJ performance 24 hours following an RT priming intervention involving  
1466 5x4 squat jumps (40% 1RM), with improvements ranging from 1.8-19.0% (Hedges'  $g = 0.29-$   
1467 0.92, Small-Large) in stronger participants, whereas no significant changes were observed in

1468 weaker participants. Further to this, a large positive correlation was observed between changes  
1469 in CMJ height and participants' relative half-squat 1RM strength ( $r = 0.61$ ).

1470 Performance improvements were reported following several RT priming interventions, despite  
1471 authors not reporting participant strength characteristics [150,151,153,156,169,171,172,180].  
1472 Among studies that both reported participant strength characteristics and demonstrated  
1473 performance improvements, participants were typically relatively strong  
1474 [123,148,149,152,153,173,178,181], with the lowest reported relative strength values of  $1.6 \pm$   
1475  $0.2$  kg/BM for the parallel back squat [181] and an absolute strength of  $139.8 \pm 22.4$  kg ( $\sim 1.81$   
1476 kg/BM) for the half squat [173]. In contrast, performance decrements were more frequently  
1477 observed in weaker individuals (mean squat strength  $101.7 - 114$ kg; relative strength  $\sim 1.38 -$   
1478  $1.44$  kg/BM) [155,158,182–184], particularly following high-volume interventions ( $\sim 2160 -$   
1479  $5040$  AU) or when repetitions were performed to failure [155,182–184]. However, when  
1480 session volume loads were lower ( $1080 - 2520$  AU) and submaximal repetitions were  
1481 performed, weaker individuals maintained performance levels when measured six-, 24-, and  
1482 48-hours post intervention [155,182–184]. Notably, even among stronger individuals (back  
1483 squat 1RM  $\sim 173.4$ - $182$ kg; relative strength  $\sim 2.11 - 2.15$  kg/BM), high volume load  
1484 interventions ( $\sim 3204$ - $5600$  AU) led to performance reductions persisting up to 22-48 hours  
1485 post training [154,185].

### 1486 **3.4.3 Training Intensity**

1487 Exercise interventions were sub-categorised based on the relative intensities used, and in  
1488 accordance with previous distinctions made in the literature, particularly with regards to  
1489 definitions of high-, moderate-, and low intensity loading [122,173,181,185]. Accordingly, 21  
1490 studies included high-intensity RT exercises ( $\geq 80\%$  1RM) across 30 interventions. Ten studies  
1491 included moderate-intensity (50-79% 1RM) exercise interventions (16 interventions), while  
1492 nine studies included low-intensity bodyweight (four interventions) or lighter resistance

1493 exercise ( $\leq 40\%$  1RM; seven interventions). Three interventions did not fit within the pre-  
1494 specified categories. One involved flywheel training [158], another quantified intensity using  
1495 a RPE scale [180], and one utilised a load described as ‘maximal power’, which was not further  
1496 specified [186].

### 1497 **3.4.3.1 High-Intensity Training**

1498 Following high-intensity RT protocols ( $\geq 80\%$  1RM), performance improvements were most  
1499 commonly observed within four to eight hours post-intervention, as reported in nine studies  
1500 [148,149,151,153,169,171,173,178,181]. A variety of exercises (e.g., back squat, half squat,  
1501 weightlifting derivatives) and set configurations (2–8 working sets per session) were utilised,  
1502 with relatively low total session volume loads (780–2155 AU). Performance increases across  
1503 the measured outcomes ranged from trivial to large effects (1.3–9.7%; Hedges’  $g = 0.15$ – $0.77$ ,  
1504 Small-Moderate).

1505 However, considerable variability in performance effects were observed. CMJ improvements  
1506 were reported in five of the nine interventions (2.6–6.5%; Hedges’  $g = 0.15$ – $0.4$ , Trivial-Small),  
1507 whereas sprint performance outcomes (on ice, 40-meter, cricket-specific) were more  
1508 consistently elicited from three interventions (1.3–7.4%, Hedges’  $g = 0.41$ – $0.77$ , Small-  
1509 Moderate). Three studies reported improvements in strength-based outcomes, including 80%  
1510 1RM squat mean velocity and power (8.1–9.7%, Hedges’  $g = 0.26$ – $0.32$ , Small) [173], 3RM  
1511 bench press and squat performance (3.6–4.2%, Hedges’  $g = 0.37$ – $0.59$ , Small-Moderate) [149],  
1512 and Olympic weightlifting performances (+5.8–6.2kg) [169]. Single studies also reported  
1513 improvements in backward overhead shot throw performance (2.6%, Hedges’  $g = 0.22$ , Small)  
1514 after four to six hours of recovery [171], drop jump performance after six hours (3.0–5.5%)  
1515 [148], broad jump performance after six hours (4.8%, Hedges’  $g = 0.64$ , Moderate), and squat  
1516 jump performance following eight hours of recovery (4.5%, Cliff delta= 0.20, Small) [181].

1517 However, no concurrent improvements in CMJ performance were observed across these  
1518 studies within the same timeframes [148,151,171,181].

1519 There is limited evidence to support performance enhancement beyond the day of a high-  
1520 intensity RT session. Exceptionally, Harrison et al. [181] reported improved CMJ height 32  
1521 hours following a back squat intervention (up to 87% 1RM, 4.8%, Cliff delta: 0.28, Small).  
1522 However similar improvements were also observed in a control condition, limiting attribution  
1523 to the RT intervention.

1524 Several studies reported no significant changes in performance outcomes following high-  
1525 intensity RT (500–3400 AU) [154,156,157,170,183,184,186–188]. In contrast, other studies  
1526 reported performance decrements, particularly following higher volume load protocols (1080–  
1527 3840 AU) [155,158,177,184]. Notably, CMJ performance impairments were reported when  
1528 assessed after 48 hours of recovery, with reductions ranging from -3.7 to -9.6% (Hedges'  $g = -$   
1529 0.44 to -0.82, Small-Large) [155,158,177,185]. Furthermore, Pareja-Blanco et al. [155] and  
1530 Gonzalez-Badillo et al. [184] demonstrated that performance effects were influenced by effort  
1531 level, with repetitions performed to failure resulting in significant reductions when measured  
1532 six-, 24-, and 48-hour after training, whereas submaximal repetition schemes resulted in no  
1533 significant changes.

#### 1534 **3.4.3.2 Moderate Intensity Training**

1535 Few studies demonstrated improvements following moderate-intensity interventions, with  
1536 relative loads ranging from ~59.5% to 75% 1RM and effects observed five, eight, 32, and 33  
1537 hours post-training (780–3750 AU) [180,181,185]. Harrison et al. [181] reported significant  
1538 improvements in CMJ and squat jump performance 32 hours after 4x3 half squats at 65% 1RM  
1539 (6.1-6.5%, Cliff delta: 0.27-0.30, Small), but no changes when measured at 24 hours and only  
1540 small improvements in CMJ height at eight hours (3.1%, Cliff delta: 0.16). Similarly, Raastad

1541 & Hallen. [185] reported a 5% increase in CMJ height 33 hours following a moderate-intensity  
1542 session (~59.5-65% 1RM, 2242 AU), while only small and non-significant changes were  
1543 observed at earlier time points between three and 30 hours post intervention. Russell et al. [180]  
1544 was the only study to investigate the effects of an upper-body session (5x10 bench press at 75%  
1545 1RM) on lower-limb performance outcomes. After five hours of recovery, improvements in  
1546 two of six repeated 40-m sprint efforts (2.0-2.3%) in male professional rugby players, with no  
1547 significant changes in CMJ or reaction time.

1548 Similar to high-intensity RT, several studies reported no significant changes in performance  
1549 outcomes when session volume loads ranged from 2250-4500 AU [155,156,173,182,183,188].  
1550 Higher volume load protocols (4500-5600 AU) were associated with performance decrements  
1551 persisting up to 48 hours post-intervention [154,155,182,183]. Even in relatively strong  
1552 individuals (squat 1RM:  $173.4 \pm 31.7$  kg; relative strength ~2.11 kg/BM), reductions in CMJ  
1553 peak power of 9.6% and 7.8% were observed 24 and 48 hours following a high volume-load  
1554 intervention (8x10 squats at 70% 1RM, 5600 AU) [154]. Moran-Navaro et al. [182] further  
1555 evidenced that set configuration influenced performance outcomes. When session volume was  
1556 lower (3x5, 2250 AU or 6x5, 4500 AU), CMJ performance was maintained at six-, 24-, and  
1557 48-hours post-intervention, whereas a higher-repetition protocol performed to failure (3x10,  
1558 4500 AU) resulted in significant reductions at all assessed time points.

### 1559 **3.4.3.3 Low Intensity Training**

1560 Low-intensity, low-volume load RT interventions (450 -800 AU) sessions, involving externally  
1561 loaded jumps (30–40% 1RM) performed for 3–5 sets of 4–5 repetitions, were consistently  
1562 associated with performance improvements between six- and 48-hours post-training  
1563 [123,148,177]. Significant improvements in CMJ (9.0%) and drop jump performances (4.2%)  
1564 were observed after six hours of recovery [148]. Nishioka & Okada. [177] reported small  
1565 improvements in CMJ height after 24 hours recovery (5.4%, Hedges'  $g = 0.46$ , Moderate), in

1566 addition to improvements in other force-time variables (1.8-19.0%, Hedges'  $g = 0.29-0.92$ ,  
1567 Small-Large). However, no concurrent improvements were observed in squat jump or drop  
1568 jump performance. Similarly, Tsoukus et al.[123] reported improvements in CMJ, drop jump,  
1569 and isometric leg press RFD 24 hours post-intervention (5.1–18.3%, Hedges'  $g = 0.29-0.69$ ,  
1570 Small-Moderate), although only CMJ and RFD 0-100ms gains sustained after 48 hours (3.0%–  
1571 9.8%, Hedges'  $g = 0.31$ , Small).

1572 In contrast, Mason et al. [150] reported that an intervention involving band-resisted 'explosive'  
1573 back squat and bench press exercises significantly increased bench press throwing performance  
1574 (8.5-13.9%, Hedges'  $g = 1.01-1.17$ , Large), whereas non-significant decreases were observed  
1575 in CMJ performance after one hour and 45 minutes of recovery (-2.3 to -3.4%, Hedges'  $g = -$   
1576 0.36 to -0.46, Small). Similarly, small but significant reductions in 50-meter crawl swim time  
1577 (-2.51%, Hedges'  $g = -0.29$ , Small) were reported 24 hours following an intervention involving  
1578 bodyweight CMJ and resistance band exercises, although no changes in CMJ performance were  
1579 observed.

1580 Several interventions involving light lower-limb (~30% 1RM) or bodyweight jumping  
1581 exercises demonstrated no significant changes in jump or isometric strength performance when  
1582 measured between six and 48 hours post training [148,179,188]. Further to this, high-volume  
1583 plyometric training (4x15 plyometric squat jumps or exhaustive rebound jumps ~92  
1584 repetitions) were associated with performance reductions, with decrements in jump outcomes  
1585 persisting up to 48 hours after (-4.9% to -9.9%, Hedges'  $g = -0.5$  to -0.73, Moderate) [158,189].

#### 1586 **3.4.4 Study Quality**

1587 Study quality was evaluated using the PEDro scoring system (Table 3.3). All included studies  
1588 scored between 4-6, indicating fair methodological quality, with an overall median quality

1589 score of 5. The most common reasons for loss of scores were the lack of blinding of researchers  
 1590 and participants, and the absence of concealed group allocation.

1591 **Table 3.2 Results from the PEDro checklist**

Article	Criterion Item											Total Score
	1	2	3	4	5	6	7	8	9	10	11	
Gonzalez-Garcia et al. [178]	Y	Y	N	N	N	N	N	Y	Y	Y	Y	5/10
Nishioka & Okada. [152]	Y	N	N	N	N	N	N	Y	Y	Y	Y	4/10
Tseng et al. [177]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Rud et al. [157]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Harrison et al. [181]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Lagrange et al. [151]	Y	N	N	N	N	N	N	Y	Y	Y	Y	4/10
Pareja-Blanco et al. [155]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Tsoukos et al. [123]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Mason et al. [150]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Bartolomei et al. [154]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Moran-Navaro et al. [182]	Y	Y	N	N	N	N	N	Y	Y	Y	Y	5/10
Parejo-Blanco 16 [183]	Y	Y	N	N	N	N	N	Y	Y	Y	Y	5/10
Johnstone. [187]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Raeder et al. [158]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Gonzalez-Badillo et al. [184]	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5/10
Russell et al. [180]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Howatson et al. [179]	Y	Y	N	N	N	N	N	Y	Y	Y	Y	5/10
Cook et al. [149]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
McCaulley et al. [188]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
De Villarreal et al. [148]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Gilbert & Lees. [186]	Y	N	N	Y	N	N	N	Y	Y	Y	N	4/10
Horita et al. [189]	N	N	N	N	N	N	N	Y	Y	Y	Y	4/10
Raastad & Hallen. [185]	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5/10

*1. Eligibility criteria were specified; 2. Participants were randomly allocated to groups (in crossover study, participants were randomly allocated an order in which treatments were received); 3. Allocation was concealed; 4. The groups were similar at baseline; 5. There was blinding of all participants; 6. There was blinding of all therapists who administered the therapy; 7. There was blinding of all assessors who measured at least one key outcome; 8. Measures of at least one key outcome were obtained from more than 85% of the participants initially allocated to groups; 9. All participants for whom outcome measures were available received the treatment or control condition as allocated or, were this was not the case, data for at least one key outcome was analysed by 'intention to treat'; 10. The results of between-group statistical comparisons are reported for at least one key outcome*

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**Table 3.1 A summary of the studies investigating the effects of resistance priming type exercise on neuromuscular athletic performance within a 1–48-hour timeframe**

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
Gonzalez-Garcia et al. [178]	14 (10 M, 4 F) Age: 24.9 ± 3.7 y Mass: 73.2 ± 13.4 kg Height: 1.74 ± 0.08 m	Parallel squat 1RM: 120.5 ± 28.0 kg Relative parallel squat: 1.6 ± 0.2 kg/BM	2x parallel back squat sets (80% 1RM), with a velocity loss of ~20%  Rep set 1: 4.7 ± 1.2 Rep set 2: 4.4 ± 0.9	Cannot determine	6h	↔ All CMJ force-time metrics <sup>(C)</sup> ↔ Jump strategy <sup>(C)</sup>  <i>Individual effects: CMJ Height was increased for 4/14, decreased for 4/14 and maintained for 6/14, RSImod was increased in 5/14 participants, decreased in 6/14 and maintained in 3/14.</i>
Zaras et al. [172]	13 (11M, 2F) swimmers: Age: 14.6 ± 0.9 y (M), 15.5 ± 2.1 y (F) Mass: 62.9 ± 8.5 kg (M), 59.4 ± 7.6 kg (F)	NR	3 x 8 slam ball (4kg M; 2kg F), 3 x 8 CMJ, 3 x 12 stretch cord swim exercise.	Cannot determine	24h	↓ 50m swim crawl time -2.51% ( $g=-0.29^S$ ) <sup>(C)</sup> ↔ CMJ Height and Power <sup>(C)</sup>
Nishioka & Okada [152]	20 (M) resistance trained participants: Age: 22.4 ± 1.5 y Mass: 71.3 ± 7.4 kg Height: 172.2 ± 5.0 cm <b>Stronger group (SG):</b> n = 10 <b>Weaker group (WG):</b> n = 10	<b>SG:</b> Relative half squat: 2.2 ± 0.23 kg/BM  <b>WG:</b> Relative half squat: 1RM:1.76 ± 0.16 kg/BM	5 x 4 continuous squat jumps (40% 1RM)	800 AU	24h	<b>SG:</b> CMJ: ↑ Height 5.4% ( $g=0.46^S$ ), ↑ Eccentric RFD 19.0% ( $g=0.78^M$ ), ↑Eccentric Mean Velocity 8.8% ( $g=-0.84^L$ ), ↑Eccentric Mean Power 9.3% ( $g=-0.92^L$ ), ↑Concentric Mean Force 1.8% ( $g=0.29^S$ ), ↑Concentric Mean Velocity 3.1% ( $g=0.48^S$ ), ↑Concentric Mean Power 4.5% ( $g=0.40^S$ ), ↔ Eccentric Peak Displacement <sup>(P)</sup> ↔ SJ: Height, Concentric Mean Force, Mean Velocity, Mean Power <sup>(P)</sup> ↔ DJ RSI <sup>(P)</sup> ↔ SJ force velocity profile <sup>(P)</sup> ↑ CMJ force velocity profile ( $g=0.55-0.87^{M-L}$ ) <sup>(P)</sup> <b>WG:</b> ↔ All CMJ, SJ, DJ variables <sup>(P)</sup> ↔ SJ & CMJ force velocity profile <sup>(P)</sup>
Nutt et al. [153]	16 (M) professional cricketers: Age 26 ± 6 y	NR	3x4 trap bar deadlift (50%, 60%, 70% 1RM), 3x4 trap bar deadlift (85% 1RM)	1740 AU	5.5h	↓ 'run-two' sprint time -1.3% ( $g=-0.50^M$ ) <sup>(C)</sup> ↑CMJ Height 2.6% ( $g=0.15^T$ ) <sup>(C)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
	Mass $88.1 \pm 8.4$ kg Height $184.5 \pm 3.6$ cm					
González-García et al. [173]	11 (10 M, 1F) Age: $24.6 \pm 4.1$ y Mass: $77.0 \pm 8.9$ kg Height: $1.76 \pm 0.08$ m	Half squat 1RM: $139.8 \pm 22.4$ kg	<b>Optimal Load (OL):</b> x2 half squat sets ('optimal load', ~60% 1RM) with a velocity loss of ~20% Rep set 1: $10.4 \pm 5.8$ Rep set 2: $8.9 \pm 3.3$ <b>80% RM:</b> x2 half-squat sets with a velocity loss of around 20% performed with 80% 1RM Rep set 1: $4.4 \pm 1.5$ Rep set 2: $4.7 \pm 1.6$	Cannot determine	6h	<b>OL:</b> ↔ CMJ Height, Mean Power OL, Mean Velocity OL, Mean Power 80% RM, Mean Velocity 80% RM <sup>(C)</sup>  <b>80% RM:</b> ↑ CMJ Height 6.5% ( $g = 0.40^S$ ), ↑ Mean Power 80% RM 9.7% ( $g = 0.26^S$ ), ↑ Mean Velocity 80% RM 8.1% ( $g = 0.32^S$ ) <sup>(C)</sup>
Tseng et al. [177]	16 M Volleyball players <b>Accentuated eccentric loading (AEL):</b> n = 8 Age: $21 \pm 1.6$ y Height: $178.1 \pm 8.2$ m Mass = $77.2 \pm 13.1$ kg <b>Traditional resistance loading (TR):</b> n = 8 Age: $22 \pm 1.6$ y Height: $180 \pm 5.4$ m Mass: $77.2 \pm 3.2$ kg	<b>AEL:</b> Half squat 1RM $146.3 \pm 35.2$ kg  <b>TR:</b> Half squat 1RM: $151.9 \pm 31.5$ kg	<b>AEL:</b> 3 x 4 half squat (eccentric: 105% of concentric 1RM, concentric: 80% of concentric 1RM)  <b>TR:</b> 3 x 5 half squat (85% 1RM)	Cannot determine	24, 48h	<b>AEL:</b> CMJ Height: ↔ 24h, ↘ -9.6% ( $g = -0.62^M$ ) 48h <sup>(p)</sup> CMJ Peak Velocity: ↔ 24h, ↘ -4.6% ( $g = -0.44^S$ ) 48h <sup>(p)</sup> Spike jump Height: ↔ 24h, 48h <sup>(p)</sup> IMTP Peak Force: ↔ 24h, 48h <sup>(p)</sup> IMTP RFD: ↔ 24h, 48h <sup>(p)</sup>  <b>TR:</b> CMJ (Height/Peak Velocity): ↔ 24h, 48h <sup>(p)</sup> Spike jump Height: ↔ 24h, 48h <sup>(p)</sup> IMTP Peak Force: ↘ 24h -8.0% ( $g = -0.37^S$ ), ↓ -12.1% ( $g = -0.69^M$ ) 48h <sup>(p)</sup> IMTP RFD: ↓ 24h -7.0% ( $g = -1.20^L$ ), 48h -6.9% ( $g = -1.25^L$ ) <sup>(p)</sup>
Rud et al. [157]	8 (M) National cross-country skiers: Age: $23 \pm 3$ y Height $184 \pm 6$ cm Mass: $73 \pm 7$ kg	5RM squat: $112 \pm 15$ kg 5RM sitting pull over: $37 \pm 4$ kg	3 × 3 parallel squat (smith machine) and sitting pullover (100% 5RM) (~87% 1RM)	~1530 – 1620 AU	5h	↔ CMJ height <sup>(C)</sup> ↔ 30-m Sprint test <sup>(C)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
Harrison et al. [181]	15 (M) Age: 23.8 ± 3.6 y Height: 181.6 ± 6.1 cm mass = 83.9 ± 10.2 kg	Back squat 1RM: 139 ± 24.8 kg Relative back squat: 1.66 ± 0.23 kg/BM	<b>High load (HL):</b> 1 x 3 Half Squat (67% 1RM) 1 x 3 Half Squat (77% 1RM) 2 x 2 Half Squat (87% 1RM) <b>Moderate load (ML):</b> 4 x 3 Half Squat (65% 1RM)	780 AU  780 AU	8, 24, 32h	<b>HL:</b> CMJ Height: ↔ 8h, ↔ 24h, ↑ 4.8% 32h <sup>(P)</sup> SJ Height: ↑ 4.5% 8h, ↔ 24h, ↔ 32h <sup>(P)</sup>  <b>ML:</b> CMJ Height: ↑ 3.1% 8h, ↔ 24h, ↑ 6.1% 32h <sup>(P)</sup> SJ Height: ↔ 8h, ↔ 24h, ↑ 6.5% 32h <sup>(P)</sup> <b>Control:</b> CMJ Height: ↑ 3.9% 32h <sup>(P)</sup> SJ Height: ↑ 4.5% 32h <sup>(P)</sup>
Lagrange et al. [151]	41 , elite ice hockey players <b>Experimental group: (n=21):</b> Age: 16.8 ± 1.3y Height: 177.3 ± 6.1cm* Mass: 166.8 ± 8.6kg* <b>Control group:</b> Age: 16.4 ± 1.7y Height: 181.6 ± 5.3cm* Mass: 169.6 ± 7.3kg*	NR	5 x 5 repetitions (85% 1RM) of inertia back squat with a 4-X-0-1 tempo, followed by 6 squat jumps as a superset	2155 AU	6h	<b>Experimental group:</b> ↔ CMJ Height <sup>(P)</sup> ↑ Broad jump Distance 4.8% ( $g = 0.64^M$ ) <sup>(P)</sup> ↓ Total 40m (on ice) sprint time -5.5% ( $g = -0.69^M$ ) <sup>(P)</sup> ↓ Mean 40m sprint speed 5.9% ( $g = 0.77^M$ ) <sup>(P)</sup> ↓ Sprint 1 (of 9) speed 7.4% ( $g = 0.74^M$ ) <sup>(P)</sup> <b>Control Group:</b> ↔ For all outcome measurements <sup>(P)</sup>
Terenzi & Moody. [156]	10 field hockey players Age 20.4 ± 1.9 y Height: 181.4 ± 6.4 cm Mass 82.4 ± 8.8 kg	NR	<b>High volume (HV):</b> 3x10 parallel back squat (75%1RM)  <b>High-intensity (HI):</b> 5x2 parallel back squat (90%1RM)	2250 AU  900 AU	24h  24h	<b>HV:</b> ↘ CMJ Height -4.6% ( $g = -0.28^S$ ) <sup>(C)</sup> ↔ CMJ Peak Power <sup>(C)</sup> ↔ SJ (Height/Peak Power) <sup>(C)</sup> ↘ DJ RSI 22cm -7.3% ( $g = -0.23^S$ ) <sup>(C)</sup> ↔ DJ RSI 38cm <sup>(C)</sup> ↑ 5m sprint +3.0% ( $g = 0.91^L$ ) <sup>(C)</sup> ↔ 10m, 20m, 20-40m, 40m sprint <sup>(C)</sup> <b>HI:</b> ↘ CMJ Height -3.4% ( $g = -0.18^T$ ) <sup>(C)</sup> ↔ CMJ Peak Power <sup>(C)</sup> ↔ SJ (Height/Peak Power) <sup>(C)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
						↔DJ RSI (22cm /38 cm) <sup>(C)</sup> ↔ sprint performance <sup>(C)</sup>
Pareja-Blanco et al. [155]	10 (M), age 22.1 ± 3.5 y height 1.75 ± 0.07 m mass 73.5 ± 10.7 kg	Squat 1RM: 101.7± 14.4 kg BP 1RM: 88.4 ± 19.0 kg	Back squat and bench press: 1: 3 x 12 (12RM, ~70% 1RM) 2: 3 x 10 (10RM, ~75% 1RM) 3: 3 x 8 (8RM, ~80% 1RM) 4: 3 x 6 (6RM, ~85% 1RM) 5: 3 x 4 (4RM, ~90% 1RM) 6: 3 x 6 (12RM, ~70% 1RM) 7: 3 x 5 (10RM, ~75% 1RM) 8: 3 x 4 (8RM, ~80% 1RM) 9: 3 x 3 (6RM, ~85% 1RM) 10: 3 x 2 (4RM, ~90% 1RM)	1: 5040 AU 2: 4500 AU 3: 3840 AU 4: 3060 AU 5: 2160 AU 6: 2520 AU 7: 2250 AU 8: 1920 AU 9: 1530 AU 10: 1080 AU	6,24,48h	CMJ Height: (6h, 24h, 48h) 1: ↓ -7.1%, ↓ -7.2%, ↘ -4.3% <sup>(P)</sup> 2: ↓ -8.2%, ↓ -8.6%, ↘ -4.0% <sup>(P)</sup> 3: ↓ -8.5%, ↓ -6.1%, ↘ -4.4% <sup>(P)</sup> 4: ↓ -9.0%, ↓ -6.2%, ↘ -3.7% <sup>(P)</sup> 5: ↘ -3.5%, ↓ -4.4%, ↔ <sup>(P)</sup> 6: ↔, ↘ -1.7%, ↔ <sup>(P)</sup> 7: ↔, ↔, ↔ <sup>(P)</sup> 8: ↔, ↔, ↔ <sup>(P)</sup> 9: ↘ -2.9%, ↘ -3.1%, ↔ <sup>(P)</sup> 10: ↓ -4.4%, ↘ -4.5%, ↔ <sup>(P)</sup> <i>Similar results reported for changes in bench press V1 load and back squat V1 load</i>
Tsoukos et al. [123]	17 (M) Power and team sport athletes Age: 22.7 ± 5.5 y Height: 181±8cm Mass: 80.7±8.6kg	Half squat 1RM: 163±29kg	5 x 4 squat jumps (40%1RM)	800 AU	24h, 48h	CMJ Height: ↑ 5.1% ( $g = 0.46^S$ ) 24h, ↑ 3.0% ( $g = 0.31^S$ ) 48h <sup>(P)</sup> DJ RSI: ↑ 10.7% ( $g = 0.40^S$ ) 24h, ↔ 48h <sup>(P)</sup> Leg press Isometric Peak Force: ↔ 24h, 48h <sup>(P)</sup> Leg press RFD: ↑ 9.7%-18.3% ( $g = 0.29^S$ - $0.69^M$ ) 24h, ↑ 9.8% (only RFD <sub>0-100</sub> , $g = 0.31^S$ ) 48h <sup>(P)</sup>
Mason et al. [150]	13 (M) academy rugby players Age: 18.5 ± 0.5 y Height: 181.7 ± 6.8cm Mass: 98.2 ± 16.9 kg	NR	4 x 3 explosive back squat (band) + 4 x 3 explosive bench press (band)	Cannot determine	1h 45m	Bench press throw: ↑ peak power 8.5% ( $g = 1.01^L$ ), peak force 13.9% ( $g = 1.17^L$ ) <sup>(C)</sup> , ↔ peak velocity <sup>(C)</sup> CMJ: ↘ peak power -3.4% ( $g = -0.46^S$ ), ↘ -2.3% peak force ( $g = -0.36^S$ ), ↔ peak velocity <sup>(C)</sup>
Bartolomei et al. [154]	12 (M) Age: 24.5 ± 4.2 y Height: 175.2 ± 5.5 cm Mass: 82.3 ± 8.4 kg	Squat 1RM: 173.4 ± 31.7 kg Relative Squat: at least 1.5 times body mass	<b>High volume (HV):</b> 8 x 10 squat (70% 1RM)	5600 AU	24, 48h	<b>HV:</b> ↓ CMJ Peak Power -9.6% 24h, -7.8% 48h <sup>(P)</sup> ↘ IMTP Peak Force -4.9% ( $g = -0.27^S$ ) 24h, -4.7% ( $g = -0.25^S$ ) 48h <sup>(P)</sup> ↘ IMTP RFD -10.8% ( $g = -0.50^M$ ) 24h, -11.4% ( $g = -0.46^S$ ) 48h <sup>(P)</sup> ↘ Isometric squat Peak Force -7.9% ( $g = -0.51^M$ ) 24h, -4.7% ( $g = -0.32^S$ ) 48h <sup>(P)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
			<b>High-intensity (HI):</b> 8 x 3 squat (90% 1RM)	2160 AU		↘ Isometric squat RFD -14.3% ( $g = -0.48^S$ ) 24h, -10.2% ( $g = -0.36^S$ ) 48h <sup>(p)</sup> <b>HI:</b> CMJ Peak Power ↔ 24h, 48h <sup>(p)</sup> IMTP Peak Force ↔ 24h, 48h <sup>(p)</sup> IMTP RFD ↔ 24h, 48h <sup>(p)</sup> Isometric squat peak force ↔ 24h, 48h <sup>(p)</sup> Isometric squat RFD ↘ -10.6% ( $g = -0.37^S$ ) 24h, ↔ 48h <sup>(p)</sup>
Moran-Navaro et al. [182]	10 (M): Age: 21.5 ± 4.0 y Height: 175.2 ± 7.2 cm Mass: 72.4 ± 8.4 kg	BP 1RM: 87.2 ± 15.2 kg Squat 1RM: 105.7 ± 35.2 kg	Bench press and full squat: <b>1:</b> 3 × 5(10RM, ~75% 1RM) <b>2:</b> 6 × 5(10RM, ~75% 1RM) <b>3:</b> 3 × 10(10RM, ~75% 1RM)	<b>1:</b> 2250 AU <b>2:</b> 4500 AU <b>3:</b> 4500 AU	6,24,48h	<b>1:</b> ↔ CMJ Height 6h, 24h, 48h <sup>(p)</sup> <b>2:</b> ↔ CMJ Height 6h, 24h, 48h <sup>(p)</sup> <b>3:</b> ↓ CMJ Height 6h, 24h, 48h <sup>(p)</sup> ↓ Bench press V1 LOAD compared to other protocols at 24-48h expect when compared to 6 × 5(10) at 24h ↓ Squat V1 load compared to 3 × 5(10) at 24 h
Pareja-Blanco et al. [183]	10 (M): Age: 23.6 ± 3.7 y Height: 1.75 ± 0.03 m Mass: 75.0 ± 8.7 kg	BP 1RM: 87.6 ± 20.5 kg Squat 1RM: 108.3 ± 15.0 kg	Bench press and squat (smith machine): 3 x 6 (12RM, ~70% 1RM) 3 x 12 (12RM, ~70% 1RM)	2520 AU 5040 AU	6, 24, 48h	↔ CMJ Height 6h, 24h, 48h <sup>(p)</sup> ↓ CMJ Height 6h, 24h, 48h compared to 3 x 6 (12RM)
Johnston et al. [187]	15 (M) academy ruby players Age: 21 ± 1 y Height: 185.7 ± 6.6 cm Mass: 100.5 ± 10.5 kg	NR	5 x 4 back squat (85% 1RM), 5 x 4 RDL (85% 1RM)	3400 AU	2h	↔ CMJ Peak power <sup>(p)</sup> ↔ CMJ Height <sup>(p)</sup> ↔ CMJ RFD <sup>(p)</sup> ↔ CMJ Peak velocity <sup>(p)</sup>
Raeder et al. [158]	15 (M) athletes (soccer, handball, and tennis) Age: 23.1 ± 1.9 y Height: 180.0 ± 10.0 cm Mass: 77.4 ± 8.0 kg	Squat 1RM: 114 ± 16 kg Relative squat: at least 100% of body mass	<b>1:</b> 4 x 6 parallel squat smith machine (85% 1RM) <b>2:</b> 4 x 6 parallel squat smith machine (85% 1RM + 3 drop sets 70, 55, and 40% 1RM)	<b>1:</b> 2040 AU <b>2:</b> 1500 AU	24, 48h	<b>1:</b> ↓ CMJ height -6.3% ( $g = -0.68^M$ ) 24h, -5.4% ( $g = -0.57^M$ ) 48h <sup>(p)</sup> ↓ Multiple rebound jump (MRJ) RSI -7.8% ( $g = -0.44^S$ ) 24h, -7.8% ( $g = -0.42^S$ ) 48h <sup>(p)</sup> <b>2:</b> ↓ CMJ height -7.0% ( $g = -0.76^M$ ) 24h, -6.3% ( $g = -0.71^M$ ) 48h <sup>(p)</sup> ↓ MRJ RSI -9.4% ( $g = -0.54^M$ ) 24h, -7.8% ( $g = -0.50^M$ ) 48h <sup>(p)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
			<p><b>3:</b> 4 x 6 parallel squat smith machine (70% 1RM concentric, 100% 1RM eccentric)</p> <p><b>4:</b> 4 x 6 flywheel YoYo squat (all out)</p> <p><b>5:</b> 4 x 15 plyometric squat jumps (60-cm jump box) (all out)</p>	<p><b>3:</b> Cannot determine</p> <p><b>4:</b> Cannot determine</p> <p><b>5:</b> 60 AU</p>		<p><b>3:</b> ↓ CMJ height -10.3% (<math>g = -1.19^L</math>) 24h, -7.7% (<math>g = -0.82^L</math>) 48h <sup>(P)</sup></p> <p>↓ MRJ RSI -16.7% (<math>g = -0.96^L</math>) 24h, -10.9% (<math>g = -0.67^M</math>) 48h <sup>(P)</sup></p> <p><b>4:</b> ↓ CMJ height -7.5% (<math>g = -0.80^L</math>) 24h, -6.1% (<math>g = -0.72^M</math>) 48h <sup>(P)</sup></p> <p>↓ MRJ RSI -9.9% (<math>g = -0.57^M</math>) 24h, -7.8% (<math>g = -0.49^M</math>) 48h <sup>(P)</sup></p> <p><b>5:</b> ↓ CMJ height -6.3% (<math>g = -0.67^M</math>) 24h, -4.9% (<math>g = -0.50^M</math>) 48h <sup>(P)</sup></p> <p>↓ MRJ RSI -7.3% (<math>g = -0.41^S</math>) 24h, -9.9% (<math>g = -0.59^M</math>) 48h <sup>(P)</sup></p> <p>↓ MRJ RSI intervention 3 compared with all other protocols at 24h</p>
Gonzalez-Badillo et al. [184]	9 (M): Age: 23.3 ± 3.9 y Height: 175 ± 3cm Mass: 75.3 ± 9.2kg	Squat 1RM: 108.7 ± 15.5 BP 1RM: 88.4 ± 21.6 kg	Bench press and back squat: 3 × 4(8RM, ~80% 1RM) 3 × 8(8RM, ~80% 1RM)	1920 AU 3840 AU	6,24,48h	↔ CMJ Height 6h, 24h, 48h <sup>(P)</sup> ↓ CMJ Height -8.5% 6h, -6.1% 24h, -4.4% 48h <sup>(P)</sup> ↓ CMJ Height at 6, 24, 48h compared to 3x4(8RM)
Russell et al. [180]	15 (M) French top-tier rugby players: Age: 24 ± 3y Height: 186 ± 6cm Mass: 98.2 ± 8.3kg	NR	5 x 10 Bench press (75% 1RM)	3750 AU	5h	X6 40m sprint with 180 COD: ↓ -2.3% sprint 1, ↓ -2.0% sprint 2, ↔ sprint 3-6 <sup>(C)</sup> ↔ CMJ Height <sup>(C)</sup> ↔ reaction time <sup>(C)</sup>
Howatson et al. [179]	10 (6M, 4F) elite track and field athletes: Age: M = 28 ± 2, F = 26 ± 5 Mass: M = 81.2 ± 12.2kg, F = 60.0 ± 3.7kg	Squat 1RM: M = 190.0 ± 38.0kg F = 107.5 ± 12.0	Strength: 4 x 5 squat, 4 x 5 split squat, 4 x 5 push press (16-17 / 20 RPE) Power: 4 x 5 speed squat, 4 x 5 split squat jump, 4 x 5 power press (30% of strength session load)	Cannot determine Cannot determine	24h	↔ CMJ Height <sup>(P)</sup> ↗ CMJ Height 3.4% ( $g = 0.15^T$ ) <sup>(P)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
Cook et al. [149]	18 (M) semi-pro rugby union players: Age: 22±1y Height: 184±5cm Mass: 93.7±8.3kg	Squat 3RM: 168kg	3x3 back squat and bench press (70,90,100% 3RM)	~ 1524 AU	6h	↑ 3RM bench press 3.6% ( $g=0.37^S$ ) <sup>(C)</sup> ↑ 3RM back squat 4.2% ( $g=0.59^M$ ) <sup>(C)</sup> ↑ CMJ Peak Power 2.7% ( $g=0.31^S$ ) <sup>(C)</sup> ↓ 40m sprint time -1.3% ( $g=-0.41^S$ ) <sup>(C)</sup>
Ekstrand et al. [171]	14 (8 M, 6 F) national throwing athletes Age: 20.7±2.5y Height: 178.8±11.0cm Mass: 95.1±26.9kg	NR	1 × 6 back squat (85% 1RM), 1 × back squat to failure (85% 1RM) and 1 × power cleans (85% 1RM) to technical failure	Cannot determine	4-6h	↑ Backward overhead shot-throw 2.6% ( $g=0.22^S$ ) <sup>(C)</sup> ↔ CMJ PP <sup>(C)</sup>
McCaulley et al. [188]	10 (M): Age: 21.8±1.9y Height: 176.3±7.0cm Mass: 92.4±9.5kg	Relative squat: 1.9±0.2 kg/BM	4x10 squat (75% 1RM)  11x3 squat (90% 1RM)  8 x 6 jump squat (0% 1RM)	3000 AU  2970 AU  48 AU	1h, 24h, 48h	↔ Isometric squat Peak Force 1-48h <sup>(p, C)</sup> ↔ Isometric squat RFD 1-48h <sup>(p, C)</sup>  ↔ Isometric squat Peak Force 1-48h <sup>(p, C)</sup> ↔ Isometric squat RFD 1-48h <sup>(p)</sup> , ↓ 24h <sup>(C)</sup>  ↔ Isometric squat Peak Force 1-48h <sup>(p, C)</sup> ↔ Isometric squat RFD <sup>(p, C)</sup>
De Villarreal et al. [148]	12 (M) volleyball players: Age: 22.8± 2.7 Height: 183.7±4.1cm Mass: 76.9±8.0kg	Squat 1RM: 158.3 ± 24.8kg	1: 3 x 5 CMJ “optimally loaded”  2: 2 x 4 Half Squat (80%RM), 2x3 Half squat (85%RM)  3: 2x4 half squat (80% RM), 2x2 half squat (90%), 2x1 back squat (95%)  4: 3 x 5 DJ “optimal height”	450-600 AU  1150 AU  1190 AU  15 AU	6h	↗ CMJ Height ( $p=0.062$ ) <sup>(p)</sup> ↑ Optimal DJ Height 4.2% <sup>(p)</sup> ↑ Optimal load CMJ Height 9.0% <sup>(p)</sup>  ↔ CMJ Height <sup>(p)</sup> ↑ Optimal DJ Height 3.0% <sup>(p)</sup> ↔ Optimal load CMJ Height <sup>(p)</sup>  ↔ CMJ Height <sup>(p)</sup> ↑ Optimal DJ Height 5.5% <sup>(p)</sup> ↔ Optimal load CMJ Height <sup>(p)</sup>  ↔ CMJ Height <sup>(p)</sup> ↔ Optimal DJ Height <sup>(p)</sup> ↔ Optimal load CMJ Height <sup>(p)</sup>

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
			5: 3 x 5 half squat (30% 1RM)	450 AU		↔ CMJ Height <sup>(P)</sup> ↔ Optimal DJ Height <sup>(P)</sup> ↔ Optimal load CMJ Height <sup>(P)</sup>
Gilbert & Lees. [186]	15 (M) athletes (power lifting, track, and field throwing events): Age: 24.3±3.3y Height: 1.83±0.1 m Mass: 112.6±6.3kg	Squat 1RM: 236.9±21.2kg Relative Squat: at least 2x BM	5 x 1 back squat (1RM)  5 x 1 back squat (“max power”)	500 AU  Cannot determine	1h  1h	↔ maximum isometric voluntary force <sup>(P)</sup> ↔ Maximum isometric RFD <sup>(P)</sup> ↔ CMJ Height <sup>(P)</sup>  ↔ Maximum isometric voluntary force <sup>(P)</sup> ↔ Maximum isometric RFD <sup>(P)</sup> ↔ CMJ Height <sup>(P)</sup>
Woolsten hulme et al. [170]	18 F, NCAA DIV 1 basketball players Age: 18-22y Height: 180 ± 32 cm Mass: 74 ± 9 kg	NR	3x5 hang clean, 3x5 push jerk (100% 5RM), 4x8-12 Bench press, 4x8-12 back squat, 4x8-12 Overhead press (100% 8-12RM), 3x12 prone leg curl (100% 12RM), 3x8-12 Dumbbell incline press (100% 8-12RM) (~67-87% 1RM)	Cannot determine	6h	↔ Vertical Jump performance single leg and bilateral <sup>(C)</sup> ↔ Free throws accuracy (shots made out of 20) <sup>(C)</sup> ↔ Speed spot shooting <sup>(C)</sup>
Horita et al. [189]	10 (M): Age: 28±4y Height: 180±4cm Mass: 76±5kg		Exhaustive bilateral submaximal rebound jumps along the gliding track of the sledge at 70% of their pre-determined maximal height (92+30 repetitions)	Cannot determine	2 days (48h)	↓ DJ Height -6.4% ( $g = -0.73^M$ ) <sup>(P)</sup> ↔ SJ Height <sup>(P)</sup>
Raastad & Hallen. [185]	10(M) power lifters (8), javelin throwers (1), speed skaters (1): Age: 27.5±1.4y Mass: 84.5±4.2kg	Squat 3RM: 169 ± 7kg Front squat 1RM: 121±5kg	3x3 back squat, 3x3 front squat, 3x6 knee extensions (70% of high-intensity) (~59.5 - 65.1% 1RM)  3x3 back squat, 3x3 front squat (100% 3RM), 3x6 knee	~2242 AU  ~3204 AU	3, 7, 11, 22, 26, 30, 33 h	CMJ Height: ↗ 3-30h, ↑ 5% 33h <sup>(P)</sup>  CMJ Height: ↓ 3-22h, ↘ 26-30h, ↔ 33h <sup>(P)</sup> ↓ CMJ Height following 100% compared to 70% during the same day and day after

Article	Participants	Participants Strength Level	Training Stimulus	Volume Load (AU)	Rest Period	Key Results
			extensions (100% 6RM) (~85-93% 1RM)			
Fry et al. [169]	19 (M) national weightlifters: Age: 17.3±1.9y Height: 170.9±6.8cm Mass: 72.8±14.1kg	NR	5 x 3 clean pulls (85% 1RM), 3 x 3 snatch pulls (85% 1RM)	2040 AU	5-6h	(n = 6): ↑ Vertical Jump Height 3.0cm <sup>(C)</sup> ↑ Snatch 5.8kg <sup>(C)</sup> ↑ Clean and jerk 6.2kg <sup>(C)</sup> (n = 13): ↘ Vertical Jump Height <sup>(C)</sup> ↘ Snatch <sup>(C)</sup> ↘ Clean and jerk <sup>(C)</sup>
<p>↑ indicates a significant increase (<math>P &lt; 0.05</math>), ↗ indicates a non-significant increase, ↔ indicates no change, ↘ indicates a non-significant decrease, ↓ indicates significant decrease (<math>P &lt; 0.05</math>), values are represented as mean (<math>\pm</math> standard deviations), (F) female, (M) male, (CMJ) countermovement jump, (SJ) squat jump, (DJ) drop jump, (RM) repetition maximal, (kg) kilograms, (y) years, (RFD) rate of force development, (RSI) reactive strength index, (IMTP) isometric mid-thigh pull, (V1 load) velocity attained against the load that elicits a 1 m.s in the pretest, <sup>(C)</sup> compared to control, <sup>(P)</sup> Compared to pre-test, (NR) not reported, (g) Hedges' g</p>						

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### 1595 **3.5 Discussion**

1596 The aim of this review was to investigate the effects of RT priming exercise on neuromuscular  
1597 athletic performance tasks when administered within a one- to 48-hour window post-training,  
1598 and to explore its potential to enhance performance and support longer-term training  
1599 adaptations. The findings of this review indicate that, under specific conditions, RT priming  
1600 can enhance neuromuscular athletic performance. However, performance effects were  
1601 heterogeneous, with studies reporting performance enhancements, no meaningful changes, or  
1602 performance decrements. Consequently, the following sections examine how participant  
1603 characteristics, methodological considerations, and exercise programming variables may  
1604 influence responses to RT priming

#### 1605 **3.5.1 The Influence of Participant Characteristics**

1606 The findings of this review indicate that individual strength levels may be an important  
1607 determinant to the effectiveness of RT priming interventions, with performance-enhancing  
1608 effects more commonly observed in stronger individuals and weaker participants less likely to  
1609 demonstrate improvements or even performance reductions. In support of this, percentage  
1610 changes in CMJ height have been shown to correlate positively with participants' relative half-  
1611 squat strength ( $r = 0.61$ ) following a RT priming intervention [152]. Further to this, stronger  
1612 individuals (relative half squat 1RM: 1.93–2.67 kg/BM) were shown to significantly increase  
1613 their CMJ performances 24 hours after a RT priming intervention (1.8–19.0%; Hedges'  $g =$   
1614 0.32–0.98, Small–Moderate), whereas a cohort of weaker participants (relative half squat 1RM:  
1615 1.37–1.92 kg/BM) exhibited no change in performance [152]. These findings align with  
1616 evidence from traditionally timed PAPE, where stronger individuals have demonstrated greater  
1617 performance effects, and at earlier time points when compared to weaker participants [190].  
1618 This is speculated to be because stronger individuals exhibit greater resistance to fatigue after  
1619 training compared to weaker participants [190–192]. Since fatigue and potentiation are

1620 proposed to co-exist following an exercise stimulus [122,159], stronger individuals may resist  
1621 and more rapidly dissipate fatigue, increasing the likelihood of a favourable delayed  
1622 potentiation response following RT priming.

1623 Gonzalez Garcia et al. [178] also reported inter-individual variability following an RT priming  
1624 intervention. In that study, improvements in CMJ performance were significantly associated  
1625 with absolute half-squat 1RM strength ( $r = 0.47-0.50$ ). However, in contrast to prior findings,  
1626 no significant relationship was observed when strength was expressed relative to body mass ( $p$   
1627  $> 0.05$ ,  $r = 0.18-0.21$ ). The authors proposed that several unaccounted factors could explain the  
1628 disparities in study findings, including training age, previous exposure to RT modalities,  
1629 muscle fibre composition, and possible genetic factors [178]. These factors are likely to  
1630 influence the balance between fatigue and potentiation following a RT priming stimulus but  
1631 are infrequently reported or controlled for in the current literature.

1632 For example, individuals with a higher training age are likely to have achieved a more advanced  
1633 level of neuromuscular adaptation, resulting in greater neuromuscular efficiency during  
1634 specific exercise tasks [193]. This may reduce the relative fatigue imposed, thereby shifting the  
1635 balance towards potentiation. Muscle fibre composition provides another plausible mechanism,  
1636 as stronger individuals often possess a greater percentage of type II muscle fibres [194]. Type  
1637 II muscle fibres may experience increased phosphorylation of myosin light chain [147,195],  
1638 one of the peripheral level mechanisms thought to underpin the potentiation response [195].  
1639 However, changes in muscle fibre sensitivity to calcium ions ( $Ca^{2+}$ ), have yet to be  
1640 investigated at later time points (one-48 hours) following RT priming interventions and remain  
1641 an important area for further research. Collectively, these findings indicate that both relative  
1642 and absolute strength may moderate the effects of RT priming [152,178]. Further investigation  
1643 of participant-specific factors is required, and practitioners should consider these

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1644 characteristics when implementing RT priming strategies to maximise the likelihood of  
1645 favourable performance outcomes.

1646 Collectively, the available evidence indicates that weaker individuals, and those potentially  
1647 with lower RT exposure, are less likely to experience acute performance-enhancing effects  
1648 following RT priming interventions. However, this does not diminish the potential value of RT  
1649 priming within this population, as it may function as a strategy to facilitate resistance training  
1650 exposure without impairing neuromuscular performance when appropriately programmed.  
1651 From an applied perspective, even in the absence of acute performance benefits, RT priming  
1652 may allow for RT to be integrated within congested competitive schedules without inducing  
1653 the prolonged neuromuscular decrements typically associated with traditional RT approaches  
1654 [110]. This may be of relevance for weaker athletes, who may not yet have reached their full-  
1655 strength potential and could therefore benefit from additional RT delivered via frequent low-  
1656 fatigue exposures. This aligns with the micro-dosing concept discussed in Chapter 2 and may  
1657 be of particular value in sports such as golf, where in-season training opportunities are limited  
1658 but the maintenance and development of neuromuscular force-production capabilities remain  
1659 important for performance.

1660 This interpretation is supported by studies demonstrating preserved neuromuscular  
1661 performance levels following RT priming interventions, despite the absence of potentiation  
1662 effects. For example, Rud et al. [157] reported no significant changes in CMJ or sprint  
1663 performance within six hours of a high-intensity RT priming intervention (~87% 1RM, ~1530-  
1664 1620 AU) in national-level male cross-country skiers (back squat 1RM: ~129 kg, body mass:  
1665  $73 \pm 7$ kg) who were relatively unaccustomed to RT and the testing procedures. This occurred  
1666 despite evidence of low frequency fatigue, which the authors suggested may have delayed,  
1667 diminished, or counterbalanced any performance benefits accrued from delayed potentiation.  
1668 Low-frequency fatigue has been shown to involve the blunting of calcium release [217],

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1669 potentially counteracting increases in muscle fibre calcium sensitivity, one of the peripheral  
1670 mechanisms proposed to underpin the delayed potentiation response [122,157,195]. Similarly,  
1671 Terenzi & Moody. [156] demonstrated that both moderate (75% 1RM, 2250 AU) and high-  
1672 intensity (90% 1RM, 900 AU) squat-based RT priming interventions led resulted in no  
1673 significant changes in CMJ, squat jump, drop jump, or sprint performance (10 to 40 meters)  
1674 when assessed 24 hours post-training. Collectively, these findings indicate that RT priming can  
1675 permit RT exposure close to competition without incurring fatigue-related performance  
1676 decrements in key neuromuscular performance outcomes.

### 1677 **3.5.2 The Influence of Session Volume Loads and the Level of Effort**

1678 It has previously been recommended that the use of a volume load calculation (number of sets  
1679  $\times$  number of repetitions  $\times$  % 1RM = arbitrary units (AU)) may be a useful tool for prescribing  
1680 RT priming sessions, with strength-power development RT sessions typically involving total  
1681 volume loads in excess of 3000 AU [122]. The findings of this review indicate that RT priming  
1682 sessions associated with significant improvements in at least one neuromuscular athletic  
1683 performance outcome generally involved lower total session volume loads (450–2155 AU),  
1684 with the exception of a single upper-body intervention that utilised a higher volume load (3750  
1685 AU) [180]. However, comparable volume loads have also been associated with unchanged or  
1686 impaired performance, highlighting the limited predictive value of AU when considered in  
1687 isolation and emphasising the need to interpret volume load alongside other factors, including  
1688 participant characteristics and the level of effort performed.

1689 For example, significant and lasting reductions in CMJ and multiple rebound jump  
1690 performance were noted 24 and 48 hours following five separate squat-based protocols of  
1691 different configurations (-4.9% to -16.7%, Hedges'  $g$  = -0.41 to -1.19, Small-Large), despite  
1692 volume loads ranging from as little as 50 AU (4 $\times$ 15 plyometric squat jumps) to 2040 AU (4 $\times$ 6  
1693 parallel back squats at 85% 1RM) [158]. Notably, participants in this study were relatively

1694 weak (squat 1RM:  $114 \pm 16$  kg, relative strength:  $\sim 1.47$  kg/BM) compared with cohorts in  
1695 which RT priming was effective, where the lowest reported relative strength values were  $\geq 1.6$   
1696  $\pm 0.2$  kg/BM [181] and absolute half-squat strength exceeded  $139.8 \pm 22.4$  kg [173]. As such,  
1697 these findings suggest that lower fatigue resistance in weaker individuals may increase the  
1698 likelihood of negative performance effects following comparable RT stimuli [190–192].

1699 The level of effort exerted during RT priming sessions also appears to be an important  
1700 moderator influencing performance outcomes. Several studies demonstrated that when  
1701 repetitions were performed to failure across multiple sets (e.g. 3 sets of bench press and back  
1702 squat at 4-12RM), significant reductions in CMJ performance were observed, in some cases  
1703 persisting beyond 48 hours post-intervention [155,182–184]. Comparatively, when sub-  
1704 maximal repetitions were performed, performance generally returned to baseline levels within  
1705 six hours of RT, even when comparable volume loads were utilised. For instance, Moran-  
1706 Navaro et al. [182] reported that CMJ performance returned to baseline six hours following a  
1707 submaximal protocol of 6x5 at 10RM (4500 AU), whereas significant reductions persisted for  
1708 up to 48 hours following a protocol when repetitions were performed to failure (3x10 at 10RM,  
1709 4500 AU). These differences likely reflect the higher levels of mechanical stress and fatigue  
1710 induced by protocols involving repetitions to failure, as evidenced by increased metabolic  
1711 stress, hormonal responses, and signs of muscle damage [155].

1712 Stronger individuals may be able to tolerate higher-effort and, in some cases, higher-volume  
1713 RT priming sessions due to greater fatigue resistance [190–192]. However, this should be  
1714 applied with caution, as excessive effort may still attenuate potentiation and shift the balance  
1715 toward fatigue. Cook et al. [149] demonstrated that in relatively strong, semi-professional  
1716 rugby players (squat 3RM: 168 kg, body mass:  $93.7 \pm 8.3$  kg), a protocol involving one set of  
1717 bench press and back squats at 100% of 3RM loads elicited small-to-moderate improvements  
1718 in 3RM bench press (3.6%, Hedges'  $g = 0.37$ ) and 3RM back squat strength (4.2%, Hedges'  $g$

1719 = 0.59), CMJ peak power (2.7%, Hedges'  $g = 0.31$ ), and a reduction in 40 m sprint time (-  
1720 1.3%, Hedges'  $g = -0.41$ ). These findings suggest that high relative loading can be utilised  
1721 within RT priming sessions, provided total session volume is low and effort to failure is  
1722 avoided. In support of this, Ekstrand et al. [171] reported only small increases in backwards  
1723 overhead shot throw performance, and no change in CMJ peak power following a high-  
1724 intensity session involving back squats and power cleans performed to technical failure (85%  
1725 1RM) in national-level throwing athletes. Despite the high relative loads used, the requirement  
1726 to perform repetitions to failure may have increased fatigue accumulation, thereby attenuating  
1727 any potentiation effects.

1728 This comparison indicates that effort regulation, rather than intensity alone, may be a critical  
1729 determinant of performance outcomes following RT priming. In support of this, Gonzalez-  
1730 Garcia et al. [173] reported small increases in CMJ, and strength-based performance (6.5-9.7%,  
1731 Hedges'  $g = 0.26-0.41$ ) six hours following an intervention where two sets of back squats were  
1732 performed using a velocity loss threshold of approximately 20%, to limit the level of effort  
1733 exerted by participants. Collectively, these findings suggest that while stronger individuals may  
1734 better tolerate high-intensity RT priming, limiting effort accumulation, and avoiding repetitions  
1735 to failure, appears to be important for optimising the fatigue-potentiation balance. Accordingly,  
1736 practitioners seeking to minimise the risk of fatigue-related performance decrements may  
1737 consider using velocity loss thresholds to limit the effort exerted during RT priming sessions,  
1738 which can be easily monitored with commercially available equipment [155].

### 1739 **3.5.3 The Influence of Exercise Intensity and Time Course of Effects**

1740 Several studies included in this review have demonstrated that a morning RT priming session  
1741 can significantly improve neuromuscular athletic performance when assessed later the same  
1742 day. One of the proposed mechanisms underpinning these same-day effects is the attenuation  
1743 of natural diurnal declines in testosterone and cortisol concentrations following morning RT

1744 [122]. Testosterone and cortisol are hormones which follow circadian rhythmicity, typically  
1745 peaking in the morning and declining as the day progresses [196]. Attenuating this decline may  
1746 contribute to delayed potentiation response, potentially via improvements in an athlete's  
1747 psychological state [149]. Associations have previously been reported between salivary free  
1748 testosterone concentrations and muscular force expression during strength (squat 1RM,  $r =$   
1749  $0.92$ ), power (CMJ height,  $r = 0.62$ ), and sprint performance tasks ( $r = -0.87$ ) [197,198]. In  
1750 line with this, both Russell et al. [180] and Cook et al. [149] demonstrated that moderate- and  
1751 high-intensity RT priming activities significantly improved afternoon sprint performance  
1752 outcomes, and also attenuated the decline in salivary free testosterone concentrations from  
1753 baseline values when compared to control conditions.

1754 Comparatively, Harrison et al. [181] reported that salivary testosterone concentrations were  
1755 similar across moderate- and high-intensity RT priming activities and a control condition when  
1756 measured eight, 24, and 32 hours post-intervention. However, increases in jump performance  
1757 were observed eight hours after the high-intensity protocol and 32 hours after the moderate-  
1758 intensity session, suggesting that hormonal responses may not be responsible for performance  
1759 responses resulting from RT priming activities. In line with this, hormonal responses may not  
1760 fully explain the performance enhancements observed in the days following RT priming  
1761 activities [123,152,153,181,185]. As such, alternative peripheral or neuromuscular  
1762 mechanisms are likely to contribute to performance responses across longer recovery  
1763 timeframes [181].

### 1764 **3.5.3.1 High-Intensity Training**

1765 When considering exercise intensity, the result of this review indicates that increases in same-  
1766 day performance were most commonly reported following high-intensity RT priming  
1767 interventions ( $\geq 80\%$  1RM), particularly when outcomes are assessed four to eight hours post-  
1768 exercise. Across the included studies, increases have been demonstrated in jump (2.6–6.5%;

1769 Hedges'  $g = 0.15-0.4$ , Trivial-Small), sprint (1.3-7.4%, Hedges'  $g = 0.41- 0.77$ , Small-  
1770 Moderate), throw (2.6%, Hedges'  $g = 0.22$ , Small), and strength-oriented performance  
1771 outcomes (3.6-9.7%, Hedges'  $g = 0.26-0.59$  Small-Moderate). Notably, these effects were most  
1772 often observed when relatively low total session volume loads (780–2155 AU) were applied,  
1773 with sessions typically involving lower-body exercise (e.g. squat, deadlift, Olympic lifting  
1774 variations) or a combination of lower- and upper-body compound movements, such as the squat  
1775 and bench press [148,149,151,153,169,171,173,178,181].

1776 However, the effectiveness of high-intensity RT priming appears to be time-dependent. While  
1777 several studies demonstrate favourable same-day effects, evidence supporting performance  
1778 enhancement beyond 24 hours of recovery remains limited. Further to this, in some cases, high-  
1779 intensity interventions have been associated with reductions in performance at later recovery  
1780 intervals. For example, despite increases in squat jump height eight hours following a high-  
1781 intensity intervention, Harrison et al. [181] reported no change in CMJ or squat jump height  
1782 after 24 hours of recovery, and a 4.5% increase in jump time and a decline in perceived  
1783 'physical performance' capabilities (Cliff's delta: 0.33, Small), indicating that the intervention  
1784 may therefore have been somewhat detrimental to performance at later time points.

1785 In-support of this, Raastad & Hallen [185] also reported a rapid recovery of jump performance  
1786 within the first three to eleven hours after a high-intensity RT protocol (~85-93% 1RM, ~3204  
1787 AU), followed by a second performance drop between eleven- and 22-hours post-session. This  
1788 indicates that high-intensity RT may follow a biphasic recovery pattern, with a second drop in  
1789 performance perhaps as a result of a delayed exercise-induced mechanism [195]. In summary,  
1790 these findings suggest that high-intensity RT priming is best suited for eliciting same-day  
1791 performance enhancements but may be suboptimal for improving performance on subsequent  
1792 days. Accordingly, practitioners should apply high-intensity RT priming cautiously when using  
1793 such sessions as a micro-dosing strategy within 24–48-hour timeframes, due to the potential

1794 for reductions in performance levels. However, it should be noted that few studies to date have  
1795 explicitly examined the effects of high-intensity RT priming methods as a means of enhancing  
1796 performance within a 24–48-hour period of the applied training session [156], and would  
1797 therefore benefit from further research.

### 1798 **3.5.3.2 Moderate Intensity Training**

1799 In contrast to high-intensity RT priming, moderate-intensity exercise (~50–79% 1RM) appears  
1800 less effective for enhancing same-day performance but may be more appropriate than high-  
1801 intensity RT priming when the goal is to maximise performance the following day [181,185].  
1802 Limited evidence suggests that moderate-intensity RT priming can facilitate delayed  
1803 performance benefits, when sufficient recovery time is available. For example, Raastad &  
1804 Hallen. [185] reported a significant 5% increase in CMJ height 33 hours after a moderate-  
1805 intensity RT priming session (~59.5–65% 1RM, 2242 AU). Similarly, Harrison et al. [181]  
1806 reported increases in both CMJ and squat jump performances 32 hours after a moderate-  
1807 intensity intervention (65% 1RM, 6.1–6.5%, Cliff's delta: 0.27–0.30, Small), whereas the high-  
1808 intensity protocol in the same study produced only a smaller increase in CMJ height (4.8%,  
1809 Cliff's delta: 0.28, Small). However, these results should be interpreted with caution as the  
1810 authors noted that repeated physical testing across multiple time points (eight, 24, and 32 hours)  
1811 may have influenced the reported responses, and similar improvements were also reported in  
1812 the control condition after 32 hours of recovery. Furthermore, although moderate-intensity  
1813 protocols may be associated with delayed improvements, several studies have reported no  
1814 change or performance decrements within 24–48 hours when moderate-intensity exercise is  
1815 combined with high session volume loads (2250–5600 AU) [155,182–184].

1816 In contrast, moderate-intensity RT (50–79% 1RM) appears less effective for eliciting same-  
1817 day performance benefits. Gonzalez Garcia et al. [173] reported that a high-intensity back squat  
1818 protocol (80% 1RM), performed for two sets at a 20% velocity loss threshold significantly

1819 improved CMJ and strength-based performances after six hours of recovery (6.5–9.7%,  
1820 Hedges'  $g = 0.26-0.40$ , Small). Comparatively, a moderate-intensity session (~60.9% 1RM)  
1821 resulted in no meaningful performance changes. As more repetitions were performed per set in  
1822 the moderate-intensity session (8.9–10.4 vs. 4.4–4.7 repetitions), the authors suggested that this  
1823 configuration could shift the balance towards fatigue rather than potentiation, requiring longer  
1824 recovery periods for any potentiation effects to be realised. In support of this, Bartolmei et al.  
1825 [154] reported that high-volume, moderate-intensity RT (8x10 squats at 70% 1RM) led to  
1826 significant performance declines and elevated muscle damage markers (creatine kinase, lactate  
1827 dehydrogenase, and myoglobin), necessitating longer recovery periods than a high-intensity  
1828 protocol with substantially lower volume (8x3 squats at 90% 1RM). As such, these findings  
1829 indicate that moderate-intensity RT priming may only be beneficial when volume and effort  
1830 are carefully controlled, and that high-intensity interventions may be preferable when the  
1831 objective is to maximise same-day performance outcomes.

### 1832 **3.5.3.3 Low Intensity Training**

1833 Low-intensity interventions involving externally loaded vertical jumping activities (30-40%  
1834 1RM) have demonstrated favourable effects on neuromuscular performance outcomes,  
1835 including CMJ, drop jump, and isometric leg press RFD, when measured six, 24, and 48 hours  
1836 after [123,148,177]. De Villarreal et al. [148] reported that loaded CMJs (3×5 at 30–40% 1RM)  
1837 significantly improved externally loaded CMJ and drop jump performance (4.2–9.0%) after six  
1838 hours of recovery, alongside near-significant increases in bodyweight CMJ height ( $p = 0.062$ ).  
1839 Notably, in the same study, high-intensity RT ( $\geq 80\%$  1RM) improved drop jump performance  
1840 (3.0–5.5%) but did not enhance CMJ performance, whereas a low-intensity back squat protocol  
1841 (30% 1RM) resulted in no meaningful performance changes. These findings suggest that the  
1842 effectiveness of RT priming strategies may be influenced by exercise intent and contraction  
1843 velocity, rather than the magnitude of load in isolation.

1844 One of the proposed mechanisms underpinning delayed potentiation is increases in high  
1845 frequency motor neuron excitability [122,148]. In-accordance with Henneman's size principle,  
1846 heavier loaded RT is commonly associated with greater activation of high threshold motor units  
1847 [199]. These motor units may consist of a greater percentage of type II muscle fibres, which  
1848 have been shown to be more responsive to traditionally timed potentiation strategies [147,195].  
1849 This, in turn, may explain the effectiveness of RT priming strategies involving high-intensity  
1850 ( $\geq 80\%$  1RM) and heavily loaded exercises, particularly in stronger individuals who may  
1851 possess a greater percentage of type II muscle fibres [194]. Ballistic exercises, characterised as  
1852 movements performed with maximal intent and movement velocity and involving the rapid  
1853 acceleration of mass throughout the entire movement and without a braking phase, such as  
1854 jumping or throwing actions [165,200], can also stimulate the recruitment of high threshold  
1855 motor units [201].

1856 In comparison to high-intensity RT, low-intensity ballistic jumps (40% 1RM) have been shown  
1857 to be effective in improving performance measures in the day(s) following the training stimulus  
1858 [123,177]. This may be explained by the fact that ballistic activities provide a strong excitatory  
1859 drive, enabling the motor neuron pool to be activated within a few milliseconds with low  
1860 recruitment thresholds [201]. In contrast, slower and ramped contractions observed in heavier  
1861 loaded exercises may result in higher levels of fatigue to achieve the same level of recruitment  
1862 [165,202]. In-line with this, in traditionally timed PAPE, there is some evidence to support that  
1863 ballistic exercises can elicit enhancements in vertical jump performances with a greater effect  
1864 when compared to traditional RT methods [147].

1865 While delayed potentiation is cited to influence performance outcomes within one- to -48 hours  
1866 post-training [122], evidence for specific timeframes is currently limited. Only one study in  
1867 this review demonstrated enhanced performance at 48 hours following a low-intensity  
1868 intervention [123], where CMJ height and isometric leg press RFD improved by 3.0-9.8%

1869 (Hedges'  $g = 0.31$ , Small). However, greater improvements were observed at 24 hours (5.1-  
1870 18.3%, Hedges'  $g = 0.29-0.69$ , Small-Moderate). Further to this, evidence for shorter recovery  
1871 windows of between one and four hours post intervention is also limited. Mason et al. [150]  
1872 were the only study to report increases in performance within such timeframes, demonstrating  
1873 increases in bench press throwing performance (8.5-13.9%, Hedges'  $g = 1.01-1.17$ , Large) one  
1874 hour and 45 minutes following a low-intensity band resistance intervention, although no  
1875 concurrent improvements were observed in jump performance.

1876 While immediate reductions in muscular force-producing capabilities are commonly observed  
1877 following RT and may persist for several hours after [155], other evidence suggests that  
1878 neuromuscular performance can return to baseline within one to two hours in well-trained  
1879 individuals [186–188]. For example, Gilbert & Lees. [186] reported that strong athletes ( $\geq 2x$   
1880 body mass back squat) experienced an immediate drop in jump height following heavy RT (5  
1881  $\times$  1 back squats at 1RM), but returned to baseline within one hour. These findings highlight the  
1882 potential for the application of such methods prior to sports competition without incurring  
1883 significant declines in performance. However, a better understanding of the recovery and  
1884 potentiation time course, especially within a four-hour window post-training on competition  
1885 days, would be of value in assisting practitioners to more effectively schedule RT priming  
1886 sessions. This is particularly relevant for athletes with dynamic and reactive schedules, such as  
1887 golfers, whose tournament start times can vary between 6 am and 3 pm, and often with less  
1888 than 24 hours' notice provided, requiring the player to adapt their preparation strategies  
1889 accordingly [24].

#### 1890 **3.5.4 The Influence of Exercise specificity**

1891 In traditionally timed PAPE, results from a systematic review with meta-analysis indicate that  
1892 shallower squat depths (top of the thighs above parallel) produce considerably larger effect  
1893 sizes (ES = 0.58) compared to deeper squats (top of the thighs at or below parallel, ES = 0.25)

1894 [147]. This is likely as full squats are performed over a larger range of motion, requiring longer  
1895 time under tension, and involve higher levels of muscle activation, which may consequently  
1896 induce greater levels of fatigue [203]. However, when individual strength levels were  
1897 accounted for, stronger individuals were able to produce comparable effect sizes following  
1898 deeper squats ( $ES = 0.55$ ), whereas shallower squats were more effective in weaker individuals  
1899 compared to deeper squats ( $ES = 0.67$  vs  $0.12$ ). As such, it is plausible that this interaction  
1900 between squat depth and strength levels may also extend to the delayed potentiation response.

1901 In accordance with this, an intervention involving half squats elicited significant improvements  
1902 in jump performance six hours post-exercise in moderately trained individuals (half squat  
1903 1RM:  $139.8 \pm 22.4$  kg) [173]. In contrast, following an almost identical protocol of x2 sets at  
1904 80% 1RM, but instead using the parallel back squat (squat 1RM:  $120.5 \pm 28.0$  kg) resulted in no  
1905 significant group-level changes, with only the strongest individuals demonstrating performance  
1906 improvements [178]. Similarly, stronger individuals with greater absolute squat strength (3RM  
1907 squat: 168 kg) exhibited significant improvements in jump performance six hours following a  
1908 high-intensity ( $\geq 80\%$  1RM) parallel back squat protocol [149]. Taken together, it is possible  
1909 that shallower squats may be preferable for weaker individuals, whereas stronger individuals  
1910 may tolerate and benefit from both shallow and deeper squat exercises when used within RT  
1911 priming sessions. From a practical standpoint, more concentrically oriented exercises such as  
1912 half squats, box squats, or hexagonal bar deadlifts, may be preferable in some contexts due to  
1913 reduced eccentric loading, which may lower the risk of exercise-induced muscle damage and  
1914 soreness that could negatively affect competitive performance [204].

1915 The degree of specificity between the RT priming exercise and the subsequent performance  
1916 task also appears to be an important determinant of performance outcomes. Nishioka & Okada.  
1917 [152] reported that a priming intervention involving loaded jump squats improved CMJ  
1918 performance, but not squat jump or drop jump performance. The authors noted that the

1919 biomechanics of the loaded jump squats more closely resembled the slow SSC action of the  
1920 CMJ, whereas the squat jump is primarily concentrically oriented [205], and drop jumps  
1921 represent a fast SSC action [55]. Supporting this, increases in CMJ height were significantly  
1922 associated with eccentric phase variables of the CMJ following the RT priming protocol ( $r =$   
1923  $0.56\text{--}0.70$ ). As such, the improvements may be explained by enhancements in SSC function  
1924 [152], particularly around the hip, as the CMJ is considered a hip-dominant movement [206].  
1925 In contrast, researchers have demonstrated that drop jumps involve greater knee and ankle joint  
1926 moments and power output values in comparison to the CMJ, which may account for the results  
1927 of this study [206].

1928 Further evidence for the role of exercise specificity was provided by Cook et al. [149], reporting  
1929 that a sprint-based priming intervention solely improved 40 m sprint, whereas a high-intensity  
1930 RT priming intervention involving back squat and bench press exercises elicited improvements  
1931 in maximal strength (3RM squat and bench press), CMJ, and sprint performance. Similarly,  
1932 Gonzalez Garcia et al. [173] reported that back squat mean power and velocity at 80% 1RM  
1933 improved following an RT priming intervention at the same load. Comparatively, no  
1934 improvements were observed at a lower ‘optimal load’ ( $\sim 60\%$  1RM), providing further  
1935 evidence that increases in neuromuscular performance may be specific to the exercise task and  
1936 the loads used. Accordingly, practitioners and researchers should carefully consider the  
1937 correspondence between the exercise task, loading parameters, and the desired performance  
1938 outcome when designing RT priming interventions to maximise subsequent performance.

### 1939 **3.5.5 Limitations and Directions for Future Research**

1940 This review investigated the effects of RT priming exercise on neuromuscular athletic  
1941 performance when administered within a one-to-48-hour window post-training. Effect sizes  
1942 were calculated where possible to provide insight into the magnitude of these effects. However,  
1943 this was not possible for all the included studies. Due to the heterogeneity in study designs,

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1944 training protocols, outcomes measures, and time-course of testing, a meta-analysis was not  
1945 conducted. Nevertheless, due to the relatively low sample sizes in these studies, future meta-  
1946 analytic investigations would be of value. Increasing total sample size would improve the  
1947 statistical power and allow for more precise estimation of the effects of RT priming strategies  
1948 [207].

1949 The post RT priming response is commonly conceptualised to be dictated by the net balance  
1950 between fatigue and potentiation following an exercise stimulus [181]. In accordance with this,  
1951 the findings of this review highlighted large variations between performance effects, with  
1952 studies reporting significant reductions, showing no changes, and demonstrating significant  
1953 improvements in performance outcomes. These disparities may in part be explained by the  
1954 differences in study aims, as some investigations were designed to enhance performance,  
1955 whereas others focused on fatigue and recovery responses to RT. While this could be  
1956 considered as a confounding factor, the inclusion of both perspectives provides valuable insight  
1957 into factors that may predict whether RT priming elicits positive or negative performance  
1958 outcomes.

1959 The primary proposed objective of RT priming is to implement sessions prior to competition  
1960 in order to maximise subsequent performance [122,162,163]. While several factors can be  
1961 manipulated to enhance the likelihood of eliciting a favourable outcome, much is currently still  
1962 unknown in this context. Many studies assessed outcomes at isolated time points and relied on  
1963 single performance measures (e.g., jumping, sprinting, throwing, or strength tasks). Although  
1964 these measures are of value, relatively few studies included sport-specific outcomes, such as  
1965 50-meter swim crawl performances [172], cricket and ice hockey specific sprint tasks  
1966 [151,153], or Olympic weightlifting performance in national-level weightlifters [169]. As such,  
1967 it remains unclear whether these improvements can extend to competitive sport performance  
1968 outcomes.

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1969 The effects of RT priming on sports that require the reproducibility of actions over extended  
1970 periods, and in unpredictable and reactive environments also remains unclear [172]. While  
1971 some research supports that performance levels can remain enhanced for several hours  
1972 following the training stimulus (e.g. 24-48 hours [123]), evidence regarding the reproducibility  
1973 of these effects across shorter-term efforts is inconsistent. Rusell et al.[180] reported that sprint  
1974 performance improvements were limited to the first two of six sprints in rugby union players.  
1975 Consequently, such findings may limit the practical relevance of RT priming for enhancing  
1976 performance in sports involving consistently repeated high-intensity actions, such as rugby,  
1977 soccer, and basketball. Alternatively, the use of RT priming for maximising performance  
1978 outcomes may be best suited to sports that require lower volumes of high-intensity actions and  
1979 interspersed with longer recovery periods, such as track and field events or individual sports  
1980 like golf.

1981 One of the proposed mechanisms attributed to the delayed potentiation response, particularly  
1982 following a morning RT session, is the attenuation of diurnal declines in testosterone  
1983 concentrations [122]. However, only a limited number of studies have concurrently assessed  
1984 hormonal responses and neuromuscular performance outcomes following RT priming, with  
1985 conflicting findings reported [149,180,181]. Consequently, the extent to which hormonal  
1986 responses contribute to performance changes remains unclear, especially following later  
1987 recovery intervals (e.g. 24-48 hours). Further research is therefore necessary to clarify the  
1988 physiological mechanisms underpinning RT priming effects.

1989 While the mechanisms underpinning the delayed potentiation response are yet to be fully  
1990 understood, this review highlights that several key factors appear to influence RT priming  
1991 outcomes, including exercise intensity, volume load, effort, exercise and outcome specificity,  
1992 participant characteristics, and recovery timing. Given that sports performance practitioners  
1993 appear to already be employing these strategies in high-performance settings, the findings of

1994 this review could assist in refining and enhancing the delivery of such sessions. Further  
1995 evidence clarifying the time course of training effects, examining sport-specific outcomes, and  
1996 reviewing inter-individual changes and key athlete characteristics (i.e. strength level, gender,  
1997 age, and sport) would therefore strengthen the current evidence base, and assist practitioners in  
1998 applying RT priming strategies more effectively and with greater confidence.

### 1999 **3.6 Conclusions and Practical Applications**

2000 The findings of this review indicate that, under the specific conditions, neuromuscular athletic  
2001 performance can be enhanced by RT priming activities. Performance improvements have most  
2002 consistently been observed when RT priming sessions involve either high-intensity ( $\geq 80\%$   
2003 1RM), low-volume interventions (780–2155 AU) within four to eight hours, or low intensity  
2004 ballistic exercises (30-40% 1RM, 450–800 AU) assessed between six- and 24-hours post-  
2005 exercise. These RT priming protocols appear to offer the most reliable potential for eliciting  
2006 improvements across tasks such as jumping, sprinting, strength-based assessments, and, to a  
2007 lesser extent, some sport-specific outcomes.

2008 Despite these identified trends, the current evidence base remains heterogeneous, with several  
2009 studies reporting unchanged performance or even transient declines within 48 hours of RT. The  
2010 magnitude, direction, and time course of performance effects appear to be influenced by both  
2011 participant characteristics, particularly strength levels, and methodological factors, including  
2012 session volume load, the proximity of repetitions to failure, exercise selection and specificity,  
2013 and recovery interval durations. Notably, stronger individuals have demonstrated greater  
2014 positive changes following RT priming interventions, particularly when total session volume  
2015 loads are low and repetitions to failure are avoided.

2016 Beyond the pursuit of acute performance enhancement, the current evidence more consistently  
2017 supports the use of RT priming as a low risk means of implementing RT in close proximity to

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2018 sport training or competition, without inducing prolonged reductions in neuromuscular  
2019 performance. Indeed, performance levels were frequently shown to be preserved following a  
2020 diverse range of protocols, even when performed within one to 48 hours following the training  
2021 stimulus. This is of significant applied relevance, particularly in sports where traditional RT is  
2022 often avoided during congested competitive periods. However, the largest and most persistent  
2023 reductions in performance were typically observed in weaker or less resistance trained  
2024 individuals and following interventions characterised by high total volume loads, multiple sets  
2025 performed to or near failure, and moderate-intensity loading combined with high repetition  
2026 schemes. These approaches should therefore be avoided or applied with caution when  
2027 performed within prior to sporting competition.

2028 The findings of this review therefore suggest that RT priming may be most appropriately  
2029 conceptualised as a strategy that facilitates continued exposure to RT while minimising the risk  
2030 of performance reductions, with the additional possibility of acute performance increases when  
2031 performed under favourable conditions. This provides a pragmatic framework within applied  
2032 practice, whereby RT priming can be used more reliably as a RT stimulus during competitive  
2033 periods, while researchers continue to explore the mechanisms underpinning the delayed  
2034 potentiation response, and the protocols in which performance enhancing effects could be  
2035 realised.

### 2036 **3.7 Chapter Perspectives**

2037 Chapter 3 synthesised the current evidence examining RT priming interventions and their  
2038 effects on neuromuscular performance outcomes within a one- to 48-hour window post-  
2039 training. Collectively, the findings demonstrate that while RT priming can, under specific  
2040 conditions, elicit short-term improvements in neuromuscular performance, responses have  
2041 been shown to be highly variable. As this area of research is still relatively novel, uncertainty  
2042 exists regarding the magnitude, direction, and time course of performance effects, with both

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2043 methodological factors and participant characteristics appearing to moderate post-intervention  
2044 responses.

2045 Notably, although several investigations reported statistically significant improvements in  
2046 isolated performance measures, such as jumping, sprinting, throwing and strength-oriented  
2047 performance outcomes, the practical significance of these findings within competitive sport  
2048 contexts remains unclear. Evidence suggests that performance enhancements may be limited  
2049 to a small number of short-duration, high-intensity actions and to neuromuscular performance  
2050 tasks that may not necessarily translate directly to competitive performance outcomes. This  
2051 limitation is particularly relevant in team sports, where performance is influenced by complex  
2052 and reactive environments, repeated high-intensity efforts, cumulative fatigue, and tactical and  
2053 skill-based demands, which may attenuate the impact of transient improvements in  
2054 neuromuscular performance.

2055 In contrast, golf could represent a more suitable applied context for RT priming strategies. Golf  
2056 performance is characterised by a relatively small number of high-force, high-velocity actions  
2057 interspersed with prolonged recovery periods between shots, potentially allowing for increases  
2058 in neuromuscular function to be expressed with limited interference from accumulated fatigue.

2059 While golf-specific outcomes such as CHS and BS have yet to be directly examined within the  
2060 RT priming literature, improvements in relevant performance measures including CMJ  
2061 performance and lower- and upper-limb force-expression characteristics provides a plausible  
2062 pathway for performance transfer. As outlined in Chapter 2, these neuromuscular qualities have  
2063 been shown to be strongly associated with key determinants of golf shot performance.

2064 While RT priming methods are often implemented with the primary aim of enhancing  
2065 performance and competitive readiness, the evidence synthesised in this review indicates that  
2066 the most consistent value of RT priming as it currently stands may not lie in its ability to elicit

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2067 acute performance enhancements. Instead, RT priming methods could offer a more consistent  
2068 and predictable benefit in preserving neuromuscular performance levels when RT is performed  
2069 in close proximity to sport training or competition. Across the included studies, neuromuscular  
2070 performance was frequently maintained within one to 48 hours following RT priming sessions,  
2071 highlighting its potential as a practical strategy for maintaining RT exposure during periods in  
2072 which traditional RT is often reduced or avoided. Indeed, findings indicate that more traditional  
2073 and higher volume RT methods may increase the risk of transient reductions in performance.  
2074 This is of significant practical relevance, as at the highest level of sport, even small decrements  
2075 in neuromuscular function could meaningfully influence outcomes. Consequently, identifying  
2076 practically feasible strategies that allow RT to be implemented around competitive constraints  
2077 is essential, particularly as prolonged reductions or avoidance of RT during in-season periods  
2078 may also involve performance-related risks, such as detraining.

2079 Despite the growing body of empirical evidence advocating the importance of RT for golf  
2080 performance, structured S&C in the sport remains comparatively new and underdeveloped  
2081 relative to sports such as rugby or athletics, where its role is established and well accepted.  
2082 Further to this, there is a clear lack of empirical evidence describing how RT is currently  
2083 implemented within elite golf populations. As a result, the extent to which evidence-based  
2084 recommendations align with the real-world practice of such athletes, as well as the practical  
2085 and perceived barriers faced by golfers when attempting to implement such strategies, remains  
2086 poorly understood. Accordingly, the findings of this review provide rationale for the subsequent  
2087 Chapter (4), which seeks to characterise current S&C practices and perceptions among elite  
2088 touring professional golfers. By examining existing training behaviours, perceptions, and  
2089 constraints, the following survey and observational study provides a foundation on which RT  
2090 priming interventions can be appropriately designed, contextualised, and elevated within elite  
2091 golf environments.

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2092 **4 Chapter 4: Elite Professional Golfers' Physical Preparation**  
2093 **Practices and Perceptions**

2094 **4.1 Citation:**

2095 Sean R. White<sup>1</sup>, Daniel A. Coughlan<sup>2,3,5,6</sup>, Carly Wood<sup>1</sup>, Jack E. T. Wells<sup>2,3,4</sup>, Andrew  
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2099 **4.2 Affiliations:**

- 2100 1 School of Sport, Rehabilitation, and Exercise Sciences, University of Essex,  
2101 Colchester, United Kingdom
- 2102 2 European Tour Health and Performance Institute, European Tour Group, Virginia  
2103 Water, UK
- 2104 3 England Golf, Woodhall Spa, Lincolnshire, UK
- 2105 4 Medical and Scientific Department, The R&A, St Andrews, UK
- 2106 5 Cambridge Centre for Sport & Exercise Sciences, Anglia Ruskin University,  
2107 Cambridge, UK
- 2108 6 Health and Performance Institute, Ladies European Tour, Denham, UK
- 2109 7 Medical and Scientific Department, The R&A, St Andrews, UK
- 2110 8 UK Collaborating Centre for Illness and Injury Prevention (IOC Research Centre),  
2111 University of Edinburgh, Edinburgh, UK.

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### 2112 **4.3 Abstract**

2113 Physical preparation for improving golf performance is a topic of rising interest. However,  
2114 little is known of how advancements in empirical evidence have integrated with the practices  
2115 and perceptions of elite professional golfers. To address this shortfall in knowledge, forty-nine  
2116 (n = 32 European Tour, n = 17 Challenge Tour) professional golfers were surveyed on their  
2117 physical preparation practices and perceptions. Additionally, golfers' in-tournament training  
2118 practices were observed at the 148th Open Championship gym facility. The majority of  
2119 surveyed golfers had experience of following a "structured resistance training plan" (89.8%).  
2120 However, players face challenges to incorporate physical preparation throughout a tournament  
2121 year. In-turn, the development of physical attributes including muscular strength, power and  
2122 muscle mass known to underpin clubhead speed/driver distance, and the training methods  
2123 typically required to stimulate such adaptations were often not prioritised during the in-season  
2124 period. Limited engagement with heavy load and high velocity resistance training methods  
2125 were observed at the Open Championship. However, in order to maximise their potential,  
2126 players can enhance key physical qualities on a year-round basis (i.e. during the in-season).  
2127 Consequently, further education and research on how to effectively organise and optimise  
2128 resistance training within tournament constraints would be of value.

### 2129 **4.4 Introduction**

2130 Recent advancements in empirical evidence have contributed to a greater acceptance of the role  
2131 of physical preparation in the sport of golf [7]. A considerable amount of research has now  
2132 demonstrated that S&C interventions can positively impact a golfer's clubhead speed CHS [4],  
2133 and develop key physical attributes associated with high performance including muscular  
2134 strength, power, impulse, and mass [4,5]. Likewise, various dynamic and resistance-based  
2135 warm-up strategies have been shown to significantly improve a golfer's short-term CHS and  
2136 DD performances [6]. Anecdotally, many players now engage in physical preparation to

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2137 improve their performance and reduce their risk of injury, which is supported by the philosophy  
2138 implemented by the ETHPI [10]. In support of this, a recent study investigated the sports  
2139 science practices and perceptions of PGA Assistant Professionals (future-qualified coaches, n  
2140 = 430). The authors reported that some golfers perceived S&C as beneficial for performance  
2141 and injury risk reduction, with most participants training year-round (75.81%) [86]. However,  
2142 no empirical research has investigated how professionals competing at the highest level have  
2143 integrated physical preparation strategies into their routines, and how they may navigate their  
2144 training around extensive tournament schedules and throughout busy tournament weeks.

2145 The season structure of a current touring professional golfer includes long competitive seasons.  
2146 For example, the 2023 European Tour/DP World Tour season comprised 45 events, spanning  
2147 five continents, and 26 separate countries, with tournaments being scheduled every month of  
2148 the calendar year [208]. As a result, golfers are facing shorter off-season breaks in which to  
2149 recuperate and establish physical goals for the subsequent competitive period, with the largest  
2150 break between tournament scheduling for the DP World Tour often being less than one month.  
2151 Currently, the typical touring professional will compete in 18 to 30 tournaments over the course  
2152 of a year [24]. Each golfer's schedule is individually unique, with higher ranked players  
2153 typically having greater choice in the events they play in, with more freedom to design their  
2154 season structure [24]. In attempting to maintain their tour status or progress their ranking, lower  
2155 ranked players may be required to play in more events and have more reactive schedules.

2156 Tournament weeks are also intensive and depending on a player's level of success, they may  
2157 compete on four consecutive days (Thursday to Sunday) with a minimum of two-tournament  
2158 rounds if the player were to miss "the cut" (Thursday and Friday). Individual rounds span 4-6  
2159 hours of play, with tee off times which can range from 6.00 am to 3.00 pm. In the days  
2160 preceding competition, golfers will need to familiarise themselves with the venue and engage  
2161 in on and off course practice. Additionally, travel commitments and time zone changes between

2162 events are often significant. As such, the delivery of optimal physical development strategies  
2163 for a touring professional golfer is highly complex, and a greater understanding of how players  
2164 may organise and approach their physical preparation throughout their annual training cycle is  
2165 needed. Accordingly, the aims of this study were to investigate if physical preparation practices  
2166 and perceptions of touring professionals align with scientific recommendations for the sport of  
2167 golf and to explore how approaches and the barriers to engagement may vary between the in-  
2168 season and off-season periods, as well as during tournament weeks.

## 2169 **4.5 Method**

### 2170 **4.5.1 Survey Design**

2171 A survey was created using Qualtrics™ (Qualtrics, Provo, UT) and developed based on a  
2172 review of the scientific literature pertaining to the use of physical preparation strategies for  
2173 golf. Feedback was sought throughout the development of the survey from ETHPI S&C  
2174 coaches with regards to the content, language used, and duration of the survey so as to  
2175 maximise the content validity and ensure that the survey questions would be easily interpreted  
2176 by players prior to distribution and data collection. Ethical approval was granted by the  
2177 \*\*\*\*\* \*\* \*\*\*\*\* Ethics Committee.

### 2178 **4.5.2 Survey Questions**

2179 Questions related to players' general (Table 4.1), in-season and off-season (Table 4.2), and in-  
2180 tournament physical preparation (Table 4.3) can be found in the respective tables. Each table  
2181 details the specific questions asked, outlines the range of responses available to players, and  
2182 describes the process by which players were prompted to provide follow-up answers. For all  
2183 questions relating to training activities (questions 10, 11, 17 and 19), examples were provided  
2184 for clarity. Examples included: heavy load/low volume (HL/LV) resistance training (RT) (e.g.  
2185 3x3 back squats at 85% 1RM), low load/high volume (LL/HV) RT (e.g. 3x10-15 lunges),  
2186 weighted explosive training (e.g. weighted squat jumps/ballistic bench-press throws),

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2187 bodyweight explosive training (e.g. box jumps / explosive press-ups), resistance-band exercise  
2188 (e.g. shoulder rotations / crab walk), aerobic exercise (e.g. running / cycling / swimming),  
2189 proprioception (e.g. balance / co-ordination / movement quality), and mobility (e.g. range of  
2190 motion exercise / stretching). Examples were constructed through pre-existing knowledge, and  
2191 through consultation with ETHPI S&C coaches.

### 2192 **4.5.3 Survey Recruitment**

2193 The survey was primarily distributed online to all registered European Tour Players via direct  
2194 email on the 24th June 2019. The email provided detail on the purpose of the survey and  
2195 contained a unique link to the questions. The survey was further promoted by ETHPI staff  
2196 members to European Tour players throughout tournaments commencing between the 24th  
2197 June 2019 to 20th July 2019, and to Challenge Tour players at tournaments between 2nd  
2198 August 2019 to 3rd September 2019. During the tournaments, the survey was made available  
2199 to all competing players. All survey responses were anonymised, and participants gave their  
2200 informed consent after reading a survey information sheet. Partially completed surveys were  
2201 also incorporated in the analysis.

### 2202 **4.5.4 In-tournament Observation**

2203 Following ethical approval granted by the \*\*\*\*\* \*\* \*\*\*\*\* Ethics Committee,  
2204 information was distributed regarding the onsite gym facility usage at the 148th Open  
2205 Championship at Royal Portrush, Northern Ireland 2019. The tournament took place between  
2206 the 18th and 21st July 2019, with 156 players entered to compete [209]. Data were collected  
2207 with the use of observational records completed by ETHPI staff members at the championships  
2208 fully equipped gym. The gym was exclusively accessible to Open Championship players, with  
2209 no other facilities available at the venue. The observational records were split between staff  
2210 observing players' training habits from 6am-1pm and 1pm-9pm on Wednesday 17th and  
2211 Thursday 18th July 2019. Data were anonymised with staff members recording each entry to

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2212 the gym. Staff members also observed the nature of gym usage, with each exercise recorded to  
2213 the most appropriate exercise modality from a pre-determined list. The pre-determined list  
2214 included both exercise modality names and examples for reference and was constructed  
2215 through pre-existing knowledge and through consultation with ETHPI S&C coaches. The  
2216 observational record sheet can be seen in the Supplementary material.

## 2217 **4.6 Statistical Analysis**

### 2218 **4.6.1 Survey**

2219 Descriptive and frequency analysis for each question were conducted and analysed using SPSS  
2220 statistics (Version 28.0, SPSS Inc. Chicago, IL, USA) for Microsoft windows. Results are  
2221 presented as the absolute volume of responses and as percentages. Median response and  
2222 standard deviation are provided for scaled responses, with individual tables highlighting the  
2223 range of each scale. The mean, median, and standard deviation are reported for the number of  
2224 answers selected, for multiple-choice questions wherein multiple answers could be selected.  
2225 Direct comparisons between in-season and off-season practices and perceptions were made  
2226 with descriptive and frequency analysis. Partially completed responses wherein answers were  
2227 not recorded for both in-season and off-season questions were removed from the analysis so as  
2228 to draw direct comparisons. A Wilcoxon Signed Ranked test was used to compare in-season  
2229 and off-season practices and perceptions. Specifically, the median number of weekly RT  
2230 sessions reported between the in-season and off-season, and the number of multiple-choice  
2231 answers selected for questions pertaining to participants' key training goals during the in-  
2232 season/off-season, and participants self-regarded prioritised training modalities in-season and  
2233 off-season. The Alpha level was set at 0.05.

### 2234 **4.6.2 In-tournament Observation**

2235 The results are presented as the absolute number of gym entries each day, and were expressed  
2236 as a percentage of the number of players entered to compete in the tournament ( $n = 156$ ) [209].

2237 The volume of engagement in categorised training modalities was also recorded and expressed  
2238 as a percentage in relation to the number of players entering the gym.

## 2239 4.7 Results

2240 A total of forty-nine survey responses were collected, with forty-five full responses and four  
2241 partially completed responses (13-84% completion). Twenty-nine full responses were obtained  
2242 from European Tour professionals, with three partially completed responses. Sixteen full  
2243 responses were recorded from Challenge Tour professionals, with one partially completed  
2244 response. Eleven participants started but did not submit a response for any question.

### 2245 4.7.1 General Physical Preparation

2246 Participant responses to questions relating to their general physical preparation practices and  
2247 perceptions are shown in Table 4.1. Descriptive statistics indicated that the majority of  
2248 surveyed golfers had historically followed a structured RT plan, with the median response  
2249 being “4+ years” (57.1%). The most frequently reported reasons for having not had experience  
2250 (n = 5, 10.2%) were due to: “time constraints” (60.0%), “fatigue” (40.0%), “fear of injury”  
2251 (40.0%) and they “would rather practice golf” (40%). The most commonly selected reasons for  
2252 engaging with RT were to: “improve strength” (93.0%), “stay healthy” (83.7%), and “improve  
2253 power” (81.4%).

2254

**Table 4.1 Surveyed golfers general physical preparation practices and perceptions.**

Question	Choice Selection	Responses (n)	%	Number of Responses Selected (mean ± SD)
<i>Q1</i>	<i>Single Choice</i>	<i>49 Total</i>		
How many years have you followed a structured RT plan for?	I haven't	5	10.2%	1.0 ± 0.0
	0-1 year	4	8.2%	
	1-2 years'	2	4.1%	
	2-3 years'	5	10.2%	
	3-4 years'	5	10.2%	
	4+ years'	28	57.1%*	

<i>Q2</i>	<i>Multiple Choice</i>	<i>5 Total</i>		
Why do you not follow a RT plan? (Follow-up Q1, if "I haven't" was selected)	Time constraints	3	60.0%	2.2 ± 0.8
	Fatigue	2	40.0%	
	Would rather practice golf	2	40.0%	
	Fear of injury	2	40.0%	
	RT will not improve golf performance	1	20.0%	
	Lack of facilities	1	20.0%	
	RT will worsen golf performance	0	0.0%	
Other	0	0.0%		
<i>Q3</i>	<i>Multiple Choice</i>	<i>44 Total</i>		
Why do you RT? (Follow-up Q1, if "I haven't" was not selected)	Improve strength	40	93.0%	6.4 ± 2.2
	Stay healthy	36	83.7%	
	Improve power	35	81.4%	
	Improve flexibility	30	69.8%	
	Improve balance/co-ordination	29	67.4%	
	Improve swing technique	28	65.1%	
	Improve CHS/DD	27	62.8%	
	Improve cardiovascular fitness	20	46.5%	
	Increase muscle mass	19	44.2%	
	Decrease body fat	9	20.9%	
	Other	0	0.0%	

*%= Percentage of participants responses, \*= Indicates the median response, RT= resistance training, CHS = clubhead speed, DD= Driver distance*

#### 2255 **4.7.2 In-season and Off-season Physical Preparation**

2256 Participant responses to questions relating to their in-season and off-season physical  
 2257 preparation practices and perceptions are shown in Table 4.2. Descriptive statistics indicated  
 2258 that surveyed golfers were more likely to resistance train in the off-season (89.4%) compared  
 2259 to in-season (76.1%). Golfers would only "sometimes" resistance train in the off-season (n =  
 2260 11; 23.9%) due to: "time constraints" (72.7%), "fatigue" (63.6%), "lack of facilities" (63.6%),  
 2261 and because they "would rather practice golf" (54.4%). Comparatively, during the off-season  
 2262 golfers would only "sometimes" (n = 5, 10.6%) resistance train due to "time constraints"  
 2263 (60.0%), and "fear of injury" (60.0%). Results of the Wilcoxon Signed Ranked test revealed a  
 2264 significant difference between participants weekly RT frequencies ( $Z = -5.647$ ,  $p < 0.001$ ), with  
 2265 a median training frequency of "4 times" per week (43.5%) during the off-season and only "2  
 2266 times" per week (39.1%) in-season.

2267 No statistically significant difference between the volume of answers selected detailing players  
 2268 prioritised training activities during the in-season and off-season periods were observed ( $Z = -$   
 2269 1.342,  $p < 0.180$ ). However, the most commonly selected training modalities varied. For

2270 example, “heavy load/low volume” (HL/LV) RT was commonly perceived to be a training  
 2271 priority in the off-season (67.4%), but not during the in-season (32.6%). Other training  
 2272 modalities including “low load/high volume” (LL/HV) RT, “weighted explosive training” and  
 2273 “aerobic exercise” were also more commonly perceived as a priority during the off-season,  
 2274 whereas “resistance-band exercise”, “proprioception”, and “mobility” were more frequently  
 2275 perceived to be training priorities in-season. The results of the Wilcoxon signed ranked test  
 2276 revealed that golfers selected a significantly greater number of key training goals during the  
 2277 off-season compared to the in-season ( $Z = -4.060, p < 0.001$ ). Players most commonly reported  
 2278 improving “strength” (91.3%), “power” (78.3%), and to “stay healthy” (71.3%) as their key  
 2279 training goals in the off-season, whereas “maintenance” (84.4%) of condition, and to “stay  
 2280 healthy” (80.4%) were most commonly selected for the in-season. Fewer participants regarded  
 2281 increasing “muscle mass” (13.0%; 54.4%) and improving “strength” (52.2%; 91.3%),  
 2282 “CHS/DD” (23.9%; 60.9%), “power” (50.0%; 78.3%) and “cardiovascular fitness” (23.9%;  
 2283 37.0%) as key training goals during the in-season period when compared to the off-season.

2284 **Table 4.2 In-season and off-season physical preparation practices and perceptions**

Question	Choice selection	Off-season			In-season		
		Responses (n)	%	Number of Responses Selected (mean ± SD)	Responses (n)	%	Number of Responses Selected (mean ± SD)
<i>Q4 &amp; 5</i>	<i>Single Choice</i>	<i>47 Total</i>			<i>46 Total</i>		
Do you resistance train during the off-season/in-season?	Yes	42	89.4%*	1.0 ± 0.0	35	76.1%*	1.0 ± 0.0
	Sometimes	5	10.6%		11	23.9%	
	No	0	0.0%		0	0.0%	
<i>Q6 &amp; 7</i>	<i>Multiple choice</i>	<i>5 Total</i>			<i>11 Total</i>		
Why would you not train during the off-season/in-season? (Follow-up Q4 & 5 if “yes” was not selected)	Time constraints	3	60.0%	2.6 ± 1.1	8	72.7%	2.9 ± 1.4
	Fatigue	2	40.0%		7	63.6%	
	Lack of facilities	2	40.0%		7	63.6%	
	Would rather practice golf	2	40.0%		6	54.5%	
	Fear of injury	3	60.0%		3	27.3%	
	Won’t improve performance	1	20.0%		1	9.1%	
	Will worsen Performance	0	0.0%		0	0.0%	
		0	0.0%		0	0.0%	

		Only train during the in-season/off-season	0	0.0%	0	0.0%		
		Other						
<i>Q8 &amp; 9</i>	<i>Single choice</i>	<i>46 Total</i>			<i>46 Total</i>			
How many times do you resistance train per week during the off-season/in-season? (Follow-up Q4 & 5 if “no” was not selected)	1 time	1	2.2%	1.0 ± 0.0	8	17.4%	1.0 ± 0.0	
	2 times	3	6.5%		18	39.1%*		
	3 times	10	21.7%		12	26.1%		
	4 times	20	43.5%*		6	13.0%		
	5 times	5	10.9%		1	2.2%		
	6 times	7	15.2%		1	2.2%		
	7+ times	0	0.0%		0	0.0%		
<i>Q10 &amp; 11</i>	<i>Multiple choice</i>	<i>46 Total</i>			<i>46 Total</i>			
Which of the following activities do you prioritise during off-season/in-season training? (Follow-up Q4 & 5 if “no” was not selected)	HL/LV RT	31	67.4%	4.2 ± 1.9	15	32.6%	3.8 ± 1.6	
	LL/HV RT	23	50.0%		19	41.3%		
	Resistance-band exercise	18	39.1%		23	50.0%		
	Weighted explosive training	29	63.0%		25	54.4%		
	Bodyweight explosive training	24	52.2%		22	47.8%		
	Mobility	29	63.0%		33	71.7%		
	Proprioception	18	39.1%		23	50.0%		
	Aerobic exercise	18	39.1%		14	30.4%		
	Other	1	2.2%		0	0.0%		
<i>Q12 &amp; 13</i>	<i>Multiple Choice</i>	<i>46 Total</i>			<i>46 Total</i>			
What are your key goals for training during the off-season/in-season? (Follow-up Q4 & 5 if “no” was not selected)	Improve strength	42	91.3%	6.3 ± 2.3	24	52.2%	5.0 ± 2.4	
	Improve power	36	78.3%		23	50.0%		
	Improve flexibility	26	56.5%		27	58.7%		
	Improve balance/co-ordination	22	47.8%		20	43.5%		
	Improve cardiovascular Fitness	17	37.0%		11	23.9%		
	Improve swing technique	27	58.7%		24	52.2%		
	Improve CHS/DD	28	60.9%		11	23.9%		
	Increase muscle mass	25	54.4%		6	13.0%		
	Decrease body fat	11	23.9%		10	21.7%		
	Stay healthy	33	71.7%		37	80.4%		
	Maintenance	24	52.2%		39	84.4%		
	Other	0	0.0%		0	0.0%		

*% = Percentage of participants responses, \* = Indicates the median response, HL/LV = heavy load/low volume, LL/HV = low load/high volume, CHS = clubhead speed, DD = Driver distance*

### 2285 4.7.3 In-Tournament Physical Preparation

2286 Participant responses to questions relating to their in-tournament physical preparation practices  
2287 and perceptions are shown in Table 4.3. Descriptive statistics revealed that 93.5% of players  
2288 (n = 46) reported that they would resistance train during their current tournament week.  
2289 Monday to Wednesday were the most commonly selected training days (50.0 – 58.7%), and  
2290 Thursday (23.7%) and Sunday (8.7%) were the least common. Players reported mixed  
2291 perceptions, when asked whether they would partake in a morning training session prior to an  
2292 afternoon (1pm) tournament round, with the median response being “might or might not”  
2293 (23.9%). The most commonly selected justification for not wanting to train was due to

2294 “fatigue” (66.7%), because they “will train another time” (43.6%), due to “time constraints”  
 2295 (28.2%), and due to a “lack of facilities” (23.1%). When asked what activities golfers would  
 2296 include in this session, mixed perceptions were reported with each of the proposed training  
 2297 modalities being selected by at least 25.0% of players.

2298 **Table 4.3 Self-reported in-tournament physical preparation training practices and**  
 2299 **perceptions**

Questions	Choice Selection	Responses (n)	%	Number of Responses Selected (mean $\pm$ SD)
<i>Q14</i>	<i>Multiple Choice</i>	<i>46 Total</i>		
Which days will you train this week? (At current Tournament)	I Won't Train	3	6.5%	1.0 $\pm$ 0.0
	Monday	27	58.7%	
	Tuesday	26	56.5%	
	Wednesday	23	50.0%	
	Thursday	10	21.7%	
	Friday	19	41.3%	
	Saturday	19	41.3%	
	Sunday	4	8.7%	
<i>Q15</i>	<i>Single Choice</i>	<i>46 Total</i>		
If you had a 1 pm tee time, would you train on the morning of the first round of golf?	Definitely yes	7	15.2%	1.0 $\pm$ 0.0
	Probably yes	8	17.4%	
	Might or might not	11	23.9%*	
	Probably not	14	14.0%	
	Definitely not	6	13.0%	
<i>Q16</i>	<i>Multiple Choice</i>	<i>39 Total</i>		
Why would you not train on the morning of the first round of golf? (Follow-up Q15 if “definitely yes” was not selected)	Fatigue	26	66.7%	2.3 $\pm$ 1.1
	Will train another time	17	43.6%	
	Time constraints	11	28.2%	
	Lack of facilities	9	23.1%	
	Will have a negative impact on performance	7	17.9%	
	Would rather practice golf	7	17.9%	
	Fear of injury	6	15.4%	
	Will not improve golf performance	4	10.3%	
	Only RT off-season	2	5.1%	
	Other	1	2.6%	
<i>Q17</i>	<i>Multiple Choice</i>	<i>40 Total</i>		
Which of the following fitness activities would you include in this training session? (Follow-up Q15 if “definitely not” was not selected)	Mobility	29	72.5%	3.7 $\pm$ 1.5
	Resistance-band exercise	23	57.5%	
	Proprioception	21	52.5%	
	Body-weight explosive training	20	50.0%	
	Weighted explosive training	17	42.5%	
	LL/HV RT	14	35.0%	
	Aerobic exercise	11	27.5%	
	HL/LV RT	10	25.0%	
	Other	1	2.5%	

%= Percentage of participants responses, \*= Indicates the median responses, HL/LV = heavy load/low volume, LL/HV = low load/high volume, RT= resistance training, CHS = clubhead speed, DD= Driver distance

2300 Participant responses to questions relating to their in-tournament warm-up practices and  
 2301 perceptions are shown in Table 4.4. Descriptive statistics indicated that the majority of players  
 2302 would “definitely” warm-up prior to the first round of golf at their current tournament. An  
 2303 average of  $3.7 \pm 1.2$  separate exercise activities would be included in this warm-up, with the  
 2304 most commonly selected being: “Hitting golf balls” and “mobility” (91.1%), followed by  
 2305 “proprioception” and “resistance-band exercise” activities (60.0%). Only one (2.2%) player  
 2306 indicated that they would exclusively “hit golf balls” during their warm-up.

2307 **Table 4.4 Self-reported in-tournament warm-up practices**

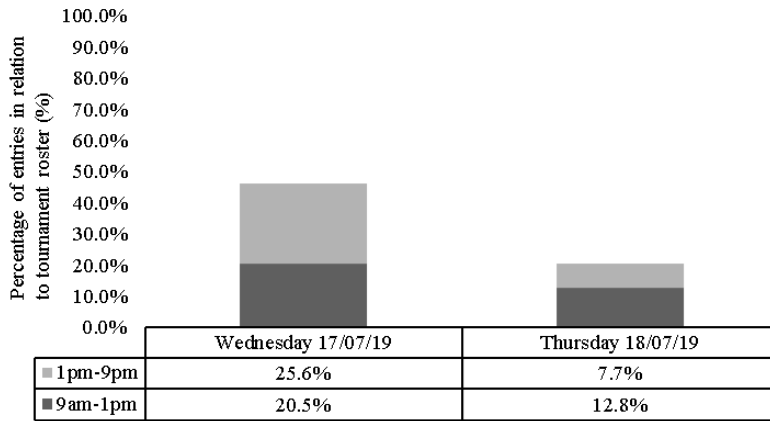
Question	Choice Selection	Responses (n)	%	Answer selection (mean $\pm$ SD)
<i>Q18</i>	<i>Single choice</i>	<i>46 Total</i>		
Will you warm-up before the first round of golf? (At current tournament)	Definitely yes	43	93.5%*	1.0 $\pm$ 0.0
	Probably yes	3	6.5%	
	Might or might not	0	0.0%	
	Probably not	0	0.0%	
	Definitely not	0	0.0%	
<i>Q19</i>	<i>Multiple Choice</i>	<i>46 Total</i>		
Which of the following fitness activities will you include in this warm-up? (Follow-up Q18)	Hitting golf balls	41	91.1%	3.7 $\pm$ 1.2
	Mobility	41	91.1%	
	Resistance-band exercise	27	60.0%	
	Proprioception	27	60.0%	
	Body-weight explosive training	11	24.4%	
	Aerobic exercise	9	20.0%	
	Weighted explosive training	4	8.9%	
	LL/HV RT	4	8.9%	
	Other	2	4.4%	
	HL/LV RT	1	2.2%	

*% = Percentage of participants responses, \* = Indicates the median response, HL/LV = heavy load/low volume, LL/HV = low load/high volume, RT = resistance training, CHS = clubhead speed, DD = Driver distance*

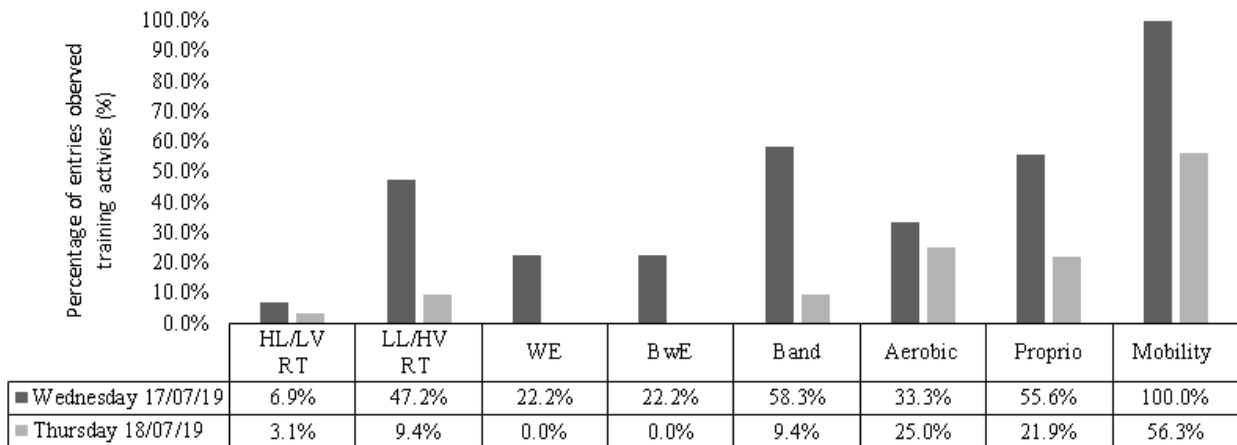
#### 2308 4.7.4 In-Tournament Observation

2309 A total of 72 gym entries were recorded on Wednesday accounting for 46.2% of the total  
 2310 players who competed in the tournament (n = 156) (Figure 4.1). Comparatively fewer entries  
 2311 were observed on the Thursday in-line with the start of the tournament (20.5%). On the  
 2312 Wednesday, the most commonly observed training activities from players observed to enter the  
 2313 gym were “mobility” (100.0%), “resistance-band” (58.3%), “proprioception” (55.6%), and  
 2314 “LL/HV RT” (47.2%) exercises. Comparatively, fewer golfers partook in all observed training

2315 modalities on the Thursday. Limited engagement was observed for “HL/LV RT” (6.9%, 3.1%),  
 2316 “weighted explosive” (22.2%, 0.0%), and “bodyweight explosive” (22.2%, 0.0%) training  
 2317 activities on both the Wednesday and Thursday (Figure 3.2).



2318 **Figure 4.1 Recorded gym entries at the 148th Open Championship**



*HL/LV RT = heavy load/low volume resistance training, LL/HV RT = Low load/high volume resistance training, Band = Resistance-band, WE = Weighted explosive, BwE = bodyweight explosive, Proprio = proprioception.*

**Figure 4.2 Recorded training activities at the 148th Open Championship gym facility**

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## 2319 **4.8 Discussion**

2320 The aims of this study were to investigate whether elite professional golfers' physical  
2321 preparation practices and perceptions aligned with scientific best practice within the sport and  
2322 to explore players approaches to physical preparation during the in-season and off-season  
2323 periods, in-addition to during tournament weeks.

### 2324 **4.8.1 General Physical Preparation**

2325 Physical preparation appears to be part of many elite professional golfers' routines, with the  
2326 majority of players reporting having had experience following a structured RT plan (89.8%),  
2327 RT both during the in-season and off-season periods, warming-up prior to tournament rounds,  
2328 and making use of gym facilities during events. For the most part, players reasoning for  
2329 engaging with RT also comply with scientific recommendations. For example, the majority of  
2330 players resistance train to "stay healthy" (83.7%), complying with the principal  
2331 recommendations from the ETHPI S&C service, whose primary goal is to assist players in  
2332 avoiding injury [10]. In their 'probability of performance-impact model' Brearley et al. [10]  
2333 stated that the avoidance of injury (and illness) is likely to have the largest impact on a golfers'  
2334 performance in allowing them to train and compete as frequently as they like, thus resulting in  
2335 a positive and indirect long-term performance effect. In keeping with scientific  
2336 recommendations, the majority of players also acknowledged the importance of RT for  
2337 developing muscular "strength" (93.0%) and "power" (81.4%). Muscular strength, impulse,  
2338 and power qualities have been shown to be the physical attributes with the strongest  
2339 correlations with CHS [5], and improvements in golfers CHS, distance, and associated strength  
2340 and power qualities have been observed to improve following RT interventions [32,36,38,98].

2341 Currently, improving CHS and DD are the clearest and most researched means through which  
2342 physical development may directly impact a golfers' performance [6]. Indeed, PGA Tour  
2343 players' who drive the ball further are significantly more likely to achieve lower scores on par-

2344 4 and par-5 holes [11]. The importance of DD was also reported by Brodie [12], who showed  
2345 that PGA Tour professionals who could drive the ball 20-yards further should save 0.75 strokes  
2346 per round, equalling a reduction of three shots over the course of a typical four-day tournament.  
2347 However, over a third of golfers did not regard improving “CHS/DD” as a reason for engaging  
2348 in RT, and only 23.9% of players considered this to be a key training goal during the in-season  
2349 period. Given the fine margins of success at the elite level of sport, it would however appear  
2350 important for players to focus on their physical development to generate greater speed and  
2351 distance in attempting to gain a competitive advantage over their opposition. Further player  
2352 education may therefore be of value.

2353 It has been suggested that physical preparation may play a key role in assisting a golfer to make  
2354 a change in their swing technique [4]. This perception is common amongst surveyed golfers,  
2355 with over two thirds of players engaging in RT to improve their “swing technique”. While there  
2356 is some evidence to support that changes in swing kinematics can amount from longitudinal  
2357 S&C training interventions, this evidence is currently limited [10,54,61,62]. This highlights the  
2358 need for further research in this area, especially considering the findings of this study. A  
2359 common perception among golfers, while not directly examined in this review, is that RT  
2360 exercises performed in the gym should replicate the golf swing, perhaps to elicit a change in  
2361 technique. Indeed, Wells et al. [86] reported that 63.25% of surveyed PGA Assistant  
2362 Professional golfers agreed to some extent, with the statement that S&C training needs to  
2363 replicate the golf swing under load. However, it has been recommended that the gym is likely  
2364 not to be an optimal environment for rehearsing golf-specific swing movements [10]. The  
2365 primary focus, instead should likely be on enhancing physical capacities [10], such as  
2366 muscular force expression, which have been identified through both associative analysis and  
2367 S&C interventions as key to improving golf performance outcomes such as CHS/DD [4,5].  
2368 This may be particularly relevant, given that “time constraints” were commonly reported as a

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2369 barrier to engagement in RT. However, adaptations in muscular force expression gained from  
2370 such training may need to be coupled with technical training outside the gym environment to  
2371 refine this capacity and apply it to the golf swing. For example, a golfer who improves their  
2372 vertical force-producing capacity in the lower limb, may also require technical refinement to  
2373 effectively and efficiently transfer that force through the kinetic chain during the golf swing,  
2374 to elicit increases in CHS [3].

2375 The results of this study indicate that many golfers prioritise “proprioception” and “mobility”  
2376 in their training and warm-ups, and train to improve “balance/co-ordination” and “flexibility”  
2377 qualities. This is not well supported by current empirical evidence, with poor relationships  
2378 between balance and flexibility characteristics and golfers CHS having been observed [5,69],  
2379 and a current lack of research demonstrating that development of such qualities in isolation can  
2380 lead to improved golf performance outcomes [4]. For example, Ehlert. [5] reported in a  
2381 systematic review with quantitative analysis that flexibility characteristics as a whole  
2382 demonstrated only trivial correlations with CHS ( $r = 0.03$ ; 95CI: -0.08, 0.14), and in a sub-  
2383 category analysis only small correlations were found for trunk rotation flexibility ( $r = 0.17$ ;  
2384 95CI: -0.26, 0.60). This may partly be explained in that measures of passive flexibility appear  
2385 to not adequately reflect the dynamic and fluent movement of the golf swing [5]. With that  
2386 being said, the importance of rotational ability should not be overlooked entirely, with the  
2387 degree of separation between the hips and thoracic spine at the top of the backswing (i.e. X-  
2388 factor), and the maximal X-factor that occurs as the hips rotate back towards to lead leg (X-  
2389 factor stretch) recognised as important factors for generating CHS [3,87]. Comparatively,  
2390 single leg balance ability has shown to be poorly related to measures of golf performance [69],  
2391 likely as this does not reflect the specific balance demands of the golf swing. Indeed, given the  
2392 task-specific nature of balance adaptations [133], it is questionable whether generalised balance  
2393 or unstable surface training can effectively translate to improved golf performance outcomes.

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#### 2394 **4.8.2 In-season and Off-season Physical Preparation**

2395 The results of this study indicate that there are large differences between golfers' approach to  
2396 in-season and off-season physical preparation. Notably, it appears that while players  
2397 consistently engage with physical preparation strategies, physical development is often not  
2398 prioritised on a year-round basis. For example, the development of muscular “strength”,  
2399 “power”, “muscle mass”, and “CHS/DD” were commonly perceived as key training goals in  
2400 the off-season, but not during the in-season. Instead, “maintenance” of condition was  
2401 commonly prioritised in-season (84.4%). In accordance with other professional sports with  
2402 long in-season periods such as rugby and soccer, it is common practice for athletes to aim to  
2403 achieve a peak in their physical condition during their off-season preparation [26]. They will  
2404 then subsequently aim to maintain their physical fitness during competition periods of up to 35  
2405 weeks duration [26]. However, with the limited time available for most touring golfers to  
2406 develop upon key physical qualities aside from competitive commitments, the aspiration of  
2407 maintenance of condition could be argued to be a poor in-season training goal. In order to  
2408 maximise their potential, players can also focus on their physical development during the in-  
2409 season period by maximising adaptations and reducing fatigue through the strategic  
2410 programming of RT during tournament weeks.

2411 Players prioritising their physical development solely in the off-season may indicate a  
2412 misconception on the time course required for certain training adaptations to occur. For  
2413 example, developing “CHS/DD” and increasing “muscle mass” were commonly prioritised in  
2414 the off-season (54.4%-60.9%), but not during the in-season (13.0%-23.9%). However, highly  
2415 skilled golfers may require training of a longer duration, greater frequency, higher volume,  
2416 and/or higher intensity to elicit increases in their physical capacities to contribute to CHS/DD  
2417 [4]. For instance, Alvarez et al. [38] investigated the effects of a periodised RT intervention  
2418 within a cohort of skilled golfers. The initial six-week strength phase was sufficient to elicit

2419 improvements in participants' strength and power, but a further six-weeks of power training  
2420 was required to enhance their driver performance. Likewise, muscle hypertrophy is often stated  
2421 to take several weeks or months to develop [193]. Contributions to muscular force-producing  
2422 capabilities resulting from hypertrophy will often occur after eight-weeks of training [210,211],  
2423 approximately twice the duration typically afforded for a break in DP World Tour players  
2424 tournament scheduling. This further highlights the importance of physical development during  
2425 the in-season period, or at least during strategically planned periods, to ensure that long-term  
2426 training adaptations are achieved, and the risk of de-training is minimised. Players' reluctance  
2427 may be partly attributed to the challenges of incorporating development strategies alongside  
2428 their in-season commitments. As such, this issue will be explored in subsequent sections, with  
2429 potential solutions proposed.

2430 RT frequencies of 2-3 weekly sessions as performed by the majority of surveyed players  
2431 (67.4%), have shown to be sufficient to develop a golfer's CHS/DD and associated physical  
2432 qualities [32,36,38,94], and may therefore enable players to progress their physical  
2433 development during the in-season. However, this speaks nothing of the specific training  
2434 methods being used, with the high-intensity and velocity training methods required to elicit  
2435 such adaptations often not being prioritised. Further to this, contradictions between players  
2436 reported training goals and their prioritised training activities were evident. For example, It is  
2437 generally accepted that improvements in strength are best achieved with lower repetition ranges  
2438 of 1-5RM exercises (HL/LV RT) [112,212]. While players acknowledged the importance of  
2439 "HL/LV RT" methods in the off-season (67.4%), conflicting perceptions were reported in-  
2440 season (32.6%) despite 52.2% of players seeking to develop their "strength". Similarly, many  
2441 players reported to not prioritise the high-velocity "explosive" training modalities (45.6% -  
2442 52.2%) during the in-season, which are typically required to develop an athletes' ballistic  
2443 capabilities [102,103]. In-turn, even if a golfer were to enhance their muscular strength and

2444 power in the off-season, a lack of strength and power training during the in-season can result  
2445 in de-training [213]. For instance, Ronnestad et al. [214] reported that a frequency of once  
2446 weekly strength training was sufficient to maintain improvements obtained by professional  
2447 soccer players during pre-season up to 12-weeks after. Comparatively, training only once every  
2448 two weeks resulted in an average loss of 10% in participants 1RM strength.

### 2449 **4.8.3 In-tournament Physical Preparation**

2450 The significant barriers faced by touring professionals during tournaments may in-part account  
2451 for the differences between player approaches to in-season and off-season physical  
2452 development. For instance, players reported facing significant “time constraints” during the in-  
2453 season period (72.7%), and consequently may benefit from education on how to effectively  
2454 organise and adapt their RT throughout busy tournament weeks and dense schedules. A “lack  
2455 of facilities” was also commonly considered as a barrier to engagement in RT. However, even  
2456 when players had access to fully equipped facilities at the Open Championship, they were  
2457 reluctant to engage with high-intensity and high-velocity training methods. Players’ reluctance  
2458 to engage with such activities may therefore be attributed to the potential for reduced  
2459 competitive performance levels resulting from neuromuscular “fatigue” [212], and increased  
2460 muscle soreness and passive tension resulting from exercise-induced muscle damage (EIMD)  
2461 [204]. As such, in professional sports it is common practice for S&C coaches to ensure  
2462 adequate recovery between strength and power development sessions and competition is  
2463 provided, with sessions typically being separated by 48 hours [215]. RT should therefore in  
2464 most cases be prioritised earlier in the week to allow sufficient recovery before the first round  
2465 of golf. Players are also advised to consider the nature and timing of their training sessions  
2466 during the week, as research indicates that the most EIMD occurs when an exercise is novel,  
2467 eccentrically oriented, and/or of a higher volume [204,216]. In-line with these  
2468 recommendations, many players already report scheduling RT sessions between Monday and

2469 Wednesday (50.0% - 58.7%), however it remains unclear as to what training activities are  
2470 commonly performed during these sessions.

2471 Opportunities to resistance train later in the week may also present if the golfer were to miss  
2472 “the cut”, which may in-part account for why players reported to train on a Friday/Saturday  
2473 (41.3%). However, with travel, practice, and other lifestyle factors this is not always possible,  
2474 and the more successful golfer will have less obvious opportunities to train during a tournament  
2475 week. In such circumstances, players may benefit from scheduling short duration RT sessions  
2476 around tournament play. Evidence has demonstrated that reducing training volumes can reduce  
2477 the magnitude of fatigue induced from RT [121,142,217]. Pragmatically, players may be able  
2478 to resistance train on the morning of, or in the day(s) preceding competition and minimise the  
2479 potential for adverse effects on competitive performance levels by maximising adaptations and  
2480 reducing fatigue through strategic programming of sets, repetitions, and exercises. Shorter  
2481 sessions may also encourage greater compliance throughout busy competitive periods whilst also  
2482 enabling players to make continued physical development via a ‘micro-dosing’ training effect  
2483 [218,219], recently defined in S&C literature as “the division of total volume within a micro-  
2484 cycle across frequent, short duration, repeated bouts” [108]. Of further interest, emerging research  
2485 indicates that neuromuscular performance outcomes can be maintained, and even in some cases,  
2486 enhanced several hours (1-48 hrs) after low volume, high-intensity strength or externally  
2487 loaded ballistic ‘resistance priming’ training sessions [122], although it is currently unclear  
2488 how this may affect a golfer’s performance. Survey results indicate that some golfers already  
2489 perform “explosive” (42.5% - 50.0%) and “HL/LV RT” (25.0%) activities on the morning prior  
2490 to an afternoon tournament round. Consequently, further research would be of value to  
2491 determine the potential effects of performing short duration RT session on golf performance  
2492 outcomes and recovery on the day of and in the day(s) preceding competition.

2493 Surveyed golfers' warm-up practices appear for the most part to align with conventional  
2494 recommendations, with various dynamic stretching activities, dynamic exercises, light RT  
2495 activities, and golf practice having been shown to contribute to immediate improvements in  
2496 CHS and shot distance outcomes [40,131,132]. Warm-ups also provide an opportunity to  
2497 include a range of training stimuli to contribute to longer-term training effects [130], and for  
2498 the time poor golfer may present an ideal occasion to contribute to developing or maintaining  
2499 key physical attributes. For example, high velocity jumps and throws as an extension of a  
2500 golfers' regular warm-up could contribute to developing a golfers' long-term ballistic  
2501 capabilities [102], without excessive additional time commitments or equipment demands.  
2502 Some evidence has also shown ballistic jump exercises to elicit immediate short term  
2503 improvements in golfers' CHS over that of performing regular warm-ups [124,137]. However,  
2504 only a small percentage of golfers appear to currently be utilising such activities. Further  
2505 research and education on the potential long-term training effects which may occur through  
2506 warm-up training interventions may encourage the use of more diverse training activities to be  
2507 performed during a golfers' warm-up.

#### 2508 **4.8.4 Strengths and limitations**

2509 This study provides a unique and previously unexplored insight to the physical preparation  
2510 approaches of golfers' competing at the elite professional level on the European/Challenge  
2511 Tour and competitors at the Open Championship. However, the results of this study may not  
2512 be representative of other professional golfers competing on other tours such as the PGA Tour.  
2513 It is also possible that surveyed players who responded were more interested in physical  
2514 preparation than those that did not. This potential bias could indicate that the results obtained  
2515 from this survey may not represent the perceptions of all players, especially those less  
2516 interested in physical preparation. The survey was constructed in a manner whereby questions  
2517 and terminology would be easy to understand, and examples were provided as technical

2518 terminology could have hindered understanding of the survey questions. While the  
2519 observational records at The Open Championship offer a unique insight to one of the most  
2520 prestigious events in golf, it is possible that there were omissions to the data, with players  
2521 training outside of the observed facility. It is however likely that most training requiring  
2522 specialised equipment would be performed at the tournament's fully equipped gym facility.  
2523 The Wednesday and Thursday were the days specifically chosen for observation due to these  
2524 being the most likely days that the entire tournament field would have access to use the gym  
2525 facilities, with players arriving sporadically to the event and some being "cut" from the  
2526 tournament after Fridays round (n= 83). The days that data was collected may therefore not be  
2527 representative of other days and may miss players training for example in hotels. Finally, since  
2528 data collection was anonymised, it is possible that multiple gym entries were recorded for a  
2529 player in a single day (e.g. warming up in the morning and RT in the evening).

#### 2530 **4.9 Conclusion**

2531 The results of this study indicate that physical preparation is a regular part of elite professional  
2532 golfers' routines, with most golfers perceiving that RT can be beneficial for staying healthy  
2533 and improving CHS/DD and golf swing technique. Current scientific literature indicates that  
2534 measures of muscular strength and power have the strongest correlations with CHS, and  
2535 longitudinal S&C interventions have demonstrated that specific strength and power training  
2536 can enhance CHS and subsequent shot outcomes. In-line with this, many players appear to  
2537 acknowledge the value in developing these attributes. However, training approaches vary  
2538 considerably between the in-season and off-season periods, with physical development  
2539 seemingly being prioritised by many in the off-season. Given that the in-season period accounts  
2540 for the majority of most players annual training cycle, there is however limited time available  
2541 to develop key physical attributes aside from competitive commitments. Consequently, in order  
2542 to maximise their potential, players should also prioritise their physical development during

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2543 the in-season period. As a result, further education and research on the key physical qualities  
2544 associated with high performance, the necessary training methods required to develop such  
2545 qualities, and how to organise and effectively implement training strategies during the in-  
2546 season period would be of value. Due to players limited availability to train around tournament  
2547 commitments, future research should look to identify methods for optimising RT within the  
2548 constraints imposed by tournament play.

#### 2549 **4.10 Chapter Perspective**

2550 Chapter 4 addresses an important research-practice gap identified throughout this thesis.  
2551 Chapter 2 established the rationale for the application of RT in golf, while also introducing the  
2552 potential constraints to its implementation within competitive environments. Building on this,  
2553 Chapter 3 explored what is currently known regarding RT priming strategies, identifying their  
2554 potential suitability as a solution to these constraints, both as a micro-dosing training approach  
2555 and as a means of acutely enhancing performance. However, there remains limited  
2556 understanding of how RT is implemented in practice within elite professional golf, including  
2557 how and whether the barriers previously discussed influence engagement with RT and  
2558 decision-making within the environmental, logistical, and competitive constraints of their  
2559 schedules.

2560 The findings of this chapter evidence that physical preparation is widely accepted among elite  
2561 golf populations, with the majority of golfers reporting long-term engagement in structured  
2562 RT, applied across both the in-season and off-season periods, and regular use of gym facilities  
2563 during tournament weeks. However, despite this consistent engagement, the results revealed a  
2564 clear trend in training priorities and modalities across the competitive calendar. During the off-  
2565 season, golfers commonly prioritised the development of strength, power, muscle mass, and  
2566 CHS/DD. By comparison, during the in-season period these qualities were less frequently  
2567 perceived as priorities, with greater emphasis placed on maintaining condition, mobility, and

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2568 staying healthy through the avoidance of injury and illness. The observational data collected  
2569 during a tournament event further reinforce this difference. While many players accessed the  
2570 gym facility during the tournament week, engagement with high-intensity training modalities,  
2571 and those most closely associated with developments in neuromuscular force-producing  
2572 capabilities and known to underpin golf shot performance, were limited. Instead, players  
2573 predominantly performed lower-intensity mobility, resistance-band, proprioceptive, and low-  
2574 load activities, especially on the day of a tournament round. These practices align with survey  
2575 results indicating that fatigue and recovery concerns, time constraints, and fear of performance  
2576 decrements were key factors influencing training decisions during tournament weeks.

2577 These findings clarify the theorised applied constraints within S&C strategies must operate  
2578 within during competitive periods. While many golfers appear to recognise the importance of  
2579 physical preparation, the observed preference for low-fatigue training modalities indicates a  
2580 reluctance to engage with training modalities with a higher risk of fatigue or negative  
2581 performance effects, particularly in-season. This highlights a disconnect between what the  
2582 research suggests may be effective and what is applied in practice and provides a strong  
2583 rationale for the exploration of alternative S&C strategies that align more closely with the  
2584 realities of elite golf schedules, such as RT priming and micro-dosed training approaches.

2585 The foundation established in this chapter is therefore of significant importance. Without a  
2586 clear understanding of how elite golfers currently organise and apply S&C within the  
2587 constraints of their schedules and environments, subsequent intervention studies risk being  
2588 misaligned with the practical realities of golfers. Consequently, the findings of Chapter 4  
2589 provide the necessary applied context for the subsequent intervention chapters, ensuring that  
2590 experimental designs are informed by both the scientific literature and the practical realities of  
2591 elite golf performance.

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2593 **5 Chapter 5: The Effects of a Low-Volume Morning Power**  
2594 **Training Session on Afternoon Golf-Specific and**  
2595 **Neuromuscular Performance in Skilled Male Golfers: A Pilot**  
2596 **Study**

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## 2597 **5.1 Abstract**

2598 The purpose of this pilot study was to examine neuromuscular and golf-specific performance  
2599 effects following a low-volume, RT priming intervention in skilled male golfers. Eight skilled  
2600 amateur (N = 5) and professional (N = 3) male golfers participated in this study (age:  $20.1 \pm$   
2601  $1.1$  years, height:  $179.3 \pm 5.7$  cm, mass:  $84.3 \pm 16.0$  kg, Handicap:  $2.0 \pm 2.5$  strokes). Using a  
2602 randomised, counterbalanced crossover design, participants completed either a morning (8 to  
2603 9am) intervention consisting of 3x5 hexagonal bar jumps (50% of bodyweight) and 3x5  
2604 rotational medicine ball throws (4kg), or a passive control condition. CMJ positive impulse,  
2605 driver CHS, and BS outcomes were measured in the afternoon, four and a half hours post-  
2606 intervention (1.30-2.15pm). No statistically significant differences ( $p < 0.05$ ) were observed  
2607 between the intervention compared to the control conditions for CMJ positive impulse, CHS  
2608 or BS, and only trivial effect sizes reported for all outcomes. At the individual level, reductions  
2609 in CMJ positive impulse were observed for the majority of participants (6/8), whereas golf-  
2610 specific measures were instead largely preserved. One participant demonstrated an increase  
2611 and one a decrease in CHS, with reductions in BS reported for two participants. These findings  
2612 do not support the use of the RT priming protocol for the purpose of enhancing neuromuscular  
2613 or golf-specific performance in this cohort of skilled male golfers. In contrast, the results  
2614 indicate that the intervention was largely effective as a low-volume, micro-dosing strategy, as  
2615 golf-specific performance outcomes were generally preserved. However, the individual  
2616 variability highlights that responses to RT priming are not uniform, and such strategies should  
2617 therefore be applied cautiously and considered on an individual basis, given the potential risk  
2618 of performance impairment. Further research is required to identify RT priming protocols that  
2619 are both effective and practically feasible within golf, and to clarify the individual variability  
2620 in performance outcomes.

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## 2621 5.2 Introduction

2622 In golf, it is commonly accepted that the primary function of the full swing when using a driver,  
2623 wood and/or iron club is to maximise ball displacement while maintaining accuracy and  
2624 consistency in both the swing and ball flight [3]. Achieving greater shot distance off the tee,  
2625 particularly when using a driver club on longer par-4 and par-5 holes, is desirable, as it  
2626 increases the chances of landing the ball closer to the green and completing the hole in fewer  
2627 strokes [11,12]. Indeed, it has been reported that PGA Tour players who increase DD by an  
2628 additional 20 yards may save approximately 0.75 strokes per round, resulting in a total  
2629 reduction of three shots over a typical four-day tournament [12].

2630 CHS is commonly regarded as an important modifiable determinant of shot distance in golf.  
2631 Indeed, increases in CHS can directly lead to increases in shot distance when other swing  
2632 factors remain consistent [3]. However, increases in CHS must then translate to BS and CD to  
2633 efficiently maximise golf shot distance [34]. Accordingly increases in these metrics are  
2634 desirable for both professional and amateur golfers [95]. In a systematic review with meta-  
2635 analysis, it was reported that measures of muscular force expression in the upper and lower  
2636 body were the physical attributes which had the strongest relationships with golfers' CHS [35].  
2637 Targeted S&C interventions focusing on the development of muscular strength and power  
2638 qualities have further been shown to translate to improvements in CHS, BS, and shot distance  
2639 performances [36,38]. Consequently, while optimal golf performance requires a holistic  
2640 approach across technical, tactical, and physical domains, developing a golfer's CHS and  
2641 resultant shot distance represents an important component that can be supported through RT  
2642 [2].

2643 Acute strategies including warm-ups [6], and PAPE activities have also led to short-term  
2644 improvements in CHS and golf shot performance [124,137]. For instance, two separate PAPE  
2645 interventions involving bodyweight ballistic activities such as the CMJ have been shown to

2646 significantly increase skilled golfers' CHS performances when using a driver club, over that of  
2647 performing a regular warm-up [124,137]. However, these effects will typically subside within  
2648 minutes of the applied training activity ( $\leq 20$  minutes) [147], limiting their feasibility within  
2649 competitive rounds that may span several hours.

2650 More recently, emerging literature has suggested that neuromuscular performance may be  
2651 enhanced at later time points of between one and 48 hours, following a low-volume and short-  
2652 duration RT priming session [122]. As detailed in Chapter 3, the systematic review indicated  
2653 that neuromuscular performance is most commonly maintained within this post-exercise  
2654 window. However, improvements have been reported in some cases, depending on study  
2655 design, the characteristics of participants examined, and the timing of assessment. While the  
2656 precise mechanisms underpinning such delayed responses currently remain unclear, the  
2657 comparatively favourable time course of these effects relative to traditional PAPE strategies  
2658 suggests that RT priming may represent a practically viable approach for examining  
2659 neuromuscular and golf-specific performance effects within competitive golf environments.

2660 Several studies have demonstrated that a morning-based RT priming session involving  
2661 strength- or power-oriented exercises can result in changes in neuromuscular performance  
2662 measured later on the same day [148–150,153]. For example, De Villareal et al. [148] reported  
2663 significant increases vertical jump height six hours following low-volume interventions  
2664 involving externally loaded jumps (30-40% 1RM) and heavy back squats ( $\geq 80\%$  1RM) in well-  
2665 trained male volleyball players. Within a competitive golfer's schedule, such an approach could  
2666 theoretically allow for the implementation of a morning RT priming session prior to a late-  
2667 morning or afternoon tee-off time.

2668 Evidence also suggests that RT priming effects may be optimised when the neuromuscular  
2669 demands of the priming activity are specific to the subsequent performance task [123,148,180].

2670 The golf swing is initiated from the ground up, with force transferred sequentially through the  
2671 kinetic chain to the clubhead [3]. Consequently, lower-limb vertical force-production has been  
2672 identified as an important contributor to CHS, as evidenced by the strong relationship between  
2673 highly skilled male golfers' CMJ positive impulse and CHS ( $r = 0.79$ ) [55]. Low-volume  
2674 vertical jump exercises, when loaded between 30-40% of participants' 1RM, have been shown  
2675 to elicit favourable neuromuscular outcomes when assessed at six, 24, and 48 hours following  
2676 RT priming activities [123,148,152]. Given the established association between lower-limb  
2677 vertical force-production and CHS, it is plausible that alterations in vertical force-time  
2678 characteristics following RT priming may be reflected in golf-specific performance measures.  
2679 Accordingly, CMJ positive impulse was selected as a relevant indicator of lower-limb force-  
2680 production in this pilot investigation. To provide applied context, sport-specific performance  
2681 measures including CHS, and BS were also analysed to characterise golf-specific performance  
2682 effects alongside neuromuscular outcomes.

2683 The majority of RT priming interventions have prescribed loading relative to an individual's  
2684 maximal strength (e.g. %1RM) [123,148,152]. However, for competitive golfers, routine  
2685 assessment of 1RM strength may be impractical during the in-season period due to dense  
2686 competition, practice, and travel schedules. Alternative load-prescription strategies may  
2687 therefore be required to improve feasibility in applied settings. Bodyweight-relative loading,  
2688 while less specific to the individual's strength levels, may provide a practical alternative for  
2689 prescribing externally loaded jump training when 1RM testing is not feasible. This approach  
2690 can maintain some degree of specificity concerning individual variability in body mass and  
2691 physical capabilities. Some evidence supports the effectiveness of RT priming interventions  
2692 utilising alternative loading strategies [150,172].

2693 RT priming may also offer a practical solution for time-constrained golfers aiming to maintain  
2694 physical qualities during the in-season period. Competitive tournaments typically span multiple

2695 consecutive days, leaving limited opportunities to engage in traditional RT, and RT is often  
2696 avoided in the days immediately preceding competition to minimise the risk of residual fatigue  
2697 impairing performance [220]. In applied settings, RT priming may be most usefully and  
2698 consistently applied as a means of integrating a low-volume RT stimulus within congested  
2699 competitive schedules, rather than as a strategy intended solely to elicit acute performance  
2700 enhancement. In this context, a low-volume RT priming session performed on the morning of  
2701 an afternoon competition round may allow golfers to maintain exposure to RT without inducing  
2702 meaningful decrements in subsequent performance.

2703 Therefore, the primary purpose of this exploratory, pilot study was to examine performance  
2704 effects of a low-volume, morning power-oriented RT priming session on afternoon  
2705 neuromuscular and golf-specific outcomes in skilled male golfers, compared with a control  
2706 condition, in order to evaluate the feasibility of RT priming both as a potential performance-  
2707 enhancing strategy and as a low-risk micro-dosing approach for maintaining RT exposure  
2708 within congested competitive schedules.

## 2709 **5.3 Method**

### 2710 **5.3.1 Participants**

2711 Eight male golfers (age:  $20.1 \pm 1.1$  years, height:  $179.3 \pm 5.7$ cm, body mass:  $84.3 \pm 16.0$ kg)  
2712 were recruited to partake in this study. To partake in this study, all participants must have been  
2713 category 1 handicap ( $\leq 5.4$  strokes) or professional golfers. Five participants were amateur, and  
2714 three were professional golfers and were assigned a handicap of zero for descriptive purposes  
2715 ( $N = 8$ ; Handicap:  $2.0 \pm 2.5$  strokes). Informed consent was obtained from all golfers prior to  
2716 participation, and ethical approval was granted by the University Ethics Committee. All golfers  
2717 were free from injury and maintained their regular pattern of golf training and diet throughout  
2718 testing procedures. Given the exploratory, pilot nature of the study, a convenience sample of  
2719 appropriately skilled golfers was recruited.

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### 2720 5.3.2 Experimental Design

2721 A randomised, counterbalanced crossover design was implemented to assess the effects of a  
2722 morning ballistic training intervention on afternoon golf driver, and CMJ performance  
2723 measures. Testing took place at a university exercise science laboratory. Participants were first  
2724 required to attend a familiarisation session to become accustomed to the testing procedures and  
2725 equipment, to screen their ability to safely perform the intervention exercises with correct  
2726 technique, and to complete a physical activity readiness questionnaire (PAR-Q). Participants  
2727 were then required to attend two separate sessions, those being the control and intervention, in  
2728 a randomised order and were instructed on the morning of the testing session which protocol  
2729 they were assigned to. The familiarisation and experimental conditions were completed on  
2730 consecutive Mondays to account for and maintain the participants' similar scheduling and daily  
2731 habits, with each protocol separated by one week.

2732 Testing procedures were conducted at consistent times during the day, with the morning control  
2733 and intervention protocols commencing between 8:00 and 9:00 a.m. During the morning  
2734 session, participants performed a standardised warm-up consisting of five minutes of cycling  
2735 at a self-selected pace on a cycle ergometer, followed by a series of dynamic stretches and  
2736 exercises designed to activate and mobilise key muscle groups and ranges of motion associated  
2737 with the full golf swing. The dynamic stretches and exercises lasted approximately five minutes  
2738 and included clock lunges, overhead squats, scapula wall slides, internal and external hip  
2739 rotations, and thoracic rotations, as detailed in Langdown et al. [39]. Following the standardised  
2740 warm-up, participants were randomly assigned to either the control condition, in which they  
2741 took passive rest, or the exercise intervention, consisting of three sets of five repetitions of  
2742 externally loaded vertical jumps and medicine ball throws. Subsequent performance testing  
2743 commenced after a four-and-a-half-hour recovery interval, between 1:30pm and 2:15pm.  
2744 During the afternoon testing session, participants initially performed the standardised warm-

2745 up. Following this, participants were required to perform maximal golf shots using a driver  
2746 club, with performance outcomes recorded using a commercially available launch monitor,  
2747 followed by maximal CMJ attempts, recorded using a force plate.

### 2748 **5.3.2.1 Exercise Intervention**

2749 For the exercise intervention, participants performed the hexagonal bar deadlift jump exercise,  
2750 loaded with 50% of the participant's body weight (approximated to the nearest 0.5 kg;  $40.0 \pm$   
2751  $8.11$  kg), using a standard 25 kg bar. Participants were instructed to grasp the bar firmly while  
2752 maintaining a braced neutral spinal position throughout the movement. The jumps were  
2753 performed with the bar starting from the floor, and participants were instructed to jump  
2754 maximally as high as possible with the bar in hand. Between repetitions, participants were  
2755 instructed to reset their stance, assume a braced neutral spinal position, and perform the next  
2756 jump. In addition to the externally loaded vertical jumps, rotational medicine ball throws were  
2757 performed in a superset format (i.e. the completion of two exercises consecutively followed by  
2758 a recovery period [221]). Both exercises were performed for three sets of five repetitions each,  
2759 with three minutes' rest separating each superset. Maximal rotational medicine ball throws were  
2760 performed in a unilateral fashion, in accordance with the primary rotational direction of their  
2761 own individual golf swing. The standing rotational medicine ball throws were performed using  
2762 a 4kg medicine ball, and into a golf net.

### 2763 **5.3.2.2 Performance Testing**

#### 2764 **5.3.2.2.1 Driver Performance**

2765 A Foresight® Sports Game Changer 2 with Head Measurement Technology (GC2+HMT)  
2766 launch monitor (Foresight Sports, San Diego, CA), configured as per manufacturer's  
2767 instructions, was used to record club and ball data. Titleist ProV1 golf balls were used, and golf  
2768 shots were performed on a golf mat and into a golf net using a self-selected golf tee height, to  
2769 ensure a consistent and stable testing environment. Prior to testing, participants were permitted

2770 a self-selected number of practice shots using their own wedge/iron/driver clubs. For testing,  
2771 participants used their own driver club to maintain consistency with technique during testing.  
2772 Participants were instructed to hit maximal shots whilst maintaining accuracy and centredness  
2773 of strike. Two consecutive shots were taken for testing and separated by 60 seconds to allow  
2774 for recalibration and data recording. In the event that sufficient data was not captured by the  
2775 launch monitor, participants were instructed to re-take a shot. Participants were blinded to  
2776 testing results. Average measures of CHS and BS were recorded and subsequently used for  
2777 statistical analysis. Leach et al. [14] previously reported on the accuracy of CHS and BS  
2778 measurements between commercially available launch monitors. The results indicated 99% of  
2779 BS measurements recorded with the GC2+HMT launch monitor were accurate to within  $\pm$   
2780 2.5mph of the gold standard measurement (optical 3D dynamic displacement measurement  
2781 system), and 67% of CHS measurements were accurate to within  $\pm$  2.5mph. Prior researchers  
2782 have also reported high levels of within-session reliability in CHS outcomes measured using  
2783 the GC2 Foresight golf launch monitor in male PGA professional golfers (intraclass correlation  
2784 coefficient [ICC]: 0.94) [75].

#### 2785 **5.3.2.2.2 Countermovement Jump Performance**

2786 Following the golf-specific testing procedures, participants were required to complete two,  
2787 maximal CMJ tests separated by a 2-minute rest interval on a dual PASCO Scientific force  
2788 plate (PASCO Scientific 2141, California, USA) sampling at 1000 Hz. Verbal instruction was  
2789 provided prior to testing, whereby participants were instructed to adopt an erect standing  
2790 position with their feet shoulder width apart and hands on hips. They then lowered themselves  
2791 to a self-selected depth, before immediately jumping as high as possible. A command of '3,2,1  
2792 jump' was provided whereby participants were instructed to execute the movement upon the  
2793 command 'jump'. Two practice trials were permitted prior to the recording of two maximal  
2794 CMJs on the force plate with average CMJ positive impulse values later analysed. Prior

2795 research has shown PASCO Scientific force plates to be valid against Kistler force plates  
2796 (Kistler 9281, Kistler Instruments, Winterthur, Switzerland) and with high within-session  
2797 reliability reported when measuring CMJ positive impulse (CV = 1.71%) amongst a cohort of  
2798 skilled male golfers [15].

### 2799 **5.3.3 Statistical Analysis**

2800 Statistical tests were carried out using SPSS for Windows (version 25, SPSS Inc., Chicago, IL,  
2801 USA), with data presented as means and standard deviations (SD). Data normality was tested  
2802 using the Shapiro-Wilk test and confirmed via visual inspection of histogram, with normal  
2803 distribution assumed where  $p > 0.05$ . Group-level differences between the intervention and  
2804 control conditions were examined using paired samples t-tests, with the significance level set  
2805 at  $p < 0.05$ . Difference scores were calculated for each variable by subtracting the control  
2806 condition values from the intervention protocol values. Effect sizes (Hedges'  $g$ ) were calculated  
2807 separately using Microsoft Excel, and interpreted as trivial  $< 0.2$ , small 0.2–0.49, moderate  
2808 0.5–0.79, and large  $\geq 0.8$  in accordance with suggestions from Cohen [175]. Positive values  
2809 indicated a favourable effect of the intervention relative to the control condition, whereas  
2810 negative values indicated the opposite.

2811 Within-session reliability of the outcome measures was assessed using intraclass correlation  
2812 coefficients (ICC) with respective 95% confidence intervals [222], calculated from data  
2813 collected during the control condition. ICC values were interpreted as poor ( $<0.5$ ), moderate  
2814 (0.5–0.75), good (0.75–0.90), and excellent ( $>0.90$ ) [223]. In addition, measurement variability  
2815 was assessed at the individual level and quantified using the coefficient of variation (CV), and  
2816 interpreted in accordance with previously suggested thresholds:  $< 5\%$  = good reliability, 5–  
2817 10% = moderate reliability, and  $> 10\%$  = poor reliability [224]. Individual performance  
2818 changes were interpreted using an individualised target-score framework [225,226]. For each  
2819 participant and outcome measure, target scores were calculated from the individual

2820 participant's within-condition SD obtained during the control condition, representing the  
2821 typical variability for that metric at the time of testing. Post-intervention values exceeding these  
2822 individual target thresholds were interpreted as 'real' changes beyond the typical measurement  
2823 variability and were classified as positive or negative performance changes based on the  
2824 direction of change.

2825 CMJ positive impulse, is the product of Force x Time, and was calculated in line with previous  
2826 research [227]. Positive impulse was therefore calculated from the area underneath the force-  
2827 time curve when force first rose above zero (determined using a 10-N threshold), corresponding  
2828 to the point in which peak negative velocity of an individual's centre of mass during the  
2829 downwards phase of the jump is achieved [228], and ending at the point that force crossed back  
2830 over zero and peak positive velocity (upwards) of the centre of mass was reached.

#### 2831 **5.4 Results**

2832 Within-session reliability for all performance outcome measures was excellent, with ICC  
2833 values ranging from 0.96 to 0.99 (Table 5.1), indicating high levels of measurement  
2834 consistency. At the individual level, CV values predominantly indicated good reliability, with  
2835 the exception of a single moderate CV value observed for one participant in the CMJ positive  
2836 impulse measure (Table 5.3).

2837 At the group level (Table 5.2), paired samples t-tests demonstrated no statistically significant  
2838 differences ( $p > 0.05$ ) between the intervention and control conditions for CMJ positive  
2839 impulse, driver CHS, or driver BS. For CMJ positive impulse, a reduction was observed  
2840 following the intervention compared with the control condition (mean difference =  $-6.45 \pm$   
2841  $9.99$  N.s). However, this did not reach statistical significance ( $p = 0.111$ ) and was associated  
2842 with a trivial effect size (Hedges'  $g = -0.12$ ). Smaller, trivial reductions were observed for

2843 driver CHS and BS (Hedges'  $g = -0.02$ ), indicating that performance was largely preserved at  
 2844 the group level following the RT priming intervention.

2845 When performance changes were interpreted against the participant-specific target scores,  
 2846 inter-individual variability in outcomes was observed (Table 5.3). Despite trivial and non-  
 2847 significant group-level reductions in CMJ positive impulse, six of eight participants  
 2848 demonstrated decreases exceeding their individual target thresholds, with these changes  
 2849 ranging from -1.55% to -5.40%. In contrast, CHS and BS changes were predominantly  
 2850 unchanged at the individual level. For CHS, one participant demonstrated an increase  
 2851 (+1.96%), and one demonstrated a decrease (-2.34%), while the remaining participants showed  
 2852 changes within typical variability. For BS, two participants had decreases exceeding their  
 2853 individual target scores (-3.03 to 3.35%), with the remaining participants maintaining their  
 2854 performance levels.

2855 These findings indicate that while group-level performance outcomes were largely maintained  
 2856 following the intervention, individual performance outcomes varied in both magnitude and  
 2857 direction, with greater variability observed for CMJ positive impulse compared with golf-  
 2858 specific performance measures.

2859 **Table 5.1 Group level within-session reliability data**

Performance Outcome Measures	ICC	CI 95%	
		Lower	Upper
CMJ Positive Impulse (N.s)	0.99	0.94	1.00
Driver CHS (mph)	0.97	0.86	0.99
Driver BS (mph)	0.96	0.82	0.99

ICC = intraclass correlation coefficient; CI 95% = 95% confidence interval; N.s  
 = Newtons per second; mph = miles per hour

2860 **Table 5.2 Group differences in performance outcome measures between the intervention**  
 2861 **and control conditions**

Performance Outcome Measures	Control (mean ± SD)	Intervention (mean ± SD)	Mean Difference	95% CI		Sig. (2-tailed)	Hedges' g
				Lower	Upper		
CMJ Positive Impulse (N.s)	321.16 ± 47.75	314.71 ± 51.69	- 6.45 ± 9.99	-14.80	1.91	0.111	- 0.12
Driver CHS (mph)	112.00 ± 4.74	111.89 ± 5.16	- 0.11 ± 1.71	- 1.54	1.3	0.861	- 0.02
Driver BS (mph)	162.24 ± 7.10	162.10 ± 6.13	- 0.14 ± 4.51	- 3.91	3.63	0.933	- 0.02

CI 95% = 95% confidence interval; N.s = Newtons per second; mph = miles per hour; Mean Difference = Intervention minus Control, negative values indicate lower performance following the intervention compared with the control condition

2862 **Table 5.3 Individual changes following the intervention and control conditions across**  
 2863 **neuromuscular and golf-specific outcome measures.**

Performance Outcome Measures	Participant Number	Control (mean ± SD)	Intervention (mean ± SD)	CV (%)	Target Score Threshold (±)	Difference (Intervention - Control)	Real Change
CMJ Positive Impulse (N.s)	1	335.15 ± 3.96	329.96 ± 2.36	1.18	3.96	-5.19	↓
	2	372.72 ± 21.58	382.59 ± 3.52	5.79	21.58	+ 9.88	↔
	3	339.10 ± 3.85	344.75 ± 14.98	1.14	3.85	+ 5.66	↔
	4	336.83 ± 6.12	318.65 ± 16.28	1.82	6.12	-18.18	↓
	5	230.02 ± 3.69	218.74 ± 2.65	1.60	3.69	-11.28	↓
	6	303.23 ± 0.30	288.82 ± 3.11	0.10	0.30	-14.41	↓
	7	370.03 ± 11.59	356.14 ± 1.57	3.13	11.59	-13.89	↓
	8	282.17 ± 2.00	278.01 ± 2.70	0.71	2.00	- 4.16	↓
Driver CHS (mph)	1	107.06 ± 0.91	109.16 ± 0.76	0.85	0.91	+ 2.1	↑
	2	112.10 ± 1.56	113.64 ± 2.63	1.39	1.56	+ 1.54	↔
	3	115.66 ± 2.18	116.50 ± 1.70	1.88	2.18	+ 0.84	↔
	4	116.36 ± 4.16	113.78 ± 2.01	3.57	4.16	- 2.58	↔
	5	104.28 ± 1.30	101.84 ± 0.65	1.25	1.30	- 2.44	↓
	6	110.10 ± 2.83	109.60 ± 1.98	2.57	2.83	- 0.50	↔
	7	112.36 ± 1.90	112.04 ± 1.22	1.69	1.90	- 0.32	↔
	8	118.10 ± 1.27	118.58 ± 1.16	1.08	1.27	+ 0.48	↔
Driver BS (mph)	1	157.16 ± 3.87	160.64 ± 1.92	2.47	3.87	+ 3.8	↔
	2	156.52 ± 7.04	163.22 ± 3.79	4.50	7.04	+ 6.7	↔
	3	168.63 ± 3.45	169.24 ± 1.92	2.05	3.45	+ 0.88	↔
	4	169.76 ± 2.46	164.08 ± 5.40	1.45	2.46	- 5.68	↓
	5	154.28 ± 1.73	149.60 ± 4.24	1.12	1.73	- 4.68	↓
	6	155.84 ± 2.35	158.15 ± 4.74	1.51	2.35	+ 2.31	↔
	7	163.84 ± 4.47	164.66 ± 1.05	2.73	4.47	+ 0.82	↔
	8	172.16 ± 5.57	167.22 ± 6.19	3.24	5.57	- 4.94	↔

N.s = Newtons per second; mph = miles per hour; ↑ increase in performance exceeding target score; ↑ = positive change exceeding individual target score; ↓ = negative change exceeding individual target score; ↔ = change within individual target score

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## 2864 5.5 Discussion

2865 The purpose of this pilot study was to examine neuromuscular and golf-specific performance  
2866 effects of a low-volume, morning power-oriented RT priming intervention, when assessed four  
2867 and a half hours post-training. In contrast to some previous literature demonstrating delayed  
2868 improvements in neuromuscular performance following a morning-based RT priming stimulus  
2869 on afternoon performance [148,149,171,181], the findings of this investigation indicate that the  
2870 applied intervention did not result in consistent performance enhancement at either the group  
2871 or individual level in a cohort of skilled male golfers. Only one participant realised a  
2872 meaningful increase in CHS, whereas no other neuromuscular or golf-specific performance  
2873 measure showed improvement. Importantly, performance outcomes were largely maintained,  
2874 with no statistically significant group-level decrements observed following the intervention.  
2875 Furthermore, inter-individual variability was evident when performance changes were  
2876 interpreted relative to participant-specific target scores, consistent with previous findings that  
2877 the effects of RT priming can vary between individuals [152,178].

2878 At the group level, no statistically significant changes were observed in CMJ positive impulse  
2879 following the RT priming intervention, with only trivial reductions observed. However, when  
2880 performance effects were examined at the individual level using participant-specific target  
2881 scores, contrasting evidence emerged, with seven of the eight participants demonstrating  
2882 reductions in CMJ positive impulse exceeding their thresholds. As neuromuscular performance  
2883 tests, such as the CMJ, are commonly utilised as non-invasive methods of assessing and  
2884 monitoring the fatigue status of athletes [144,229], these individual reductions may indicate  
2885 the presence of an underlying fatigue response that was not fully resolved prior to the afternoon  
2886 assessment. Nevertheless, in most cases this fatigue did not appear to be of sufficient magnitude  
2887 to translate to reductions in golf-specific performance, with only one reduction observed in  
2888 CHS and two in BS. As such, while neuromuscular fatigue may be detectable following the

2889 applied RT priming stimulus in some individuals, it was not necessarily performance-limiting  
2890 and did not meaningfully impair golf-specific performance outcomes for many participants.

2891 The relative performance effects following a RT priming session is suggested to be determined  
2892 by the net-balance between fatigue and potentiation following an exercise stimulus, whereby  
2893 performance enhancement may be realised if the potentiated state outweighs the fatigue state,  
2894 and vice-versa [122,159]. The variability in individual outcomes in this study indicates that this  
2895 balance may have differed substantially between individuals. A number of methodological  
2896 factors including exercise selection, intensity, volume, and recovery interval duration, in  
2897 addition to participant characteristics such as their initial strength levels, are suggested to  
2898 influence this balance and may in turn account for the results observed in this study [122].

2899 Participant strength status has been identified as an important moderator of potentiation  
2900 responses following both traditionally timed PAPE methods [147], and more recently in RT  
2901 priming literature [152,178]. For example, individual performance responses were observed  
2902 six hours following a high-intensity (80% 1RM) parallel back squat intervention, with  
2903 moderate correlations reported between participants' 1RM squat strength and subsequent  
2904 changes in CMJ height, concentric peak velocity, and concentric impulse ( $r = 0.47-0.48$ )[178].  
2905 These findings suggest that individuals with greater maximal strength may be more sensitive  
2906 to potentiation-related performance increases following RT priming.

2907 One peripheral mechanism attributed to potentiation responses is the phosphorylation of  
2908 myosin regulatory light chains, which is thought to increase muscle fibre sensitivity to calcium  
2909 ions [230]. Stronger individuals will typically possess a greater percentage of type II muscle  
2910 fibres [194], which may increase their capacity to express potentiation-related increases in  
2911 force-production via the phosphorylation of myosin regulatory light chains [231]. Stronger  
2912 individuals may additionally demonstrate a greater ability to recruit high-threshold motor units

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2913 [195], with increases in neural excitability and muscle fibre recruitment also proposed to  
2914 contribute to delayed potentiation responses [122]. However, it is important to note that these  
2915 mechanisms have not been directly examined following RT priming interventions. While it  
2916 appears that a sufficient level of baseline strength may be required to realise potentiation-  
2917 related performance benefits following RT priming, this hypothesis requires further  
2918 investigation. Indeed, only a limited number of studies have explored the relationship between  
2919 strength status and RT priming responses, with conflicting findings reported for both relative  
2920 and absolute 1RM strength measures [152,178].

2921 The absence of data pertaining to the participants' maximal strength levels was however a  
2922 limitation of this current study, as differences in relative strength and training status may have  
2923 contributed to the observed individual variability in outcomess. Indeed, it is plausible that  
2924 highly resistance-trained individuals may have developed greater resistance to fatigue  
2925 following RT activities [191,232], whereas weaker and less-trained individuals may require  
2926 longer recovery periods to offset any fatigue induced by the priming stimulus [152]. This may,  
2927 in part, account for the findings of the present study, whereby relatively weaker golfers may be  
2928 more susceptible to declines in CMJ performance and, in some cases, golf-specific  
2929 performance markers. The appropriate use of RT priming as both a short-term performance aid  
2930 and a longer-term training stimulus may therefore depend on an individual's RT status and  
2931 strength levels.

2932 Although consistent performance enhancement was not observed, the findings of this present  
2933 study provide important conceptual and applied insight into the role of RT priming within golf-  
2934 specific training contexts. The results support previous claims that the primary and most  
2935 consistent utility of RT priming is as a low-volume, micro-dosing training stimulus aimed at  
2936 preserving performance and managing fatigue, as opposed to a strategy applied solely to elicit  
2937 performance enhancement. This is particularly of relevance within the context of competitive

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2938 golf, where opportunities to engage in traditional RT are limited during the in-season and  
2939 tournament weeks. Indeed, the findings presented in Chapter 4 support the view that elite  
2940 golfers often struggle to integrate high-intensity RT during these periods, most commonly due  
2941 to time constraints and concerns that fatigue may impair performance. In this context, RT  
2942 priming methods may represent a practically feasible means of maintaining exposure to RT,  
2943 provided that individual changes are appropriately monitored.

2944 While golf-specific driver performance was largely preserved for most participants, the  
2945 individual-level findings indicate that RT priming methods cannot be assumed to be without  
2946 performance risk for golfers. Two participants experienced ‘real’ reductions in BS exceeding  
2947 4 mph, a threshold suggested to correspond to approximately a 10-yard loss in DD [233], which  
2948 has previously been considered practically meaningful due to its potential to result in less  
2949 favourable club selection for the subsequent shot [95]. As such, when RT priming methods are  
2950 applied without appropriate individualisation or consideration of recovery, there appears to be  
2951 a risk of performance reductions for some golfers.

2952 The absence of true performance-enhancing effects observed in this study does not exclude the  
2953 possibility that RT priming may elicit positive performance effects under alternative  
2954 conditions. Instead, these findings indicate that further research is required to better understand  
2955 how protocol design variables, including exercise selection, loading strategy, recovery interval  
2956 duration, and individual participant characteristics, influence the balance between fatigue and  
2957 potentiation following RT priming exercise. Indeed, in an individual sport such as golf,  
2958 examining both the conditions under which RT priming supports performance preservation and  
2959 those under which it may contribute to performance enhancement is of value.

2960 Previous research indicates that improvements in vertical jump performance can be realised  
2961 following ballistic RT priming interventions when loads are prescribed relative to maximal

2962 strength (30-40% 1RM), using low volumes (3-5 sets of 4-5 repetitions), and recovery intervals  
2963 of six, 24, and to a lesser extent 48 hours post-training [123,148,152]. Contrary to these  
2964 findings, this study did not observe improvements in CMJ positive impulse following a  
2965 protocol that utilised externally loaded jump training prescribed relative to bodyweight rather  
2966 than maximal strength. Fixed loads equivalent to 50% of participants' bodyweight were  
2967 selected as a practical alternative for golfers who may be unable to routinely assess 1RM  
2968 strength during the in-season period. While this approach improved practical feasibility, it is  
2969 likely that substantial variation existed in the relative loads applied across participants, which  
2970 may have influenced the observed outcomes. Individual loading in this study ranged from 33.6  
2971 to 56.9 kg, with an average load of 42.1 kg. Comparatively, while De Villarreal et al. [148]  
2972 used heavier absolute loads ranging from 47.2 to 66.6kg (mean: 57.2kg) during an externally  
2973 loaded vertical jump intervention in a cohort of highly resistance-trained individuals (back  
2974 squat 1RM: 158.3 kg, body mass:  $76.91 \pm 8.03$ ), who were likely better conditioned to tolerate  
2975 such loads than the golfers recruited for this study. As such, it is plausible that for some  
2976 participants, their relative strength levels necessitated lighter loads to minimise the fatiguing  
2977 effects of the exercise stimulus.

2978 While the relative loading strategy employed in this study appeared sufficient to preserve  
2979 performance for some participants, the individual reductions observed in neuromuscular and  
2980 golf-specific measures indicate that further refinement of load prescription is warranted. Future  
2981 investigations would be of value to determine the efficacy of RT priming protocols employing  
2982 relative loading prescriptions based on percentage of 1RM for both preserving and enhancing  
2983 performance outcomes. Alternatively, the use of velocity-based training approaches, such as  
2984 velocity loss thresholds, has been proposed as a means of optimising the balance between  
2985 fatigue and potentiation [234]. Thresholds of approximately 10–25% velocity loss have been  
2986 shown to enhance strength and power adaptations while minimising fatigue [217,235], and may

2987 be particularly valuable for golfers by accounting for changes in physical characteristics and  
2988 daily fluctuations in readiness [236].

2989 Longitudinal S&C interventions involving power-oriented training methods such as jumping  
2990 and medicine ball throws have consistently demonstrated improvements in CHS and shot  
2991 performance outcomes alongside increases in power-related physical qualities [36,38,54,94].  
2992 Strong relationships between common measures of muscular power (e.g. vertical jump and  
2993 medicine ball throw performance) and CHS have also been established [35]. More specifically,  
2994 associations between lower-limb vertical force-production, jump impulse, and CHS have led  
2995 to recommendations that strength training and loaded jumps are implemented within golfers'  
2996 S&C programmes [55], to improve peak force and impulse production [102]. These findings  
2997 support the inclusion of both lower-limb ballistic and rotational exercises within golf-specific  
2998 training programmes, justifying their selection in this intervention. Further to this, exercise  
2999 specificity has also been shown to influence performance responses to RT priming in some  
3000 contexts [149,152,171,173]. However, the absence of direct measures of rotational power  
3001 limits interpretation of whether fatigue-related changes were present in rotational capacities, in  
3002 addition to those detected in CMJ performance.

3003 A limitation of this study was the lack of hormonal and neurophysiological testing, which limits  
3004 understandings of the individual effects observed. While equivocal results have currently been  
3005 reported [149,180,181], hormonal responses are thought to be one of the mechanisms attributed  
3006 to the delayed potentiation response between morning training and afternoon performance.  
3007 Increases in testosterone concentrations have been associated with an individual's motivation  
3008 to perform, reduced fear, and heightened assertiveness [237], and it is therefore suggested that  
3009 these psychophysiological factors could account for such performance effects [149]. As such,  
3010 further considerations for both the physiological and psychological outcomes to RT priming  
3011 exercise would be of value in future research [181].

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## 3012 **5.6 Conclusion**

3013 This pilot study examined neuromuscular and golf-specific performance effects following a  
3014 low-volume, morning power-oriented RT priming intervention in skilled male golfers. The  
3015 findings indicate that the applied protocol was largely ineffective in eliciting increases in  
3016 performance resulting from a potentiation response. Despite the absence of performance  
3017 enhancement effects, the present findings demonstrate that a low-volume RT priming  
3018 intervention can be implemented without inducing decrements in golf-specific performance  
3019 when considered at both the group and individual level. This supports the feasibility of RT  
3020 priming as a low-volume, micro-dosing training stimulus, allowing golfers to maintain  
3021 exposure to RT during tournament weeks or congested in-season schedules without incurring  
3022 reduced performance levels.

3023 However, while no statistically significant changes were observed at the group level, individual  
3024 analysis revealed variability in the direction and magnitude of individual change following the  
3025 RT priming stimulus. Reductions in neuromuscular performance, characterised by decreases  
3026 in CMJ positive impulse, were observed in several participants. These reductions did not  
3027 consistently extend to golf-specific performance outcomes, suggesting that although  
3028 neuromuscular fatigue may have been present, its magnitude was not sufficient in most cases  
3029 to meaningfully impair sport-specific performance. Nevertheless, the observed individual  
3030 variability indicates that RT priming strategies cannot be assumed to be safely or uniformly  
3031 applied across all golfers, highlighting the importance of individual-level analysis and the need  
3032 for RT priming to be implemented cautiously and monitored on a player-by-player basis within  
3033 applied settings.

## 3034 **5.7 Chapter Perspectives**

3035 This chapter presented the first intervention within the thesis, examining the effects of a low-  
3036 volume RT priming intervention on neuromuscular and golf-specific performance within a

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3037 realistic timeframe in which golfers may feasibly apply such strategies in practice.  
3038 Consideration was given to whether such an approach could be applied without meaningful  
3039 decrements in performance, while also exploring the extent to which acute performance  
3040 enhancements consistent with delayed potentiation may be observed. This pilot investigation  
3041 was designed to reflect practical considerations arising from earlier chapters and the applied  
3042 context of RT implementation within competitive golf environments. Evidence presented in  
3043 earlier chapters demonstrated that while structured S&C interventions can support golf  
3044 performance, their implementation during in-season and tournament periods is often  
3045 constrained. Accordingly, strategies that enable continued RT exposure without compromising  
3046 neuromuscular performance warrant investigation. Accordingly, exploring how RT priming  
3047 strategies can be practically implemented within these constraints represents a necessary step  
3048 in translating S&C evidence into competitive practice.

3049 While the RT priming protocol employed in this pilot study did not elicit increases in  
3050 performance consistent with a delayed potentiation effect, golf-specific performance outcomes  
3051 were largely preserved for most participants. These findings provide preliminary support for  
3052 the rationale that RT priming may be implemented as a low-volume, micro-dosing training  
3053 strategy, enabling golfers to maintain exposure to RT within congested competitive schedules  
3054 without impairment of performance. However, the examination of individual patterns of  
3055 change revealed variability in the neuromuscular and golf-specific outcomes. Notably, while  
3056 the group effects were non-significant and trivial, several participants demonstrated reductions  
3057 in CMJ performance indicative of neuromuscular fatigue, which in some cases coincided with  
3058 reductions in golf-specific performance metrics. These results highlight the potential  
3059 limitations of relying solely on group-level analysis and reinforce the importance of individual  
3060 participant analysis when interpreting the effects of RT priming interventions. Further to this,

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3061 the observed variability highlights the need to better understand the factors that may influence  
3062 outcomes, in order to inform more effective delivery of RT priming methods.

3063 A key limitation of Chapter 5 was the absence of maximal strength assessment, restricting  
3064 interpretation of whether individual strength characteristics influenced susceptibility to  
3065 performance decrements or the lack of enhancement. Given evidence that strength level may  
3066 moderate neuromuscular effects following RT priming, incorporating maximal strength  
3067 assessment represented a necessary progression for subsequent investigation. Additionally,  
3068 prescribing load relative to body mass may have resulted in heterogeneous relative intensities,  
3069 potentially contributing to the individual effects observed. Accordingly, the subsequent study  
3070 adopted loading relative to maximal strength.

3071 The present study provides preliminary insight into the effects of a power-oriented RT priming  
3072 stimulus within a realistic four-and-a-half-hour recovery window. However, competitive golf  
3073 involves varied tee-off times and consecutive days of play, and strength- and power-oriented  
3074 modalities may differ in their neuromuscular time-course. Broader examination across RT  
3075 modalities and recovery intervals, including next-day outcomes, is therefore warranted.  
3076 Building on these findings, the subsequent investigation incorporated a wider range of  
3077 neuromuscular and golf-specific measures, alongside indices of subjective readiness, to better  
3078 characterise individual patterns of change and explore how strength-related characteristics may  
3079 influence performance following RT priming. Collectively, this progression aims to clarify the  
3080 conditions under which RT priming may preserve performance, contribute to enhancement, or  
3081 pose risk of impairment.

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3082 **6 The Effects of Resistance Training Priming Methods on**  
3083 **Neuromuscular Performance, Golf-Specific Outcomes, and**  
3084 **Readiness Perceptions in Skilled Golfers**

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## 3085 6.1 Abstract

3086 This study aimed to investigate the short-term effects of two RT priming interventions, strength  
3087 (STR) and power (PWR), on neuromuscular performance, golf-specific outcomes, and  
3088 perceptual readiness in skilled male golfers. Eight skilled male amateur and professional  
3089 golfers (age:  $28.6 \pm 8.1$  years; height:  $182.8 \pm 7.3$ cm; mass:  $86.1 \pm 9.1$ kg; Handicap index:  $1.6$   
3090  $\pm 3.5$  strokes) performed three experimental protocols (STR: 3x3 hexagonal bar deadlifts at  
3091 85% 1RM; PWR: 3x3 hexagonal bar deadlift jumps at 40% 1RM; Control: no RT) in a  
3092 randomised, counterbalanced crossover design. Subjective readiness perceptions, golf driver  
3093 performance outcomes (CHS, BS, CD, self-reported shot quality), as well as CMJ, and IMTP  
3094 performances were recorded at baseline, two hours, and 24 hours following each protocol. At  
3095 the group level, no consistent effects on neuromuscular or golf-specific performance was  
3096 observed two or 24 hours following either RT priming intervention relative to baseline or the  
3097 control condition ( $p > 0.05$ ), with the exception of a significant improvement in self-reported  
3098 shot quality two hours following the STR intervention ( $p < 0.05$ ). Performance was otherwise  
3099 preserved, with no significant decrements following either intervention. At the individual level,  
3100 standard deviation-based thresholds identified meaningful changes in both directions across  
3101 neuromuscular and golf-specific outcomes following STR and PWR protocols. These changes  
3102 were not consistently associated with maximal strength characteristics. Collectively, the  
3103 findings indicate that the specific RT priming protocols employed do not represent reliable  
3104 methods for eliciting delayed potentiation-related enhancement at the group level. However,  
3105 RT priming may be considered a low-risk training-management strategy when applied on an  
3106 individual basis, supported by an applied monitoring framework to guide implementation.  
3107 Within congested competitive schedules, low-volume RT priming may provide a practical  
3108 means of maintaining resistance training exposure during the in-season period without  
3109 compromising short-term performance or perceptual readiness.

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## 3110 6.2 Introduction

3111 Recent evidence indicates that S&C training can improve golf performance, notably through  
3112 enhancements in CHS [4]. CHS is a crucial factor in achieving longer golf shot distances [3],  
3113 and increases can result in improvements in golf shot distance so long as all other variables are  
3114 held constant [34]. The ability to achieve maximal shot distance is of key importance for golfers  
3115 particularly on long par-4 and par-5 holes, as achieving greater distance has been correlated to  
3116 lower overall scoring [11]. Accordingly, the enhancing of physical capacities, such as muscular  
3117 strength, related to the golf swing can be a way to increase CHS [3]. A recent meta-analysis  
3118 indicated that lower body strength ( $r = 0.47$  [0.24-0.69]), upper body strength ( $r = 0.48$  [0.28–  
3119 0.68]), jump impulse ( $r = 0.82$  [0.63–1.02]), jump peak power ( $r = 0.66$  [0.53–0.79]), and upper  
3120 body “explosive strength” ( $r = 0.67$  [0.53–0.80]) are the physical attributes with the strongest  
3121 relationships with CHS [35]. Developing these attributes is commonly achieved through  
3122 engagement with RT, with S&C interventions that develop a golfer’s muscular force expression  
3123 qualities also eliciting increases in CHS and other golf shot performance outcomes [32,36,38].

3124 However, touring professionals encounter several logistical constraints to implementing RT,  
3125 especially during the in-season period and throughout tournament weeks when schedules are  
3126 highly congested. In practice, RT sessions are often scheduled at least two days before  
3127 competitive sporting events to avoid the residual fatigue effects which can negatively affect  
3128 performance [163,238,239]. As a typical professional golf tournament spans four consecutive  
3129 days of play, depending on a player's success, and with regular international and  
3130 intercontinental travel between events, there are limited opportunities to engage in RT during  
3131 and between tournaments. As such, having the option to train on the day of, or in the days  
3132 preceding, a tournament round without incurring meaningful impairments in performance  
3133 levels may assist players in achieving or maintaining physical fitness throughout the congested  
3134 in-season period.

3135 Providing that the total workload performed is relatively low, neuromuscular performance can  
3136 remain preserved [155,183,184], and, in some contexts, improved within 48 hours of a RT  
3137 stimulus [122]. Within this timeframe, RT priming describes a training strategy through which  
3138 neuromuscular performance may be preserved or, depending on context, enhanced across  
3139 outcomes including strength expression [149,173], jumping [123,149,152,153,173], throwing  
3140 [150,171], and sprinting performance [149,153]. However, evidence regarding the optimal  
3141 methods for administering RT priming around competition remains limited, with inconsistent  
3142 performance outcomes reported following training [163,239]. These mixed findings are  
3143 commonly attributed to the co-existence of potentiation and fatigue following RT [159],  
3144 whereby performance outcomes depend on the relative balance between these states and the  
3145 recovery time available. Variability between studies may further reflect differences in training  
3146 methods, loading strategies, recovery duration, and individual athlete characteristics such as  
3147 baseline strength [122], highlighting the need to evaluate RT priming strategies within the  
3148 practical constraints of golf schedules and their influence on golf-specific performance.

3149 A morning RT session performed prior to a late-morning or early-afternoon tournament round  
3150 represents a realistic opportunity for golfers to engage in RT during competition weeks. While  
3151 RT priming is often cited as having the potential to influence neuromuscular performance  
3152 within one to 48 hours post-training, relatively few investigations have examined outcomes at  
3153 shorter recovery intervals of approximately one to three hours [150,240,241]. For example,  
3154 Mason et al. [150] reported improvements in bench throw peak power ( $8.5 \pm 5.8\%$ ) one hour  
3155 and 45 minutes following a RT session of 4x3 band resisted back squat and bench press  
3156 exercises, whereas CMJ peak power was impaired relative to a control condition ( $-3.4 \pm 4.9\%$ ,  
3157  $P > 0.05$ ). Given these conflicting performance outcomes, further clarity on the neuromuscular  
3158 and golf-specific performance responses to RT priming within this timeframe is of value.

3159 Since tournament rounds are often played on consecutive days, it is important to identify the  
3160 effects of RT priming on both same-day and next-day performance. Additionally, the day prior  
3161 to a tournament's commencement represents another key opportunity for players to engage in  
3162 RT during a typical tournament week (e.g. Wednesday RT, Thursday tournament round).  
3163 Predominantly, increases in performance resulting following high-intensity, strength-oriented  
3164 RT priming ( $\geq 80\%$  1RM) are most commonly observed several hours post-training, typically  
3165 between four and eight hours [148,149,151,169,171,181]. However, comparatively few studies  
3166 have examined performance outcomes both following shorter recovery periods and beyond the  
3167 same day, particularly following longer recovery intervals of 24 hours [156,181].

3168 Comparatively, some evidence supports that jump performance can be improved 24 hours  
3169 following power-oriented RT priming protocols (5 x 4 jump squats at 40% 1RM) [123,152].  
3170 Of note, individual strength levels appear to moderate these outcomes, with stronger  
3171 individuals more likely to demonstrate favourable performance changes following RT priming  
3172 than weaker individuals[152]. This may represent a confounding factor in the implementation  
3173 of RT priming strategies in golfers, as variation in baseline strength may influence fatigue  
3174 tolerance and, consequently, the likelihood of expressing potentiation-related performance  
3175 changes following RT [191,232]. Nevertheless, RT priming may provide a practical means of  
3176 sustaining RT exposure during congested competition periods, while avoiding meaningful  
3177 decrements in performance. The regular implementation of such strategies could in-turn  
3178 contribute a golfers' longer-term physical development plan through the accumulation of  
3179 greater training volumes during weekly micro-cycles, via a 'micro-dosing' training effect  
3180 [242].

3181 Given that performance outcomes following RT priming reflect the interaction between fatigue  
3182 and potentiation [122], neuromuscular performance measures such as the CMJ are useful for  
3183 investigating this balance, allowing for interpretation of whether force-production

3184 characteristics are preserved, enhanced, or impaired following RT priming [229]. However,  
3185 not all neuromuscular responses are expressed through changes in peak force, with time-  
3186 dependant characteristics, such as RFD, providing additional insight into how force is  
3187 expressed particularly when fatigue is present [243]. It is also important to contextualise  
3188 neuromuscular responses against performance actions with a more direct influence on sporting  
3189 outcomes. In golf, driver performance has been shown to be strongly related to underlying  
3190 physical capacities and may therefore be influenced by changes in neuromuscular function  
3191 [35]. In addition, perceptual measures of fatigue and readiness, and their adaptations, have  
3192 frequently been used to assess participants' perceptual states following RT priming  
3193 interventions [173,178,240]. Such perceptual effects are considered one of the proposed  
3194 mechanisms underpinning delayed potentiation and may therefore influence performance  
3195 independently of objective neuromuscular outputs [122]. Collectively, the inclusion of  
3196 neuromuscular, perceptual, and golf-specific measures enables a comprehensive evaluation of  
3197 the effects of RT priming interventions on performance.

3198 The aim of this study was to examine the effects of two modes of RT priming, strength (STR),  
3199 and power (PWR), on neuromuscular performance, golf-specific outcomes, and perceptual  
3200 outcomes at 2 h and 24 h post-training. Based on evidence indicating that baseline strength  
3201 may moderate responses to RT priming [152,178], it was hypothesised that: (1) inter-individual  
3202 variability in changes would be observed across measured outcomes following RT priming; (2)  
3203 baseline strength would be associated with the magnitude of individual changes in performance  
3204 outcomes; and (3) neuromuscular performance, golf-specific performance, and perceptual  
3205 readiness would be preserved following the low-volume RT priming interventions.

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## 3206 **6.3 Method**

### 3207 **6.3.1 Participants**

3208 Eight male participants were recruited to take part in this study (age:  $28.6 \pm 8.1$  years; height:  
3209  $182.8 \pm 7.3$ cm; mass:  $86.1 \pm 9.1$ kg; hexagonal bar deadlift 1RM:  $174.5 \pm 22.1$  kg; relative to  
3210 body mass hexagonal bar deadlift 1RM:  $2.05 \pm 0.3$  kg/BM). Participants were required to be  
3211 highly skilled amateur (handicap index:  $\leq 6.0$  strokes) or professional golfers. Participants were  
3212 also required to be able to perform the intervention exercises safely, and with the correct  
3213 technique which was screened in the familiarisation session. Five participants were amateur,  
3214 and three were professional golfers who were provided with a handicap of zero for the purpose  
3215 of this study (Handicap index:  $1.6 \pm 3.5$  strokes). Informed consent was obtained from all  
3216 golfers prior to participation, and ethical approval was granted by the University Ethics  
3217 Committee. All golfers were free from injury and maintained a regular pattern of golf training  
3218 throughout testing procedures.

3219 A power analysis was carried out using G\*Power (v3.1.9.7 for windows) to determine the  
3220 required sample size. Sample size estimation indicated that six participants were sufficient to  
3221 detect a within-factors effect in a repeated-measures design, assuming a partial eta-squared  
3222 ( $\eta^2$ ) of 0.533 for CMJ performance, as reported in previous comparable research [173,240],  
3223 with an alpha level of 0.05. to achieve a power of  $>80\%$ .

### 3224 **6.3.2 Overview**

3225 Experimental conditions were completed in a randomised cross-over design with pre and post  
3226 measures to examine the effects of low-volume lower-limb STR and PWR interventions, along  
3227 with a control condition of passive rest (Figure 6.1.). Participants visited the testing facilities  
3228 on ten separate occasions to carry out a familiarisation session and partake in the experimental  
3229 conditions. Golfers' driver CHS, BS, CD and self-reported shot quality scores were tested to  
3230 assess changes in sport specific performances at baseline, and then two-, and 24-hours post-

3231 intervention. The CMJ and IMTP tests were also implemented to assess changes in  
 3232 neuromuscular performance. Participants were additionally required to complete a perceptual  
 3233 readiness questionnaire at each time point. Experimental conditions were separated by a  
 3234 minimum of 48 hours, and a maximum of 7 days. Participants were instructed to not engage in  
 3235 any RT in the 72-hours prior to the familiarisation and testing sessions. Participants were also  
 3236 asked to refrain from high-intensity exercise throughout the testing period. All permitted  
 3237 exercise completed, including golf practice, was recorded and standardised across each  
 3238 condition. Similarly, participants were instructed to standardise their nutritional habits and  
 3239 timings across the three conditions and were asked about this during each visit to ensure their  
 3240 compliance with the instructions

<b>Familiarisation</b>	<b>Baseline</b>	<b>Priming/control</b>	<b>2 hours</b>	<b>24 hours</b>
	7.30 am-8.30am	8.30 – 9.00 am	11.00 – 12.00pm	9.00 – 10.00am
Informed Consent	Perceptions	<b>STR</b> 3x3 85%	Perceptions	Perceptions
Descriptive Data	Standardised warm-up	Hexagonal bar deadlift	Standardised warm-up	Standardised warm-up
Hexagonal bar deadlift 1RM assessment	Golf Shots	<b>PWR</b> 3x3 40%	Golf Shots	Golf Shots
Testing procedures familiarisation	CMJ	Hexagonal bar deadlift jump	CMJ	CMJ
	IMTP	<b>CON</b> Passive rest	IMTP	IMTP

3241 *1RM: 1-Repetition-Maximum; Perceptions: Perceptual Questionnaire; CMJ: Countermovement Jump; IMTP: Isometric*  
 3242 *Mid-Thigh Pull; STR: Strength intervention; PWR: Power Intervention; CON: Control Condition.*

3243 **Figure 6.1 Outline of study procedures.**

### 3244 **6.3.3 Familiarisation and Strength Testing**

3245 During the familiarisation session, participants signed the informed consent and PAR-Q  
 3246 documents, and descriptive measurements were recorded (i.e. body mass, height). A  
 3247 standardised warm-up was first administered and consistently used throughout each  
 3248 experimental condition prior to each intervention and testing session. The warm-up consisted  
 3249 of a series of dynamic stretches and exercises designed to activate and mobilise key muscle

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3250 groups and ranges of motion associated with the full golf swing. Dynamic stretches and  
3251 exercises lasted for approximately five minutes and consisted of clock lunges; overhead squats;  
3252 scapula wall slides; internal and external hip rotations and thoracic rotations; as detailed in  
3253 Langdown et al. [39].

3254 Two minutes rest was provided following the dynamic warm-up prior to the hexagonal bar  
3255 deadlift 1RM strength testing protocol. Using a previously outlined protocol [244], participants  
3256 were instructed to perform repetitions at 50% (1x10), 70% (1x5), 80% (1x3) and 90% (1x1) of  
3257 their predicted 1RM. Three minutes of rest were given between warm-up sets. After the warm-  
3258 up, participants completed maximal attempts at progressively higher loads until a failed attempt  
3259 occurred. Each 1RM attempt load was determined by the primary investigator, and study  
3260 participant based upon the previous attempt. A minimum 2.5 kg increase was required per  
3261 attempt. If the subjects were not able to execute the lift successfully, the weight was reduced  
3262 by a minimum of 2.5kg. Each participant was permitted up to five attempts to determine their  
3263 1RM. Five minutes of recovery were permitted between maximal effort attempts. Deadlifts  
3264 were performed with a conventional shoulder width stance. The lift was deemed successful if  
3265 at the end of the ascent of the movement, the participant stood erect with knees and hips fully  
3266 extended, torso upright, and shoulders retracted. This was visually monitored by the principal  
3267 investigator. Participants were permitted to wear a weightlifting belt during the assessment,  
3268 deadlifting shoes and chalk. This remained consistent for all experimental conditions. All  
3269 testing was performed using a standard 25-kilogram or 32-kilogram bar so as to enable multiple  
3270 participants to be tested within the same facility, with the midpoint of the bar equally standing  
3271 22.5cm from the ground. Participants consistently used either the 25kg or 32kg bar throughout  
3272 all testing procedures. Following the 1RM assessment, participants were familiarised with the  
3273 intervention exercises, and testing procedures.

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### 3274 **6.3.4 Experimental Conditions**

3275 Three separate conditions were implemented during this study, including a control condition  
3276 (CON) where no exercise was performed, and two experimental conditions including strength  
3277 and power-oriented RT priming activities. For the STR intervention participants performed  
3278 conventional hexagonal bar deadlifts as per the instructions provided in the 1RM testing  
3279 session. Warm-up sets of 1x4 repetitions at 50% and 70%, and 1x3 at 80% 1RM were  
3280 performed. Participants then performed 3x3 sets at 85% 1RM and were instructed to perform  
3281 each lift with maximal intent. For the PWR intervention, participants performed the hexagonal  
3282 bar deadlift jump exercise. Participants were instructed to grasp the bar firmly whilst assuming  
3283 a braced neutral spinal position throughout the movement. The jumps were performed with the  
3284 bar starting on the floor and participants being instructed to maximally jump as high as possible  
3285 with the bar in hand. Participants were instructed to reset their stance between repetitions.  
3286 Warm-up sets of 1x4 sub-maximal jumps at 20% and 30%, and 1x3 repetitions at 35% of  
3287 participants 1RM were initially performed prior to 3x3 jumps loaded at 40% 1RM and  
3288 performed with maximal intent. For each exercise, loads were approximated to the nearest  
3289 0.5kg. Inter-set rest intervals of 3 minutes were employed between work sets, with 2 minutes  
3290 recovery between each warm-up.

### 3291 **6.3.5 Testing Procedures**

#### 3292 **6.3.5.1 Perceptual Measures**

3293 Subjective readiness scores were recorded using the Short Recovery and Stress Scale (SRSS)  
3294 [245], using paper-based handouts. The SRSS measures the current recovery-stress state of an  
3295 individual multidimensionally with the use of items answered on a seven-point Likert scale  
3296 from '0' (does not apply at all) to '6' (fully applies). Items relating to an individual's recovery  
3297 include physical performance capability (PPC), mental performance capability (MPC),  
3298 emotional balance (EB), and overall recovery (OR), with higher scores indicative of greater

3299 recovery. Each item of the SRSS lists four adjectives as descriptors for context. For example,  
3300 the item “Physical Performance Capability” will have the descriptors of “strong, physically  
3301 capable, energetic, full of power.” The psychometric test is a valid and reliable assessment of  
3302 acute recovery and stress assessments in high performance sports [246].

### 3303 **6.3.5.2 Golf Driver Performance**

3304 A FlightScope Mevo+ (EDH, Inc., Orlando, FL, USA) launch monitor set up as per  
3305 manufacturer instructions was used to track golf shots using a driver club. The system was set  
3306 to short indoor mode, with the launch monitor placed 2.4m behind the ball. Titleist Pro V1x  
3307 Radar Capture Technology golf balls were used for all testing, which are specifically designed  
3308 for indoor use with radar-based launch monitors. Golfers used their own driver club for testing  
3309 and were blinded to all results. Shots were carried out on an artificial turf golf mat and into a  
3310 golf net. Participants were permitted a self-defined number of practice swings and instructed  
3311 to hit balls until they felt ready to begin testing. Participants maintained the same number of  
3312 warm-up shots throughout all testing procedures (12.5 + 3.5 shots), which was determined in  
3313 the familiarisation session. A selection of different golf tee heights was provided; however,  
3314 participants were required to select and maintain one height throughout all testing procedures.  
3315 After the warm-up three maximal shots with a driver were performed, separated by 60 seconds  
3316 for re-calibration of the launch monitor and for data recording by the principal investigator.  
3317 Participants were instructed to ‘hit the ball as hard as you can, whilst maintaining control’, and  
3318 were given an appropriate and standardised target point behind the net. In the event that any  
3319 data were missing from the launch monitor, participants were required to re-take shots.  
3320 Research has indicated that the FlightScope Mevo+ is valid when compared to the TrackMan  
3321 4 launch monitor (which is considered to be the ‘benchmark standard’), with near perfect  
3322 correlations between CHS and BS metrics ( $r \geq 0.96$ ), and very large correlations for CD ( $r =$   
3323 0.88) [247]. From a reliability standpoint, each of the metrics have also demonstrated

3324 acceptable levels of variability (Coefficient of variation < 10%). Consequently, CHS, BS and  
3325 CD metrics were recorded for analysis. For all measured shots, participants were also required  
3326 to provide a self-reported shot quality score (0-10), where 0 represented the worst possible shot  
3327 and 10 represented their best possible shot [248].

### 3328 **6.3.5.3 Neuromuscular Performance**

3329 Following the golf-specific testing, neuromuscular performance assessments of the CMJ and  
3330 then the IMTP tests were completed using VALD ForceDecks Mini dual force plate systems  
3331 (VALD Performance, Brisbane, Australia), sampling at 1000 Hz. For all testing procedures the  
3332 plates were zeroed before the participants stepped on. Participants were then instructed to place  
3333 one foot on each plate and stand still to record their body mass prior to testing.

#### 3334 **6.3.5.3.1 CMJ**

3335 For testing, three maximal CMJ attempts were recorded and separated by one minute to allow  
3336 for recovery and data recording. Participants were instructed to keep their hands on their hips  
3337 throughout the jump, and that knee and hip flexion were not permitted during the flight phase  
3338 of the jump. If any of these parameters were not followed, the test was repeated. Verbal  
3339 instruction was provided prior to testing, with instruction to adopt an erect standing position  
3340 with feet shoulder width apart and hands placed on hips. They then lowered themselves to a  
3341 self-selected depth, before immediately jumping as high as possible and with maximal intent.  
3342 A command of ‘3,2,1 jump’ was provided whereby participants were instructed to execute the  
3343 movement upon the command ‘jump’. Two practice trials were permitted prior to the testing.  
3344 CMJ positive takeoff impulse (“area above bodyweight in the takeoff phase”) and peak power  
3345 were recorded for analysis. Prior research has indicated that such measures have shown high  
3346 levels of reliability (ICC: 0.96 – 0.99), and validity when compared against ‘gold standard  
3347 laboratory quality force-plates’ (1% - 3% accuracy) [249].

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**3348 6.3.5.3.2 IMTP**

3349 Participants performed three maximal IMTP trials, with three minutes recovery between trials  
3350 following recommendations from Comfort et al. [250]. They were secured to an immovable  
3351 bar using lifting straps to prevent their hands from slipping while executing the motion. Prior  
3352 to data collection, participants performed three sub-maximal attempts for three seconds each  
3353 at 50, 75, and 90% of their perceived maximal effort, separated by one minute. Participants  
3354 were positioned into their second-pull position of the clean exercise, and the bar was then  
3355 adjusted up or down to assume optimal knee (125-145°) and hip (140-150°) angles, confirmed  
3356 using a universal goniometer. Once the lifting position was confirmed, participants took  
3357 “slack” from the bar and remained motionless. Participants were then instructed to “push your  
3358 feet into the ground as fast and as hard as possible” for 5 seconds. Each pull was initiated after  
3359 a countdown of “3, 2, 1 pull”. Verbal encouragement was provided during each attempt.  
3360 Between maximal attempts, participants sat on a chair but remained strapped to the bar to  
3361 maintain a consistent hand position. The maximum vertical force produced during each attempt  
3362 was reported as peak force, with the mean of three IMTP attempts used for statistical analysis.  
3363 Prior research has demonstrated that IMTP peak vertical force recorded using VALD ForceDecks  
3364 has shown to be highly reliable (test-retest reliability ICC: 0.99 [0.97-1.00] [249]) and valid  
3365 when compared against Hawkins Dynamics systems (difference 0.00% [0.00 to 0.01%]) [251].  
3366 RFD was calculated as the average rate of force increase, defined as the change in vertical force  
3367 divided by the change in time, across a time interval of 0–200 ms. This interval was selected  
3368 due to its previously reported significant relationship with CHS in skilled golfers, whereas  
3369 earlier RFD time intervals (0–50 ms and 0–100 ms) have been shown to demonstrate no  
3370 significant relationship with CHS [55]. Furthermore, RFD calculated over 0–200 ms has  
3371 demonstrated lower, though still relatively high, variability (CV = 10.5–14.5%) compared with  
3372 earlier time intervals, which have reported substantially greater variability (CV = 28.6–34.7%)

3373 in highly skilled golf populations [15,55]. Although variability remains higher for RFD  
3374 measures than for peak force, RFD (0–200 ms) was included to characterise time-dependent  
3375 force expression following RT priming, with interpretation undertaken with consideration.

#### 3376 **6.4 Statistical Analysis**

3377 Statistical analysis was performed using SPSS 27.0 (SPSS Inc., Chicago, IL, USA) with  
3378 statistical significance set at  $p \leq 0.05$ . Results are expressed as mean  $\pm$  standard deviation (SD).  
3379 Data reported during baseline were normally distributed as determined by the Shapiro–Wilk  
3380 test of normality. Variance and sphericity assumptions were checked with the Levene and  
3381 Mauchly tests. In the case of violation of the assumption of sphericity, significance was  
3382 established using the Greenhouse-Geisser procedure. A two-way repeated measures ANOVA  
3383 was performed to identify the effects of the RT priming interventions and control condition  
3384 (within participants: intervention x time). Partial eta-squared ( $\eta_p^2$ ) values were calculated to  
3385 compare effect sizes between the three conditions and classified as follows: small 0.01;  
3386 medium; 0.06; and large: 0.14. Bonferroni's post-hoc test was used to check pairwise  
3387 comparisons. Hedges' g effect sizes were calculated for the pre- and post-testing data and were  
3388 interpreted as follows:  $< 0.2$ , small 0.2–0.49, moderate 0.5–0.79, and large  $\geq 0.8$  in accordance  
3389 with suggestions from Cohen [175].

3390 ICC values and their respective 95% confidence intervals were calculated for neuromuscular  
3391 and golf-specific variables with the data obtained from baseline [222]. ICC values were  
3392 interpreted based on the following criteria: poor reliability,  $< 0.5$ ; moderate reliability, 0.5–0.75;  
3393 good reliability, 0.75–0.90; and excellent reliability,  $> 0.90$  [223]. In addition, measurement  
3394 variability was assessed at the individual level and quantified using the coefficient of variation  
3395 (CV), and interpreted in accordance with previously suggested thresholds:  $< 5\%$  = good  
3396 reliability, 5–10% = moderate reliability, and  $> 10\%$  = poor reliability [224]. CV values were

3397 used to describe the typical variability of neuromuscular and golf-specific measures at the time  
3398 of testing.

3399 Individual effects were also calculated using an individualised target-score framework,  
3400 consistent with the approach described in Chapter 5 [225,226]. For each participant and  
3401 outcome measure, target scores were calculated using the participant's within-condition  
3402 standard deviation obtained from the baseline testing, representing typical measurement  
3403 variability at the time of testing. Post-intervention values exceeding these individual target  
3404 thresholds were interpreted as changes beyond typical variability and were classified as  
3405 positive or negative based on the direction of change. Relationships between percentage  
3406 changes in neuromuscular and golf-specific variables following the RT priming interventions  
3407 and participants' relative hexagonal bar deadlift 1RM strength were examined using Pearson's  
3408 correlation coefficient ( $r$ ). The strength of the correlation coefficient was interpreted as:  $< 0.1$   
3409 = trivial,  $0.1-0.29$  = small,  $0.3-0.49$  = moderate,  $0.5-0.69$  = large,  $0.7-0.89$  = very large,  $> 0.9$   
3410 = nearly perfect [252].

## 3411 **6.5 Results**

### 3412 **6.5.1 Reliability of Outcome Measures**

3413 The reliability of outcome measures assessed at baseline demonstrated excellent reliability  
3414 across the STR, PWR, and CON conditions for all neuromuscular and golf-specific variables  
3415 ( $ICC > 0.90$ ), apart from IMTP RFD (0–200 ms), which demonstrated moderate reliability  
3416 ( $ICC = 0.59$ ) (Table 6.1).

3417 This pattern was similarly reflected in the individual-level CV results (Tables 6.4-6.6). IMTP  
3418 RFD (0–200 ms) demonstrated substantial levels of variability, with CV values exceeding 10%  
3419 in the majority of participants (6-8 of 8 participants) across the three experimental protocols.

3420 In contrast, all other outcome measures demonstrated CV values  $\leq 10\%$  across participants and  
 3421 protocols at baseline, indicating generally good to moderate measurement variability.

3422 **Table 6.1 Reliability of performance outcome metrics for measurements recorded at**  
 3423 **baseline between conditions**

Outcome Measures	ICC	CI 95%	
		Lower	Upper
CMJ Positive Takeoff Impulse (N.s.)	0.95	0.83	0.99
CMJ Peak Power (W)	0.99	0.96	1.00
IMTP Peak Force (N)	0.97	0.90	0.99
IMTP RFD (0-200ms)	0.59	0.17	0.89
Driver CHS (mph)	0.97	0.93	0.99
Driver BS (mph)	0.98	0.94	0.99
Driver CD (y)	0.97	0.87	0.99

ICC = intraclass correlation coefficient; CI 95% = 95% confidence interval; N.s = Newtons per second; mph = miles per hour; W = Watts; y = yards

### 3424 **6.5.2 Group-level, Neuromuscular, Golf-specific, and Perceptual Outcomes**

3425 Group-level neuromuscular, golf-specific, and perceptual outcomes following the three  
 3426 experimental conditions are presented in Tables 6.2 and 6.3 respectively. For neuromuscular  
 3427 performance variables, no significant condition  $\times$  time interactions were observed for any  
 3428 outcome ( $p > 0.05$ ). A significant main effect of time was identified for CMJ peak power ( $p =$   
 3429  $0.006$ ;  $\eta_p^2 = 0.113$ , Medium). Post-hoc analyses indicated higher values at two hours compared  
 3430 with baseline ( $p = 0.009$ ), with near-significant differences at 24 h ( $p = 0.056$ ). There was no  
 3431 significant effect of time for CMJ positive takeoff impulse or IMTP peak force ( $P > 0.05$ ). A  
 3432 significant main effect of time was also observed for IMTP RFD (0-200ms) ( $p = 0.042$ ;  $\eta_p^2 =$   
 3433  $0.45$ , Large). with post-hoc comparisons indicating lower values at 24 hours relative to  
 3434 baseline. Across all other conditions and time points, group-level effects in neuromuscular  
 3435 performance outcomes were non-significant. No significant differences were observed between  
 3436 protocols at any time point.

3437 For golf-specific performance outcomes, no significant condition  $\times$  time interactions were  
3438 observed for CHS, BS, or CD ( $p > 0.05$ ). Significant main effects of time were identified for  
3439 CHS ( $p = 0.020$ ;  $\eta_p^2 = 0.171$ , Large) and BS ( $p = 0.029$ ;  $\eta_p^2 = 0.155$ , Medium), with higher  
3440 values observed at two hours compared with baseline. No significant main effect of time was  
3441 observed for CD ( $p = 0.199$ ). No significant differences were observed for any protocol when  
3442 compared to baseline or between groups.

3443 No significant main effects of time or condition  $\times$  time interactions were observed for any of  
3444 the SRSS psychological readiness variables ( $p > 0.05$ ). A significant main effect of time was  
3445 observed for self-reported shot quality ( $p = 0.036$ ;  $\eta_p^2 = 0.146$  Medium), with higher scores  
3446 reported two hours following the STR intervention in comparison to baseline ( $p = 0.007$ ;  
3447 Hedges'  $g = 0.69$ ). However, this increase was not reflected in corresponding changes in  
3448 objective golf driver performance measures.

### 3449 **6.5.3 Individual-Level Neuromuscular and Golf-Specific Changes**

3450 Substantial inter-individual variability was observed across neuromuscular and golf-specific  
3451 performance outcomes following the CON, STR, and PWR interventions (Figure 6.2-6.3;  
3452 Tables 6.4-6.6). Across all interventions and time points, participants demonstrated a mixture  
3453 of positive and negative changes exceeding their individual target thresholds, with no outcome  
3454 displaying a consistent or uniform directional pattern across the sample.

#### 3455 **6.5.3.1 Positive Individual Changes**

3456 Following the STR intervention, the most consistent patterns of positive change beyond  
3457 individual target scores were observed in neuromuscular outcomes. At two hours post-  
3458 intervention, increases in CMJ positive take-off impulse were observed in 6/8 participants,  
3459 while CMJ peak power increased in 4/8 participants. In contrast, golf-specific outcomes were  
3460 comparatively stable, with increases in CHS and CD observed in only 2/8 participants. At 24

3461 hours post-intervention, CMJ peak power remained elevated in 5/8 participants, whereas golf-  
3462 specific outcomes remained largely unchanged, with positive changes observed in  $\leq 1/8$   
3463 participants.

3464 Increases in CMJ peak power were observed in 5/8 participants, and CHS increased in 4/8  
3465 participants at two hours after the PWR intervention, representing the highest frequency of  
3466 positive golf-specific performance changes across all protocols. However, at 24 hours post-  
3467 intervention, increases in CHS were observed in only 1/8 participants, and reductions in BS  
3468 and CD were observed in 3/8 participants.

3469 In the control condition, individual changes were also observed, but these were less consistent.  
3470 At both two hours and 24 hours post, CMJ peak power was increased for 3/8 participants,  
3471 whereas golf-specific outcomes were relatively stable, with positive changes observed in  $\leq 3/8$   
3472 participants at any time point.

### 3473 **6.5.3.2 Negative individual Changes**

3474 Negative individual changes beyond individual target thresholds were observed across all  
3475 protocols and time points and were more frequently observed 24 hours post-intervention. The  
3476 STR intervention demonstrated decreases most commonly in neuromuscular outcomes, with  
3477 reductions in CMJ positive takeoff impulse and IMTP peak force observed in 3/8 participants  
3478 at 24 hours, whereas decreases in golf-specific outcomes were less frequent ( $\leq 1/8$  participants).

3479 Negative changes were more frequently observed in golf-specific performance 24 hours after  
3480 the PWR intervention, with reductions in BS and CD in 3/8 participants, in addition to IMTP  
3481 peak force in 3/8 participants. Decreases were less commonly observed at two hours after the  
3482 PWR intervention. Less consistent patterns emerged across both the neuromuscular and golf-  
3483 specific outcomes following the control condition.

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**3484 6.5.4 Correlations**

3485 Pearson correlation coefficients were calculated between participants' relative hexagonal bar  
3486 deadlift 1RM strength and percentage changes in neuromuscular and golf-specific performance  
3487 outcomes at two and 24 hours following the STR and PWR interventions. No significant  
3488 relationships were observed between relative strength and changes in CMJ positive take-off  
3489 impulse, IMTP peak force, CMJ peak power, or driver CD at either two or 24-hours following  
3490 the STR or PWR interventions ( $p > 0.05$ ). Similarly, no significant associations were identified  
3491 between relative strength and changes in CHS following the STR intervention ( $p > 0.05$ ).

3492 In contrast, significant negative relationships were observed between relative strength and  
3493 changes in golf driver performance 24 hours following the PWR intervention. Relative strength  
3494 was negatively correlated with changes in CHS ( $r = -0.64$ ,  $p < 0.05$ ) and BS ( $r = -0.70$ ,  $p <$   
3495  $0.05$ ). No other statistically significant relationships were identified between relative strength  
3496 and performance changes following the PWR intervention.

3497  
3498**Table 6.2 Differences in neuromuscular and golf-specific performance outcomes following resistance training priming and control protocols**

	CON						STR					PWR				
	%	95% CI		Hedges' g	P Vs Pre	%	95% CI		Hedges' g	P Vs Pre	%	95% CI		Hedges' g	P Vs Pre	
CMJ Positive Takeoff Impulse (N.s)																
Pre	100.00					100.00					100.00					
2 h	100.49	97.39	103.58	0.18	> 0,99	102.27	99.18	105.42	1.19	0.224	100.40	97.38	103.52	0.16	> 0,99	
24 h	99.25	96.10	102.39	-0.08	> 0,99	100.14	96.94	103.34	0.08	> 0,99	98.82	95.65	101.99	-0.11	> 0,99	
CMJ Peak Power (W)																
Pre	100.00					100.00										
2 h	103.10	99.87	106.33	1.14	0.063	101.27	98.07	104.48	0.59	0.937	102.79	99.61	105.98	1.16	0.099	
24 h	103.03	99.91	106.14	0.97	0.059	101.32	98.23	104.41	0.60	0.837	100.93	97.85	104.00	0.71	> 0,99	
IMTP Peak Force (N)																
Pre	100.00					100.00					100.00					
2 h	97.75	95.01	100.50	-0.64	0.136	99.33	97.87	103.46	-0.24	> 0,99	99.78	96.96	102.60	-0.06	> 0,99	
24 h	100.06	96.86	103.23	0.02	> 0,99	97.85	94.59	101.10	-0.69	0.301	98.73	95.45	102.01	-0.36	0.979	
IMTP RFD (0-200ms)																
Pre	100.00					100.00					100.00					
2 h	97.49	95.01	100.50	0.15	0.812	99.33	97.87	103.46	-0.36	0.218	99.78	96.96	102.60	-0.19	0.604	
24 h	95.25	92.10	98.40	-0.66	0.031*	98.12	95.60	101.90	-0.59	0.044*	96.85	93.40	100.30	-0.48	0.067	

Driver CHS (mph)																
Pre	100.00						100.00					100.00				
2 h	100.97	99.63	102.30	0.70	0.220	100.38	99.05	101.71	0.25	> 0,99	101.08	99.76	102.40	0.74	0.136	
24 h	100.70	99.43	101.94	0.43	0.464	100.12	98.90	101.35	0.08	> 0,99	99.86	98.63	101.08	-0.12	> 0,99	
Driver BS (mph)																
Pre	100.00						100.0									
2 h	101.02	99.29	102.76	0.42	0.420	101.20	99.48	102.92	0.65	0.254	100.86	99.13	102.58	0.35	0.628	
24 h	101.29	99.79	102.78	0.62	0.107	100.53	99.05	102.01	0.26	> 0,99	100.12	98.64	101.61	0.06	> 0,99	
Driver CD (yards)																
Pre	100.00						100.00									
2 h	100.71	98.45	102.94	0.19	> 0,99	101.70	99.44	103.95	0.42	0.191	101.00	98.75	103.25	0.23	0.783	
24 h	100.15	97.53	102.76	0.04	> 0,99	100.23	97.60	102.86	0.05	> 0,99	100.43	97.80	103.06	0.12	> 0,99	

CON = Control; STR = Strength; PWR = Power; SD = Standard deviation; p vs Pre = p value for pairwise comparison with baseline, % = percentage change in relation to baseline values (100.00), Hedges' g = effect sizes in comparison to baseline

3500  
3501**Table 6.3 Differences in psychological readiness and self-reported shot quality outcomes following resistance training priming and control protocols**

	CON				STR				PWR			
	Mean	SD	Hedges' g	P vs Pre	Mean	SD	Hedges' g	P vs Pre	Mean	SD	Hedges' g	P vs Pre
Physical Performance Capability												
Pre	4.38	0.92			4.50	1.07			4.16	0.99		
2 h	4.88	0.64		0.327	4.75	0.89		> 0,99	4.38	0.74		> 0,99
24 h	4.63	0.74		0.969	4.38	1.06		> 0,99	4.50	0.93		0.432
Mental Performance Capability												
Pre	4.75	1.16			4.88	1.25			4.25	1.28		
2 h	5.13	0.64		0.659	5.00	0.76		> 0,99	4.75	1.04		0.319
24 h	4.63	0.74		> 0,99	5.00	0.53		> 0,99	4.50	1.20		> 0,99
Emotional Balance												
Pre	4.88	0.99		> 0,99	5.13	1.36			5.00	0.93		
2 h	4.88	0.99		> 0,99	5.25	0.89		> 0,99	5.13	1.25		> 0,99
24 h	5.00	0.76		> 0,99	5.38	1.06		0.969	5.38	0.92		0.432
Overall Recovery												
Pre	4.13	1.36		> 0,99	4.50	0.93			4.50	1.31		
2 h	4.25	0.71		> 0,99	4.63	0.92		> 0,99	4.25	1.28		> 0,99
24 h	4.63	0.74		0.516	4.25	1.39		> 0,99	4.75	1.04		> 0,99
Self-Reported Shot Quality												
Pre	6.67	1.27			7.00	1.26			6.79	1.18		
2 h	6.79	1.05	0.20	> 0,99	7.88	1.26	0.67	0.007*	6.92	1.42	0.10	> 0,99
24 h	6.54	1.49	-0.22	> 0,99	6.96	1.47	-0.15	> 0,99	6.79	1.75	0.00	> 0,99

CON = Control; STR = Strength; PWR = Power; SD = Standard deviation; p vs Pre = p value for pairwise comparison with baseline; \*=significant time effect in comparison to baseline, Hedges' g = effect sizes in comparison to baseline

3502 **Table 6.4 Individual neuromuscular and golf-specific changes following the control condition**

Outcome Measure	Participant	Baseline (Mean ± SD)	CV%	Target Score Threshold (±)	2h (Mean ± SD)	Real Change	24h (Mean ± SD)	Real Change
CMJ Positive Takeoff Impulse (N.s.)	1	383.33 ± 22.71	5.92	22.71	385.70 ± 13.53	↔	382.27 ± 5.05	↔
	2	378.93 ± 4.93	1.30	4.93	384.40 ± 6.81	↑	375.03 ± 7.01	↔
	3	415.13 ± 2.51	0.61	2.51	422.57 ± 5.54	↑	395.73 ± 11.13	↓
	4	345.27 ± 9.42	2.73	9.42	346.27 ± 3.09	↔	346.27 ± 3.09	↔
	5	360.43 ± 10.01	2.78	10.01	352.80 ± 10.25	↔	363.03 ± 8.95	↔
	6	254.83 ± 11.24	4.41	11.24	263.33 ± 4.64	↔	267.57 ± 3.34	↑
	7	334.97 ± 11.06	3.30	11.06	330.30 ± 9.49	↔	325.73 ± 4.90	↔
	8	342.17 ± 4.20	1.23	4.20	343.40 ± 5.00	↔	338.20 ± 1.32	↔
CMJ Peak Power (W)	1	3979.00 ± 227.87	5.73	227.87	4176.33 ± 79.22	↔	4128.33 ± 72.18	↔
	2	4426.33 ± 300.63	6.79	300.63	4817.00 ± 43.97	↑	4548.33 ± 212.90	↔
	3	5708.67 ± 36.83	0.65	36.83	5698.00 ± 43.49	↔	5639.00 ± 41.68	↓
	4	3805.00 ± 194.98	5.12	194.98	3879.67 ± 83.05	↔	3879.67 ± 83.05	↔
	5	4347.00 ± 92.58	2.13	92.58	4217.00 ± 69.46	↓	4434.00 ± 34.87	↔
	6	3105.33 ± 82.59	2.66	82.59	3190.00 ± 68.64	↑	3302.00 ± 50.74	↑
	7	4277.33 ± 160.95	3.76	160.95	4376.00 ± 36.37	↔	4469.00 ± 108.06	↑
	8	5070.67 ± 46.49	0.92	46.49	5441.00 ± 107.13	↑	5369.33 ± 170.03	↑
IMTP Peak Force (N)	1	2928.00 ± 101.73	3.47	101.73	2902.67 ± 47.69	↔	3046.00 ± 186.68	↑
	2	3552.00 ± 63.93	1.80	63.93	3449.33 ± 106.93	↓	3619.33 ± 34.93	↑
	3	3310.67 ± 184.45	5.57	184.45	3228.33 ± 171.51	↔	3262.33 ± 184.28	↔
	4	2431.33 ± 85.41	3.51	85.41	2441.33 ± 125.83	↔	2475.33 ± 101.03	↔
	5	2788.67 ± 40.86	1.47	40.86	2773.33 ± 62.78	↔	2727.33 ± 45.61	↓
	6	2296.00 ± 68.55	2.99	68.55	2208.00 ± 17.35	↓	2248.33 ± 51.48	↔
	7	2827.67 ± 47.06	1.66	47.06	2674.00 ± 67.73	↓	2731.00 ± 59.23	↓
	8	2447.00 ± 38.59	1.58	38.59	2397.00 ± 171.87	↓	2485.00 ± 59.76	↔
IMTP RFD (0- 200ms)	1	4415.00 ± 1708.57	38.70	1708.57	5898.33 ± 805.61	↔	3231.67 ± 1878.47	↔
	2	8200.00 ± 88.88	1.08	88.88	7261.67 ± 665.76	↓	6035.00 ± 145.69	↓
	3	6210.00 ± 612.64	9.87	612.64	5595.00 ± 317.65	↓	4976.67 ± 769.70	↓
	4	2870.00 ± 1382.15	48.16	1382.15	1415.00 ± 200.75	↓	1808.33 ± 292.50	↔
	5	2560.00 ± 799.03	31.21	799.03	2711.67 ± 1641.35	↔	2024.00 ± 929.41	↔
	6	3468.33 ± 812.92	23.44	812.92	2993.33 ± 744.69	↔	2511.67 ± 269.55	↓
	7	6058.33 ± 645.84	10.66	645.84	5240.00 ± 842.18	↓	3711.67 ± 292.50	↓
	8	2180.00 ± 431.34	19.79	431.34	1836.67 ± 864.67	↔	1908.33 ± 327.58	↔
Driver CHS (mph)	1	108.67 ± 0.31	0.28	0.31	109.93 ± 0.32	↑	111.10 ± 1.37	↑
	2	110.30 ± 1.15	1.05	1.15	112.53 ± 1.76	↑	109.77 ± 1.59	↔
	3	130.80 ± 1.75	1.34	1.75	130.90 ± 0.95	↔	131.93 ± 2.00	↔
	4	121.77 ± 1.33	1.09	1.33	119.90 ± 0.35	↓	120.97 ± 0.25	↔

	5	120.70 ± 2.60	2.15	2.60	123.20 ± 0.62	↔	122.37 ± 2.07	↔
	6	104.33 ± 0.42	0.40	0.42	104.63 ± 2.55	↔	104.50 ± 2.10	↔
	7	105.80 ± 2.96	2.80	2.96	108.90 ± 1.37	↑	106.97 ± 1.46	↔
	8	109.30 ± 2.19	2.01	2.19	110.47 ± 1.60	↔	110.47 ± 2.77	↔
Driver BS (mph)	1	160.43 ± 1.83	1.14	1.83	163.60 ± 2.62	↑	162.40 ± 0.85	↑
	2	164.27 ± 0.75	0.46	0.75	167.67 ± 2.66	↑	163.53 ± 3.40	↔
	3	190.73 ± 1.75	0.92	1.75	189.53 ± 8.33	↔	192.53 ± 1.82	↑
	4	175.77 ± 4.05	2.30	4.05	179.50 ± 2.49	↔	176.67 ± 3.59	↔
	5	176.47 ± 6.82	3.86	6.82	180.83 ± 2.21	↔	182.13 ± 3.65	↔
	6	152.97 ± 5.32	3.47	5.32	154.00 ± 4.74	↔	156.50 ± 2.42	↔
	7	153.67 ± 1.36	0.88	1.36	151.13 ± 4.70	↓	156.77 ± 3.13	↑
	8	163.40 ± 4.20	2.57	4.20	165.13 ± 3.93	↔	164.37 ± 4.15	↔
Driver CD (y)	1	255.83 ± 12.81	5.01	12.81	262.13 ± 14.30	↔	257.53 ± 3.06	↔
	2	266.90 ± 1.61	0.60	1.61	276.67 ± 6.01	↑	264.60 ± 4.52	↓
	3	313.07 ± 3.26	1.04	3.26	315.53 ± 11.88	↔	313.80 ± 6.73	↔
	4	287.53 ± 12.29	4.27	12.29	302.33 ± 3.49	↑	288.17 ± 8.67	↔
	5	294.33 ± 11.92	4.05	11.92	288.07 ± 15.16	↔	287.93 ± 15.12	↔
	6	247.57 ± 14.99	6.05	14.99	241.27 ± 7.87	↔	253.50 ± 6.61	↔
	7	246.47 ± 7.74	3.14	7.74	239.27 ± 5.41	↔	255.10 ± 6.88	↑
	8	269.47 ± 6.66	2.47	6.66	271.07 ± 7.87	↔	263.80 ± 20.83	↔

N.s = Newtons per second; mph = miles per hour; W = Watts; y = yards; Real Change = an individual change exceeding typical measurement error, as determined using reliability data (↑ increase, ↓ decrease, ↔ no meaningful change).

3503 **Table 6.5 Individual neuromuscular and golf-specific changes following the strength condition**

Outcome Measure	Participant	Baseline (Mean ± SD)	CV%	Target Score Threshold (±)	2h (Mean ± SD)	Real Change	24h (Mean ± SD)	Real Change
CMJ	1	379.60 ± 6.46	1.70	6.46	410.27 ± 13.77	↑	378.70 ± 9.70	↔
Positive	2	369.57 ± 3.18	0.86	3.18	373.27 ± 6.13	↑	367.97 ± 6.03	↔
Takeoff	3	407.20 ± 2.96	0.73	2.96	419.17 ± 8.16	↑	402.63 ± 3.61	↓
Impulse	4	319.43 ± 5.35	1.67	5.35	334.30 ± 2.62	↑	344.30 ± 2.57	↑
(N.s.)	5	358.13 ± 5.06	1.41	5.06	363.63 ± 6.38	↑	358.07 ± 7.52	↔
	6	263.90 ± 3.63	1.38	3.63	251.07 ± 9.58	↓	268.10 ± 2.50	↑
	7	308.37 ± 6.23	2.02	6.23	323.70 ± 7.46	↑	317.93 ± 1.70	↑
	8	361.57 ± 2.73	0.76	2.73	355.27 ± 4.62	↓	334.00 ± 8.22	↓

CMJ Peak Power (W)	1	4246.67 ± 71.67	1.69	71.67	4278.67 ± 95.30	↔	4031.00 ± 77.38	↓
	2	4576.33 ± 105.64	2.31	105.64	4724.33 ± 40.15	↑	4719.00 ± 71.04	↑
	3	5650.33 ± 29.50	0.52	29.50	5833.00 ± 86.02	↑	5550.33 ± 238.73	↓
	4	3830.67 ± 46.46	1.21	46.46	3692.00 ± 36.00	↓	3955.33 ± 30.57	↑
	5	4432.00 ± 75.19	1.70	75.19	4363.33 ± 212.27	↔	4470.00 ± 100.54	↔
	6	3064.00 ± 60.56	1.98	60.56	2983.00 ± 29.61	↓	3194.33 ± 35.73	↑
	7	4200.67 ± 174.18	4.15	174.18	4480.00 ± 108.06	↑	4378.00 ± 119.53	↑
	8	4989.33 ± 70.50	1.41	70.50	5081.67 ± 111.81	↑	5154.33 ± 65.07	↑
IMTP Peak Force (N)	1	3040.00 ± 34.60	1.14	34.60	3078.33 ± 7.09	↑	3047.33 ± 66.61	↔
	2	3370.33 ± 200.01	5.93	200.01	3275.67 ± 47.38	↔	3216.67 ± 10.02	↔
	3	3299.00 ± 138.75	4.21	138.75	3180.33 ± 42.67	↔	3026.67 ± 101.69	↓
	4	2431.00 ± 127.45	5.24	127.45	2411.00 ± 47.29	↔	2462.00 ± 59.57	↔
	5	2769.00 ± 103.70	3.74	103.70	2807.67 ± 72.17	↔	2582.00 ± 40.93	↓
	6	2124.33 ± 27.97	1.32	27.97	2062.33 ± 32.52	↓	2124.00 ± 25.51	↔
	7	2703.67 ± 21.08	0.78	21.08	2754.67 ± 103.85	↑	2717.67 ± 109.44	↔
	8	2460.33 ± 72.28	2.94	72.28	2479.33 ± 28.01	↔	2544.00 ± 96.14	↑
IMTP RFD (0-200ms)	1	3633.33 ± 1289.13	35.48	1289.13	3945.00 ± 457.96	↔	2960.00 ± 1792.30	↔
	2	7091.67 ± 1307.12	18.43	1307.12	6040.00 ± 1191.35	↔	3950.00 ± 670.00	↓
	3	5430.00 ± 412.52	7.60	412.52	5870.00 ± 1099.28	↑	3545.00 ± 978.81	↓
	4	2678.33 ± 327.27	12.22	327.27	1860.00 ± 790.74	↓	2413.33 ± 776.44	↔
	5	2867.50 ± 1467.25	51.17	1467.25	4445.00 ± 820.55	↑	2606.67 ± 1269.92	↔
	6	3302.00 ± 492.20	14.91	492.20	3556.67 ± 441.17	↔	3345.00 ± 508.85	↔
	7	4130.00 ± 677.00	16.39	677.00	4938.33 ± 300.51	↑	4433.33 ± 1521.27	↔
	8	2831.67 ± 735.29	25.97	735.29	2130.00 ± 808.25	↔	2050.00 ± 564.34	↓
Driver CHS (mph)	1	108.50 ± 0.46	0.42	0.46	108.27 ± 0.80	↔	107.30 ± 0.46	↓
	2	108.83 ± 1.54	1.41	1.54	111.70 ± 2.09	↑	111.87 ± 1.96	↑
	3	133.50 ± 2.18	1.63	2.18	137.43 ± 1.06	↑	134.93 ± 2.55	↔
	4	122.97 ± 0.85	0.69	0.85	120.37 ± 0.35	↓	123.30 ± 0.87	↔
	5	123.23 ± 1.65	1.34	1.65	123.30 ± 0.52	↔	122.93 ± 0.93	↔
	6	105.40 ± 1.23	1.17	1.23	104.63 ± 2.19	↔	104.53 ± 0.93	↔
	7	108.37 ± 2.84	2.63	2.84	108.47 ± 4.80	↔	106.63 ± 2.67	↔
	8	109.37 ± 1.58	1.45	1.58	109.47 ± 0.75	↔	109.80 ± 2.88	↔
Driver BS (mph)	1	159.67 ± 3.21	2.01	3.21	163.53 ± 1.70	↑	160.57 ± 1.63	↔
	2	162.07 ± 2.29	1.42	2.29	165.40 ± 1.42	↑	163.97 ± 5.80	↔
	3	194.60 ± 1.13	0.58	1.13	200.47 ± 0.90	↑	199.63 ± 1.10	↑
	4	181.77 ± 0.55	0.30	0.55	179.00 ± 0.95	↓	184.57 ± 1.70	↑
	5	175.17 ± 1.01	0.57	1.01	177.20 ± 1.55	↑	175.63 ± 3.07	↔
	6	156.90 ± 2.76	1.76	2.76	154.77 ± 4.70	↔	155.30 ± 3.55	↔
	7	154.30 ± 9.78	6.34	9.78	158.93 ± 8.16	↔	151.83 ± 4.62	↔
	8	163.37 ± 1.85	1.13	1.85	164.70 ± 2.43	↔	163.47 ± 4.30	↔
Driver CD (y)	1	249.10 ± 13.82	5.55	13.82	254.20 ± 12.67	↔	233.10 ± 22.88	↓
	2	253.43 ± 0.40	0.16	0.40	261.87 ± 5.28	↑	261.73 ± 17.59	↑
	3	317.07 ± 9.05	2.86	9.05	331.73 ± 3.58	↑	321.07 ± 9.35	↔

4	291.47 ± 20.77	7.13	20.77	295.67 ± 4.67	↔	308.10 ± 2.45	↔
5	284.07 ± 13.41	4.72	13.41	276.83 ± 5.69	↔	289.90 ± 8.75	↔
6	256.17 ± 6.91	2.70	6.91	254.33 ± 9.94	↔	249.73 ± 11.93	↔
7	248.17 ± 21.30	8.58	21.30	260.10 ± 16.02	↔	240.57 ± 10.07	↔
8	268.87 ± 4.47	1.66	4.47	270.37 ± 6.16	↔	269.20 ± 7.87	↔

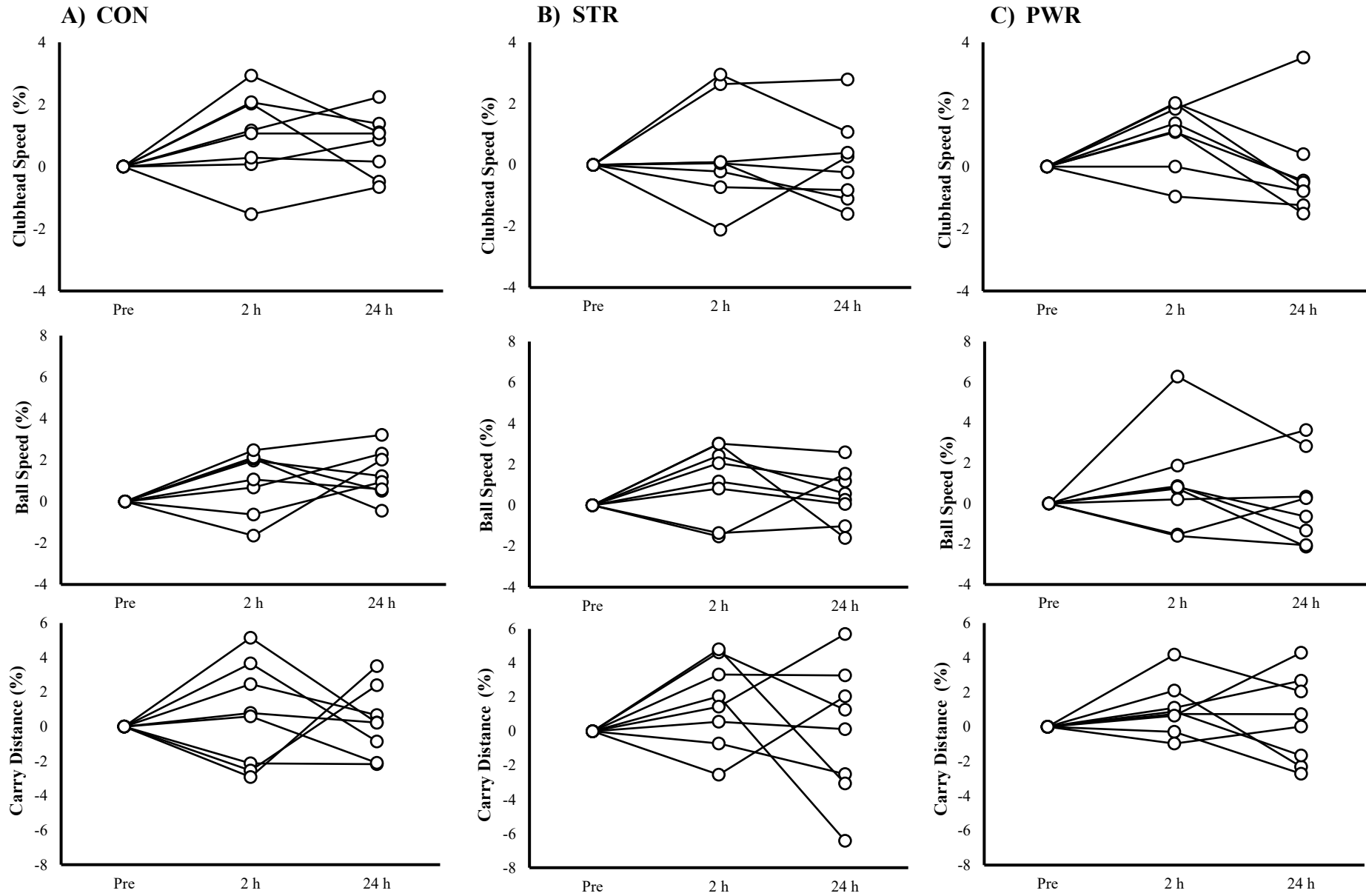
N.s = Newtons per second; mph = miles per hour; W = Watts; y = yards; Real Change = an individual change exceeding typical measurement error, as determined using reliability data (↑ increase, ↓ decrease, ↔ no meaningful change).

3504 **Table 6.6 Individual neuromuscular and golf-specific changes following the power condition**

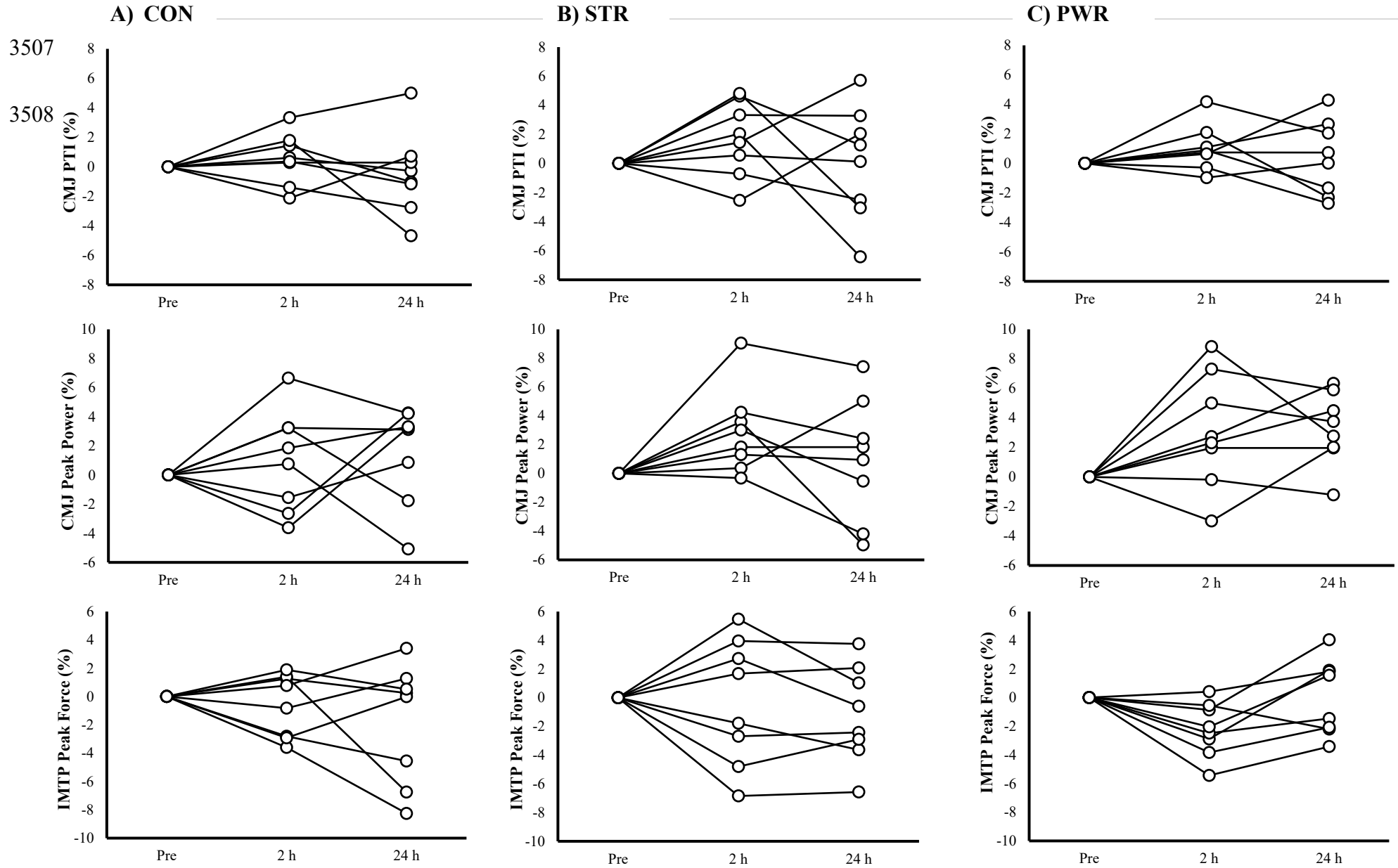
Outcome Measure	Participant	Baseline (Mean ± SD)	CV%	Target Score Threshold (±)	2h (Mean ± SD)	Real Change	24h (Mean ± SD)	Real Change
CMJ Positive Takeoff Impulse (N.s.)	1	398.70 ± 11.72	2.94	11.72	390.17 ± 8.00	↔	380.37 ± 8.04	↓
	2	357.90 ± 7.35	2.05	7.35	388.17 ± 6.25	↑	375.77 ± 4.08	↑
	3	413.67 ± 3.50	0.85	3.50	417.23 ± 6.95	↑	411.37 ± 9.99	↔
	4	325.20 ± 11.55	3.55	11.55	325.33 ± 8.75	↔	319.77 ± 11.90	↔
	5	376.80 ± 6.26	1.66	6.26	373.03 ± 4.28	↔	361.07 ± 5.22	↓
	6	265.03 ± 3.00	1.13	3.00	245.70 ± 14.18	↓	269.00 ± 3.61	↑
	7	332.80 ± 7.86	2.36	7.86	340.37 ± 4.66	↔	329.77 ± 13.55	↔
	8	324.00 ± 6.24	1.93	6.24	325.17 ± 11.18	↔	314.00 ± 18.22	↓
CMJ Peak Power (W)	1	4085.33 ± 79.41	1.94	79.41	4231.33 ± 86.03	↑	3882.33 ± 87.19	↓
	2	4487.50 ± 2.12	0.05	2.12	4893.00 ± 162.06	↑	4819.67 ± 65.68	↑
	3	5608.00 ± 84.33	1.50	84.33	5710.33 ± 139.16	↑	5710.33 ± 32.72	↑
	4	3727.33 ± 130.85	3.51	130.85	3741.00 ± 80.30	↔	3914.00 ± 17.35	↑
	5	4600.67 ± 37.87	0.82	37.87	4585.67 ± 63.79	↔	4407.33 ± 76.57	↓
	6	3130.67 ± 54.63	1.74	54.63	3263.33 ± 142.20	↑	3206.33 ± 50.33	↑
	7	4328.33 ± 88.64	2.05	88.64	4458.33 ± 105.95	↑	4305.00 ± 132.00	↔
	8	5225.00 ± 119.45	2.29	119.45	5293.00 ± 130.09	↔	5274.00 ± 117.05	↔
IMTP Peak Force (N)	1	3014.67 ± 54.85	1.82	54.85	2933.67 ± 34.12	↓	2941.67 ± 130.62	↓
	2	3132.33 ± 38.00	1.21	38.00	3303.67 ± 36.07	↑	3164.33 ± 106.82	↔
	3	3184.67 ± 51.32	1.61	51.32	3271.33 ± 20.21	↑	3165.67 ± 39.32	↔
	4	2527.33 ± 160.18	6.34	160.18	2354.33 ± 166.50	↓	2361.33 ± 78.42	↓
	5	2991.33 ± 121.82	4.07	121.82	2938.00 ± 116.05	↔	2882.67 ± 58.35	↔
	6	1991.33 ± 135.00	6.78	135.00	2070.00 ± 25.06	↔	2066.00 ± 191.95	↔
	7	2621.67 ± 41.48	1.58	41.48	2665.67 ± 91.28	↑	2676.00 ± 98.23	↑
	8	2528.33 ± 24.19	0.96	24.19	2407.00 ± 149.01	↓	2455.00 ± 52.68	↓

IMTP	1	4163.33 ± 704.31	16.92	704.31	5801.67 ± 982.50	↑	4500.00 ± 1228.00	↔
RFD (0-200ms)	2	4456.67 ± 1206.49	27.07	1206.49	4080.00 ± 942.55	↔	4103.33 ± 466.38	↔
	3	2903.33 ± 1010.82	34.82	1010.82	3363.33 ± 2507.87	↔	2813.33 ± 856.74	↔
	4	2443.33 ± 1062.56	43.49	1062.56	1831.67 ± 932.64	↔	2225.00 ± 776.21	↔
	5	4128.33 ± 2721.10	65.91	2721.10	3525.00 ± 1470.78	↔	3006.67 ± 1514.73	↔
	6	3893.33 ± 831.64	21.36	831.64	3323.33 ± 110.72	↔	4106.67 ± 581.41	↔
	7	4135.00 ± 745.00	18.02	745.00	4223.33 ± 255.26	↔	5265.00 ± 70.71	↑
	8	2323.33 ± 1188.22	51.14	1188.22	2506.67 ± 1821.79	↔	1961.67 ± 1147.24	↔
Driver	1	111.13 ± 0.80	0.72	0.80	112.37 ± 2.29	↑	110.63 ± 0.57	↔
CHS (mph)	2	108.83 ± 0.81	0.75	0.81	111.03 ± 0.15	↑	108.03 ± 0.45	↔
	3	136.20 ± 2.71	1.99	2.71	138.10 ± 0.10	↔	135.50 ± 0.26	↔
	4	118.73 ± 0.50	0.42	0.50	120.93 ± 1.40	↑	122.90 ± 1.67	↑
	5	122.33 ± 1.86	1.52	1.86	122.33 ± 0.64	↔	121.37 ± 1.70	↔
	6	107.33 ± 1.62	1.51	1.62	106.30 ± 2.90	↔	106.00 ± 0.62	↔
	7	107.47 ± 1.56	1.45	1.56	109.67 ± 0.90	↑	107.90 ± 0.26	↔
	8	108.03 ± 2.46	2.28	2.46	109.27 ± 3.01	↔	106.40 ± 2.52	↔
Driver BS (mph)	1	166.97 ± 1.75	1.05	1.75	168.40 ± 2.52	↔	164.73 ± 3.69	↓
2	162.50 ± 1.10	0.68	1.10	163.70 ± 3.27	↑	159.03 ± 3.16	↓	
3	195.70 ± 2.88	1.47	2.88	196.10 ± 4.77	↔	196.37 ± 0.35	↔	
4	176.30 ± 3.87	2.20	3.87	179.60 ± 1.95	↔	182.70 ± 2.30	↑	
5	178.17 ± 5.69	3.19	5.69	175.43 ± 2.32	↔	178.63 ± 1.88	↔	
6	160.30 ± 2.35	1.47	2.35	157.73 ± 4.58	↓	157.00 ± 1.73	↓	
7	147.23 ± 5.62	3.82	5.62	156.47 ± 3.97	↑	151.40 ± 5.65	↔	
8	159.53 ± 5.63	3.53	5.63	160.83 ± 6.59	↔	158.50 ± 3.77	↔	
Driver CD (y)	1	257.93 ± 5.25	2.03	5.25	263.33 ± 19.22	↑	251.97 ± 14.10	↓
2	264.30 ± 4.04	1.53	4.04	266.63 ± 10.10	↔	259.90 ± 6.59	↓	
3	320.00 ± 3.69	1.15	3.69	322.37 ± 8.30	↔	322.33 ± 5.20	↔	
4	291.23 ± 15.26	5.24	15.26	294.43 ± 7.71	↔	299.00 ± 8.70	↔	
5	275.47 ± 13.78	5.00	13.78	277.23 ± 10.15	↔	287.27 ± 8.43	↔	
6	262.70 ± 7.00	2.67	7.00	261.93 ± 7.59	↔	255.57 ± 5.86	↓	
7	238.13 ± 7.89	3.31	7.89	248.07 ± 19.99	↑	243.00 ± 12.54	↔	
8	260.87 ± 9.77	3.75	9.77	258.33 ± 19.67	↔	260.90 ± 10.04	↔	

N.s = Newtons per second; mph = miles per hour; W = Watts; y = yards; Real Change = an individual change exceeding typical measurement error, as determined using reliability data (↑ increase, ↓ decrease, ↔ no meaningful change).



**Figure 6. 2 Individual changes in the driver performance outcomes after the different protocols (CON, STR, PWR)** Panel A) Displays CON, panel B) displays STR, and Panel C) Displays PWR



**Figure 6.3 Individual changes in the neuromuscular outcomes after the different protocols (CON, STR, PWR)** Panel A) Displays CON, panel B) displays STR, and Panel C) Displays PWR

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## 3509 **6.6 Discussion**

3510 This study investigated the effects of two low-volume RT priming interventions on  
3511 neuromuscular performance, golf-specific outcomes, and perceptual readiness in skilled  
3512 golfers, when assessed two- and 24-hours post-exercise. To the authors' knowledge, this is the  
3513 first investigation to concurrently examine neuromuscular, golf-specific, and perceptual effects  
3514 of RT priming within a 24-hour period in a golf population. Based on previous research  
3515 suggesting that RT priming responses may be moderated by individual strength characteristics  
3516 [152,178], it was hypothesised that: (1) inter-individual variability in changes would be  
3517 observed across measured outcomes following RT priming; (2) baseline strength would be  
3518 associated with the magnitude of individual changes in performance outcomes; and (3)  
3519 neuromuscular performance, golf-specific performance, and perceptual readiness would be  
3520 preserved following the low-volume RT priming interventions. The findings of this study  
3521 partially supported the proposed hypotheses. Substantial inter-individual variability in  
3522 performance outcomes were observed, supporting the first hypothesis. However, these  
3523 individual changes were not consistently associated with relative strength values, contradicting  
3524 the second hypothesis. Finally, while group-level analyses indicated that performance  
3525 outcomes were largely preserved following both RT priming interventions, the individual-level  
3526 results highlight the importance of accounting for individual variability when applying these  
3527 strategies.

3528 The outcome measures assessed in the present study were selected to build on those reported  
3529 in Chapter 5, extending the examination of RT priming effects to include broader  
3530 neuromuscular, golf-specific, and perceptual readiness outcomes. The neuromuscular  
3531 performance outcomes included in this study were selected due to their previously established  
3532 relevance to golfers' CHS [35], and their sensitivity to both fatigue-related decrements and  
3533 potentiation-related performance changes [122,229,253]. In addition to CMJ-derived metrics,

3534 IMTP testing was included to further characterise lower-limb force-production characteristics.  
3535 While IMTP RFD has been shown to demonstrate greater sensitivity to fatigue-related  
3536 responses than peak force [253], prior research on skilled golfers has reported relatively high  
3537 variability for RFD 0–200 ms despite a significant association with CHS ( $r = 0.40$ ,  $CV =$   
3538  $14.5\%$ ) [55]. Consistent with these findings, the results of this study demonstrated only  
3539 moderate reliability alongside substantial measurement variability for IMTP RFD (0–200 ms),  
3540 as indicated by ICC and CV values, limiting the interpretation of both the group- and  
3541 individual-level results. Accordingly, while RFD (0–200 ms) was reported to contribute to the  
3542 broader evidence base regarding the utility of IMTP force–time metrics in golfers,  
3543 interpretation focused primarily on CMJ and peak force metrics, which demonstrated more  
3544 consistent measurement characteristics both within the present study and previous golf-specific  
3545 research [15,55].

3546 At the group level, neither the STR nor PWR intervention resulted in significant improvements  
3547 in neuromuscular or golf-specific performance two- or 24-hours post-training. These findings  
3548 contrast with previous research reporting performance improvements following externally  
3549 loaded jump-based priming protocols at similar recovery intervals[123,148,152,254].  
3550 Performance responses to RT priming are believed to reflect the balance between fatigue and  
3551 potentiation, with improvements occurring only when potentiation outweighs residual fatigue  
3552 [122,159]. Small variations in exercise selection, intensity, volume, recovery interval, and  
3553 participant characteristics can meaningfully influence this balance [122], making the effects of  
3554 RT priming difficult to predict. For example, studies reporting enhanced jump performance 24  
3555 hours post-training have typically employed higher volumes of squat jump loading (e.g.  $5 \times 4$   
3556 at 40% 1RM) in relatively strong individuals (average half squat relative 1RM: 2.0 - 2.2  
3557 kg/BM) [123,152,254]. Conversely, a recent study using lower-volume and lighter-load  
3558 intervention (4x3 at 20% 1RM) in moderately trained individuals (back squat relative 1RM:

3559 1.6 ± 0.2 kg/BM) [255], reported no performance enhancement, aligning with the results of  
3560 this study. These findings reinforce the view that group-level performance enhancements  
3561 following RT priming are highly variable and may not be consistently reproducible.

3562 Consistent with the results of this study, heavily loaded high-intensity RT priming activities  
3563 ( $\geq 80\%$  1RM) have generally shown to be ineffective in eliciting increases in neuromuscular  
3564 performance outcomes when measured 24 hours post-training [156,181,254]. However, at the  
3565 group level, the most notable effects of the RT priming interventions was observed two hours  
3566 following the STR protocol, where a significant increase in self-reported shot quality was  
3567 identified. This perceptual improvement occurred alongside moderate-to-large, non-significant  
3568 increases in CMJ peak power and CMJ positive takeoff impulse. These findings are broadly  
3569 consistent with the synthesis presented in Chapter 3, which suggested that higher-intensity RT  
3570 priming activities are most likely to influence same-day performance, typically within a four-  
3571 to eight-hour window and most commonly at six hours post-exercise following low volume-  
3572 load training (780-2155 AU). However, the findings of this study indicate that improvements  
3573 in self-reported shot quality and concurrent neuromuscular trends did not translate to consistent  
3574 group-level improvements in golf-specific performance, IMTP outcomes, or perceptual stress-  
3575 recovery states. While the two-hour assessment window was selected to reflect a practically  
3576 feasible opportunity for golfers to engage in RT prior to a tournament round, the shorter  
3577 recovery interval examined may have limited the expression of potentiation at the group level,  
3578 particularly if fatigue and potentiation co-existed at similar magnitudes during this period.

3579 In contrast to the absence of group-level significant effects, substantial individual variability  
3580 was observed across neuromuscular and golf-specific outcomes following both RT priming  
3581 interventions, with both positive and negative individual changes exceeding individual target  
3582 score thresholds [225,226]. These findings support the first hypothesis and are consistent with  
3583 previous research highlighting heterogeneous individual-level outcomes to RT priming

3584 interventions [152,178]. While group-level analyses remain important for characterising the  
3585 typical direction of effects and enabling comparison with existing literature, the individual-  
3586 level demonstrate that performance changes following RT priming are not uniform across  
3587 golfers.

3588 Individual increases in neuromuscular performance were most commonly observed in CMJ  
3589 performances (4-6/8 participants) two hours following the STR intervention. Given the  
3590 evidence from a recent meta-analysis identifying jump impulse ( $r = 0.82$  [95% CI 0.63–1.02])  
3591 and peak power ( $r = 0.66$  [95% CI 0.53–0.79]) as strong physical correlates of CHS in golfers  
3592 [35], it is plausible that individual increases in lower-body force-producing capabilities may  
3593 have contributed to the observed improvements in CHS and CD (2/8 participants). These  
3594 findings assist in contextualising the group-level trends reported earlier and suggest that, while  
3595 not consistently expressed across participants, RT priming may facilitate increases in  
3596 performance among certain individuals under specific conditions.

3597 However, these individual improvements should be interpreted with caution, due to the  
3598 relatively small number of participants demonstrating golf-specific performance increases, and  
3599 because changes exceeding individual target thresholds were also observed following the  
3600 control condition across multiple outcomes and time points. This suggests that factors beyond  
3601 the RT priming stimulus itself may have contributed to individual performance changes. For  
3602 example, previous research has shown that a maximal isometric half-squat RT priming  
3603 intervention may elicit delayed performance enhancements in some individuals, with  
3604 improvements in CMJ performance reported after three (5/15 participants) and 27 hours (6/15  
3605 participants) of recovery [255]. As such, it is possible that the testing procedures utilised in this  
3606 study at baseline, such as the IMTP, elicited a potentiating effect on subsequent performance  
3607 in some individuals. Additionally, circadian rhythm and chronotype (i.e. ‘morning’ or  
3608 ‘evening’ type) have been shown to influence the timing of peak force and power expression

3609 across the day[256,257], which may contribute to individual differences in responses at specific  
3610 times.

3611 While performance was largely maintained at the group level, consistent with the group-level  
3612 analyses, the individual-level findings indicate that RT priming reductions exceeding  
3613 individual target score thresholds were observed. Across both RT priming protocols, negative  
3614 performance changes were more commonly observed in neuromuscular measures with  
3615 reductions evident in two to three of participants per outcome at 24 hours following both STR  
3616 and PWR. Golf-specific decrements were less frequent but still evident, particularly following  
3617 the PWR intervention at 24 hours, where reductions in BS and CD were observed in three  
3618 participants. Accordingly, it cannot be assumed that performance will be uniformly preserved  
3619 following RT priming at the individual level. This has important implications for practitioners  
3620 seeking to apply RT priming as a micro-dosing training stimulus, as the potential benefits must  
3621 be weighed against the risk of individual performance decrements, particularly within the  
3622 context of individual sports such as golf. As such, the presence of both positive and negative  
3623 individual performance changes highlights the need to consider the factors that may influence  
3624 inter-individual variability in performance change following RT priming interventions.

3625 A key and somewhat unexpected result of this study was that individual performance responses  
3626 to RT priming were largely unrelated to participants' relative strength levels. Comparatively,  
3627 Nishioka & Okada. [152] reported increases in CMJ performance variables (3.1-19.0%) in a  
3628 stronger group (relative half squat 1RM: 2.22 [1.93–2.67] bm/kg), but not a weaker group  
3629 (relative half squat 1RM: 1.76 [1.37–1.92] bm/kg), 24 hours after a RT priming intervention  
3630 (5x4 squat jump 40% 1RM). Additionally, percentage changes in CMJ height were  
3631 significantly positively correlated with relative half squat strength ( $r = 0.612$ ). One explanation  
3632 proposed is that stronger individuals may exhibit greater resistance to fatigue following an RT  
3633 priming stimulus, thereby favouring potentiation-dominant performance changes. This may be

3634 underpinned by a greater proportion of type II muscle fibres [195], and enhanced neural  
3635 mechanisms such as increased excitation and potential for high threshold motor unit  
3636 recruitment [122], or phosphorylation of myosin regulatory light chains [230].

3637 The disparity between the findings of the present study and those reported by Nishioka and  
3638 Okada with respect to relative strength may be partly explained by differences in participant  
3639 characteristics. Although participants in the present study were relatively strong, factors such  
3640 as their RT age, exercise familiarity, the types of resistance training routinely performed, and  
3641 recent training exposure were not controlled for and may have influenced individual changes.  
3642 When an exercise task is relatively unfamiliar, neuromuscular efficiency may be reduced due  
3643 to suboptimal motor unit recruitment and coordination strategies, thereby increasing the overall  
3644 physiological demand of the task [258]. Further to this, unfamiliar movement patterns may  
3645 promote greater antagonist co-contraction, further increasing energy expenditure and  
3646 attenuating performance effects [193]. Although the participants in the present study shared a  
3647 similar demographic, the highly individualistic nature of golf as a sport likely leads to greater  
3648 disparities in these factors compared to that of team sport athletes, who typically follow more  
3649 standardised training programmes. As such, relative strength alone is unlikely to adequately  
3650 explain individual performance changes following RT priming within skilled golf populations,  
3651 and a broader consideration of training history and neuromuscular characteristics may be  
3652 required.

3653 A key contribution of the present study is that, despite some individual variability,  
3654 neuromuscular and golf-specific performance was largely preserved at the group level  
3655 following both strength- and power-oriented RT priming interventions, supporting the third  
3656 hypothesis and indicating that low-volume RT priming does not inherently reduce performance  
3657 in skilled golfers. In contrast to more traditional higher volume load RT sessions (2160–5040  
3658 AU), which have been associated with slow rates of neuromuscular recovery, elevated

3659 hormonal responses, and muscle damage, in some cases requiring longer than 48 hours to fully  
3660 resolve [155], the relatively low training volume load sessions employed in the present study  
3661 (665–1485 AU) were sufficient to preserve neuromuscular performance at both two and 24  
3662 hours post-training.

3663 From an applied perspective, the preservation of CHS, BS, and CD is particularly relevant  
3664 given their more direct contribution to golf performance. In addition to reductions in muscle  
3665 force-producing capacity, fatigue may also influence an individual's ability to execute motor  
3666 tasks through increased movement variability [259], changes in muscle activation, and altered  
3667 coordination strategies [260]. While CHS has been shown to account for 75% of the variance  
3668 in BS [33], other factors such as impact location, attack angle, and dynamic loft also play a role  
3669 [13]. Consequently, fatigue-induced increases in movement variability may negatively affect  
3670 golf-specific performance outcomes even in the absence of substantial neuromuscular  
3671 impairments. In this context, the present findings indicate that the RT priming protocols  
3672 employed largely did not adversely affect these performance outcomes when assessed post-  
3673 training.

3674 In elite sports, self-report surveys represent a cost-effective and practical method for  
3675 monitoring training response, mood, perceived internal load, and recovery–stress state [261].  
3676 The results of this study revealed that perceptual stress–recovery states were not significantly  
3677 altered following either the STR or PWR protocol, aligning with the observed preservation of  
3678 performance outcomes. Due to the many factors which may influence elite sporting  
3679 performance [262], these findings may provide practitioners with additional confidence that  
3680 the RT priming strategies employed can be implemented without detriment to perceived  
3681 readiness. This interpretation is consistent with previous RT priming research reporting  
3682 minimal or no changes in SRSS-derived perceptual outcomes [173,178,240].

3683 As such, these findings support the use of RT priming as a potentially effective micro-dosing  
3684 approach for maintaining, and in some cases developing, physical qualities during golfers' in-  
3685 season periods, while also highlighting that individual responses may vary and that  
3686 performance reductions in neuromuscular or driver-specific outcomes can occur in some  
3687 golfers. These findings directly inform the practical applications of the present study,  
3688 reinforcing the importance of pragmatic, individualised monitoring frameworks to identify  
3689 individual patterns of change, manage risk, and optimise the timing and selection of RT  
3690 priming strategies (e.g. strength- or power-oriented sessions) around tournament commitments.

## 3691 **6.7 Practical Applications**

3692 In the absence of clear predictors of individual changes following RT priming, such as baseline  
3693 strength characteristics, these findings support the use of individualised, practitioner-led  
3694 experimentation to guide the application of RT priming strategies within golf. Using the  
3695 framework adopted in this study, practitioners may implement low-risk and easily applied  
3696 individual monitoring approaches to evaluate the suitability and timing of RT priming for  
3697 individual golfers. In application, this could involve the use of individual target-score or  
3698 threshold-based approaches, wherein post-training changes are interpreted relative to each  
3699 golfer's typical variability. Such approaches commonly express variability relative to the  
3700 athlete's standard deviation across repeated assessments, assisting practitioners in determining  
3701 whether observed changes reflect 'true' change or natural variability [225,226]. This provides  
3702 a pragmatic means of contextualising the effects of RT priming strategies, without requiring  
3703 extensive testing batteries or overly complex statistical analysis in applied settings.

3704 From an outcome measure perspective, driver performance metrics such as those utilised in the  
3705 present study provide valid and reliable measures that are directly relevant to competitive  
3706 performance [11], and commonly form part of golfers' routine testing. Provided their validity  
3707 and reliability are established, these measures can be routinely monitored using commercially

3708 available launch monitors (e.g. FlightScope, Trackman) [247], further enhancing the feasibility  
3709 of consistent and regular monitoring. Additionally, neuromuscular assessments may provide  
3710 valuable contextual information regarding fatigue or potentiation responses following RT  
3711 priming. The CMJ, offers a time-efficient method of assessing performance and monitoring  
3712 fatigue [229]. Where force plates are available, their use is recommended; however, lower-cost  
3713 and more accessible alternatives may also be employed. Validated smartphone-based  
3714 applications (e.g. My Jump)[263,264] allow for relevant metrics such as net impulse to be  
3715 estimated using recently established calculation approaches, which is significantly related to  
3716 CHS ( $r = 0.69$ ) [227]. Brief perceptual measures of readiness and recovery, such as the SRSS  
3717 utilised in this study, may provide additional contextual insight beyond objective performance  
3718 testing alone. The combined use of objective and subjective monitoring enables practitioners  
3719 and golfers to better evaluate the perceived benefit-to-cost ratio of RT priming strategies and  
3720 to refine their application according to individual needs and preferences.

3721 Practitioner-led experimentation using this framework may be conducted outside of key  
3722 tournament commitments, such as during practice rounds or lower-priority competitive events,  
3723 minimising performance risk while informing decision-making in applied practice. Over time,  
3724 this approach may assist practitioners in identifying how individual golfers tolerate different  
3725 RT priming strategies and recovery windows. This may be particularly relevant when selecting  
3726 between strength- and power-oriented RT priming strategies within close proximity to  
3727 competition.

3728 Rather than applying RT priming uniformly, this individualised framework supports its use as  
3729 a targeted strategy to preserve, and in some contexts enhance, performance while maintaining  
3730 RT exposure during congested competitive schedules. While longer-term adaptations to micro-  
3731 dosing RT strategies were not examined in this study, the routine monitoring of a small number  
3732 of meaningful variables, may provide applied insight into whether the imposed stimulus is

3733 sufficient to maintain or develop key physical qualities during the in-season period. This  
3734 monitoring approach aligns with recent individualised case-series work in golf S&C literature,  
3735 where standard deviation-based thresholds have been used to interpret individual changes in  
3736 neuromuscular and golf-specific performance relative to baseline variability [265].

## 3737 **6.8 Limitations**

3738 This study is, to the authors' knowledge, the first to examine the effects of different modes of  
3739 RT priming exercises on both neuromuscular and golf-specific performance within a 24-hour  
3740 period. Despite its applied relevance, several limitations should be acknowledged. First, the  
3741 study lacked a mechanistic evaluation of hormonal and neurophysiological testing, limiting the  
3742 ability to determine the underlying mechanisms contributing to fatigue or potentiation  
3743 following the RT priming interventions. As such, the present findings are limited to observed  
3744 changes in performance and perceptual outcomes rather than explanatory physiological  
3745 processes. Second, although individual changes in neuromuscular and golf-specific  
3746 performance were observed following RT priming, baseline strength characteristics were not  
3747 significantly associated with the magnitude or direction of these changes, contrary to one of  
3748 the hypotheses of this study. This indicates that factors beyond maximal strength may influence  
3749 individual effects to RT priming in golf. Accordingly, variables such as RT age, exercise  
3750 familiarity and recent training exposure, may be worth consideration when applying RT  
3751 priming strategies.

3752 Additionally, performance was only measured at single time points, and as such it remains  
3753 unclear how neuromuscular and golf-specific performance may fluctuate over the duration of  
3754 a tournament round or across multiple consecutive days of competition. Further to this, this  
3755 study examined the effects of isolated RT priming sessions, and it currently remains unclear  
3756 whether repeated exposure to RT priming activities within the same competitive week, or

3757 across multiple weeks, may influence outcomes. Further investigation of the time course of RT  
3758 priming effects across extended competitive and training periods would therefore be of value.  
3759 Lastly, while driver related performance outcomes were the primary sport-specific  
3760 performance outcomes observed, other aspects of golf performance, such as short game and  
3761 putting, were not assessed. Future research may benefit from adopting a more holistic approach  
3762 to golf performance following RT priming protocols.

## 3763 **6.9 Conclusion**

3764 This study presents applied insight into the short-term effects of RT priming activities on  
3765 neuromuscular, golf-specific, and perceptual outcomes in skilled amateur and professional  
3766 golfers. When assessed two- and 24-hours following strength- and power-oriented RT priming  
3767 interventions, no consistent group-level performance changes were observed relative to the  
3768 control condition or baseline values. Accordingly, these findings do not support the use of the  
3769 specific RT priming protocols employed in this study as a reliable method for eliciting delayed  
3770 potentiation related increases in performance at the group level. Conversely, the interventions  
3771 were largely effective in preserving performance across the assessed outcomes, supporting the  
3772 feasibility of implementing low-volume RT strategies in close proximity to competition  
3773 without detracting from performance.

3774 At the individual level, meaningful changes in performance outcomes were observed, with both  
3775 increases and decreases evident following each RT priming intervention across both time  
3776 points. Importantly, the magnitude and direction of these changes were not consistently  
3777 associated with participants' maximal strength characteristics, indicating that factors beyond  
3778 strength alone may influence individual responses to RT priming. Such factors may include  
3779 RT age, exercise familiarity, recent training exposure, and characteristics of the RT priming  
3780 protocol, including volume, intensity, exercise selection, and recovery duration. As such, the

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3781 applied, individualised monitoring framework outlined in the Practical Applications section of  
3782 this chapter may assist practitioners in determining whether RT priming supports performance  
3783 preservation or potentiation for an individual golfer.

3784 Collectively, the findings support the utility of RT priming as a theoretical training-  
3785 management strategy, rather than a guaranteed acute means of enhancing performance. Within  
3786 congested competitive schedules, RT priming may offer practitioners a practical means of  
3787 maintaining exposure to RT during the in-season period without compromising short-term  
3788 performance, particularly where opportunities for traditional higher-volume training are  
3789 limited.

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3790 **7 Chapter 7 Conclusions, Practical Applications, and Directions**  
3791 **for Future Research**

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## 3792 7.1 Overall Summary

3793 Based on the findings presented in this thesis, it can be concluded that while S&C strategies  
3794 are relevant to supporting golf performance, their effectiveness in practice can be strongly  
3795 influenced by the constraints imposed by competitive golf schedules. Across the body of work,  
3796 it became evident that the primary challenge for golfers competing at the highest level is not a  
3797 lack of supporting evidence for the efficacy of strength- and power-oriented training, but the  
3798 feasibility of implementing such training during the in-season period without compromising  
3799 performance or readiness.

3800 The existing evidence base supports the importance of CHS for driver performance, with  
3801 implications for competitive outcomes through its influence on shot distance and its potential  
3802 contribution to reduced scoring across tournament rounds. Measures of muscular force  
3803 expression represent the physical characteristics most strongly associated with CHS [35], and  
3804 this relationship is supported by longitudinal evidence demonstrating that structured S&C  
3805 interventions can lead to meaningful increases in these physical attributes, CHS, and golf shot  
3806 outcomes [4]. However, examination of S&C practices across the competitive season  
3807 highlighted clear differences between in-season and off-season training perceptions (Chapter  
3808 4). Given the extended duration of the in-season period, combined with near-weekly  
3809 competition, travel demands, variable scheduling, and inconsistent access to equipment and  
3810 facilities, opportunities to apply training of sufficient intensity to maintain or develop these  
3811 physical qualities appear limited. Moreover, when RT is performed during the in-season,  
3812 higher-intensity training is frequently avoided due to concerns that accumulated fatigue may  
3813 negatively impact competitive performance. While this does not directly demonstrate  
3814 performance decrements, it does highlight a plausible risk that physical qualities underpinning  
3815 golf performance may be insufficiently supported across the competitive season. This context

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3816 underpins the central research–practice gap addressed within this thesis and provides the  
3817 applied rationale for evaluating practically feasible training strategies.

3818 The findings of this thesis support the proposed framework in which RT priming is viewed not  
3819 solely as a strategy for enhancing acute performance, but as a pragmatic approach for  
3820 preserving neuromuscular and golf-specific performance when RT is performed close to  
3821 competition. Across the experimental studies, low-volume strength- and power-oriented RT  
3822 priming interventions implemented within competition-relevant timeframes were associated  
3823 with the preservation of neuromuscular and golf-specific performance at the group level, while  
3824 acute performance enhancement was not consistently observed. Within this framework, the  
3825 absence of reliable enhancement is not interpreted as a limitation of RT priming. Instead, the  
3826 consistent preservation of performance supports its applied value as a feasible micro-dosing  
3827 strategy that allows for continued RT exposure within golfers' competitive schedules.

3828 Across both the systematic review and the experimental investigations, performance changes  
3829 following RT priming were characterised by substantial individual variability, evident across  
3830 neuromuscular and sport-specific outcomes. While group-level effects support its feasibility as  
3831 a training strategy, individual data demonstrated that changes were not consistent across  
3832 participants or conditions. This variability indicates that RT priming cannot be assumed to  
3833 preserve performance for all golfers and that it carries some degree of risk at the individual  
3834 level. Consequently, RT priming cannot be universally applied as a standardised strategy and  
3835 instead requires individual consideration when implemented in practice. The implications of  
3836 this variability, and the need for structured individual decision-making when applying RT  
3837 priming, are addressed in detail in Section 7.4.

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## 3838 **7.2 Overall Contribution of the Body of Work**

3839 The overall contribution of this thesis lies in integrating evidence synthesis, applied practice  
3840 insights, and experimental investigation to address the research-practice gap in implementing  
3841 S&C within competitive golf, while demonstrating the potential for RT priming to serve as a  
3842 practical training-management strategy within competitive contexts.

3843 While the existing literature provides strong support for the role of physical preparation in  
3844 enhancing CHS and golf shot outcomes, critical evaluation identified that many  
3845 recommendations are not consistently considered within the practical constraints of  
3846 competitive golf. Empirical examination of in-season practices, including original data  
3847 collected from elite professional golfers, further highlighted fatigue-related concerns, logistical  
3848 barriers, and scheduling demands that may limit the feasibility of higher-volume or higher-  
3849 intensity training approaches during competition periods. In doing so, this thesis provides  
3850 applied insights into the physical preparation practices and perceptions of golfers competing at  
3851 the highest level.

3852 Within this applied context, RT priming was examined not solely as a means of acute  
3853 performance enhancement, but as a strategy that may allow RT exposure to be maintained  
3854 without inducing meaningful decrements in performance. Across the experimental  
3855 investigations, acute enhancement was inconsistent and highly individual. However,  
3856 neuromuscular and golf-specific performance was largely preserved following low-volume  
3857 strength- and power-oriented interventions. Collectively, these findings advance understanding  
3858 of how S&C strategies can be implemented in competition-relevant timeframes, supporting RT  
3859 priming as a low-risk, micro-dosing training approach when guided by individual monitoring.  
3860 In doing so, this thesis contributes to a more applied understanding of S&C implementation in  
3861 golf, recognising performance preservation as a meaningful outcome within congested  
3862 competitive schedules.

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### 3863 7.3 Limitations

3864 The findings of this thesis should be interpreted within the applied and pragmatic context for  
3865 which the research was intended. The experimental studies were conducted with relatively  
3866 small samples of skilled amateur and professional golfers, limiting statistical power and the  
3867 detection of small acute effects at the group level. Nevertheless, group mean effects provided  
3868 an important reference point for contextualising observed changes relative to existing literature  
3869 and for determining whether the applied interventions were associated with systematic  
3870 performance enhancement, preservation, or impairment. Importantly, group-level analysis was  
3871 not interpreted in isolation. The substantial inter-individual variability observed across  
3872 neuromuscular and golf-specific outcomes highlights a key limitation of relying exclusively on  
3873 averaged data when evaluating RT priming protocols, reinforcing the value of parallel group  
3874 and individual interpretation and supporting the framing of RT priming as a strategy requiring  
3875 individualised application within golf-specific contexts.

3876 The short-term focus of the experimental interventions further constrains inference regarding  
3877 longer-term training adaptations, cumulative fatigue, or repeated exposure effects across  
3878 competitive schedules, limiting the conclusions of this thesis to acute and sub-acute  
3879 performance changes. In addition, while mechanistic investigation may enhance understanding  
3880 of fatigue and potentiation processes underpinning RT priming, such approaches are resource-  
3881 intensive and may be most appropriate when consistent and practically meaningful group-level  
3882 effects are evident. Indeed, the heterogeneous nature of individual changes limits the  
3883 immediate value of detailed mechanistic exploration, as no dominant direction of change was  
3884 observed. From a pragmatic perspective, this reinforces the applied value of the valid, field-  
3885 based performance measures employed, which allow practitioners to monitor relevant  
3886 neuromuscular and golf-specific performance changes directly within applied settings.

3887 Furthermore, although golf-specific performance outcomes were selected to maximise applied  
3888 relevance, they represent proxy indicators of performance, rather than direct indicators of  
3889 competitive success. Competitive golf performance is inherently multifaceted, with outcomes  
3890 influenced by a wide range of technical, tactical, psychological, and contextual factors,  
3891 including short-game proficiency, putting performance, decision-making, and competitive  
3892 pressure, which are difficult to isolate and control experimentally. Consequently, the findings  
3893 of this thesis reflect the influence of RT priming on selected physical and golf-specific  
3894 performance characteristics, rather than overall competitive performance.

3895 In addition, the survey and observational findings may disproportionately reflect the practices  
3896 and perceptions of golfers already engaged in structured RT and may not adequately reflect the  
3897 views of golfers operating on other major tours. Similarly, while the dual focus of the  
3898 systematic review on both performance enhancement and performance preservation enhances  
3899 applied relevance, it may also constrain the interpretation of individual study findings outside  
3900 the specific competitive contexts for which they were intended. In summary, these limitations  
3901 provide important context for the interpretation and application of the findings of this thesis,  
3902 reflecting the necessary methodological constraints inherent to applied research conducted  
3903 within competitive golf performance environments.

#### 3904 **7.4 Practical Applications**

3905 The findings of this thesis provide several important implications for practitioners working  
3906 with competitive golfers, particularly during the in-season period. RT priming can usefully be  
3907 applied as a pragmatic training-management strategy for maintaining RT exposure and  
3908 neuromuscular readiness during congested tournament schedules. In applied settings, low-  
3909 volume RT sessions may be strategically scheduled on the morning of, or the day preceding,  
3910 competition without incurring systematic reductions in neuromuscular function, golf-specific

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3911 driver performance, or perceptual readiness. This supports RT priming as a low-risk approach  
3912 to maintaining physical preparation when traditional higher-volume training is avoided.

3913 Where the primary objective is performance preservation and training continuity, both  
3914 strength- and power-oriented RT priming approaches appear viable. In practice, this is likely  
3915 to involve brief sessions comprising a small number of multi-joint exercises, low overall  
3916 volume, and sufficient inter-set recovery to maintain movement quality and intent. Such  
3917 sessions may allow for key neuromuscular qualities to be retained while minimising residual  
3918 fatigue, making them more feasible than traditional higher-volume RT when implemented in  
3919 close proximity to tournament rounds. Their time-efficient structure also aligns with the  
3920 scheduling and logistical constraints commonly reported during tournament weeks.

3921 Importantly, the selection of RT priming modality does not need to be dictated by an  
3922 expectation of acute potentiation. Instead, decisions regarding exercise selection, loading  
3923 strategy, and movement intent may be guided by practical considerations such as equipment  
3924 availability, time constraints, athlete preference, and technical familiarity, alongside longer-  
3925 term training priorities. From a load-management perspective, this supports the deliberate use  
3926 of low overall training loads, monitored relative to a golfer's typical RT exposure using  
3927 sessional AU, thereby reducing the likelihood of excessive fatigue accumulation during  
3928 tournament weeks.

3929 While RT priming should likely not be prescribed with the expectation of consistent  
3930 performance enhancement in golf, performance increases, when observed, appear to occur  
3931 under specific combinations of training intensity and recovery timing. Strength-oriented  
3932 priming involving relatively high external loads ( $\geq 80\%$  1RM) has most commonly been  
3933 associated with same-day performance increases, typically when implemented within  
3934 approximately two to eight hours post-training. In contrast, power-oriented approaches (e.g.

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3935 squat jump 30-40% 1RM), have more frequently been associated with next-day increases in  
3936 performance. However, given the substantial inter-individual variability consistently reported  
3937 across the literature and observed within the present thesis, these patterns should be interpreted  
3938 as contextual rather than prescriptive and evaluated through individual monitoring rather than  
3939 applied as fixed rules.

3940 The substantial inter-individual variability observed across the studies in this thesis  
3941 underscores the importance of individualised interpretation when implementing RT priming  
3942 strategies. In the absence of reliable predictors of individual performance change, post-priming  
3943 changes should be evaluated relative to each golfer's typical variability rather than fixed group-  
3944 level benchmarks. An applied monitoring framework based on standard deviation-derived  
3945 thresholds may therefore support practitioner-led decision-making within variable competitive  
3946 environments.

3947 Practitioners are encouraged to interpret neuromuscular and golf-specific performance data  
3948 alongside subjective indicators of readiness, fatigue, and perceived preparedness. The CMJ  
3949 assessment may provide contextual insight into fatigue or potentiation responses and, in the  
3950 absence of force plates, can be obtained validly and reliably using lower-cost, validated  
3951 smartphone-based applications, making this approach particularly suitable for applied golf  
3952 environments. Similarly, golf-specific performance measures, including CHS, BS, and CD, can  
3953 be monitored using commercially available launch monitors with established validity and  
3954 reliability in applied settings.

3955 Lower-priority competitive events, practice rounds, or off-season periods may provide  
3956 appropriate opportunities for practitioner-led experimentation with different RT priming  
3957 intensities, modalities, and recovery timings, while minimising the risk of performance  
3958 impairment. Over time, information derived from such monitoring may inform more confident

3959 application of RT priming closer to competition and enable practitioners to track responses to  
3960 repeated sessions imposed across a tournament micro-cycle. This individualised approach may  
3961 also assist practitioners in determining whether repeated micro-dosed RT exposure is sufficient  
3962 to maintain, or in some cases progress, key physical qualities during the in-season period.

## 3963 **7.5 Directions for Future Research**

3964 Future research should seek to build on the findings of this thesis by examining the longitudinal  
3965 application of RT priming strategies across extended in-season periods. Specifically,  
3966 investigating whether repeated low-volume RT exposures can maintain, or in some cases  
3967 contribute to the development of, key physical qualities when compared with more traditional  
3968 higher-volume approaches scheduled earlier in the week would provide valuable insight into  
3969 the long-term utility of RT micro-dosing strategies in golf. This may be especially suited to  
3970 case series designs, allowing for detailed examination of individual changes over time within  
3971 elite golfers operating under real-world competitive constraints.

3972 Further work is also warranted to better characterise individual factors that influence responses  
3973 to RT priming. Variables such as training history, familiarity with specific exercises, recent  
3974 training load, and baseline neuromuscular characteristics may contribute to the observed  
3975 variability in individual change and should be explored to support more precise  
3976 individualisation of priming strategies. In addition, future studies should examine the  
3977 cumulative effects of in-season RT exposure across consecutive training and competition days.  
3978 Specifically, research is needed to explore how varying the distribution and focus of RT  
3979 sessions, such as alternating upper and lower body emphasis across successive days, influences  
3980 fatigue accumulation, neuromuscular performance preservation, and golf-specific outcomes.  
3981 Understanding how diverse RT exposures interact cumulatively may help clarify how much  
3982 RT can be tolerated and scheduled without compromising performance.

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3983 Future research could consider RT priming, as applied in the present thesis, for its potential  
3984 dual role as both a means of maintaining RT exposure and preserving neuromuscular  
3985 performance during congested competitive schedules. This conceptualisation may be of  
3986 relevance in other sports characterised by extensive in-season competition, such as soccer,  
3987 basketball, and tennis, where opportunities for traditional higher-volume RT are similarly  
3988 constrained. Finally, future research examining RT priming should prioritise approaches that  
3989 integrate both group-level effects with individual-level changes, recognising that the absence  
3990 of group-level performance enhancement does not preclude meaningful individual responses.

## 3991 **7.6 Conclusions**

3992 In conclusion, this thesis demonstrates that while strength- and power-oriented S&C strategies  
3993 are relevant to supporting golf performance, their implementation within competitive  
3994 environments is strongly influenced by practical constraints. Across the body of work, RT  
3995 priming did not reliably enhance acute neuromuscular or golf-specific performance. However,  
3996 neuromuscular and golf-specific performance was often preserved following low-volume  
3997 strength- and power-oriented interventions. Within the applied framework adopted in this  
3998 thesis, the preservation of performance represents a meaningful and valuable outcome. By  
3999 reframing RT priming as a low-risk micro-dosing strategy rather than solely as a performance  
4000 optimisation tool, this work provides an evidence-informed and practically relevant approach  
4001 to maintaining physical preparation during competitive golfers extensive in-season period.  
4002 Collectively, these findings help bridge a key research–practice gap within golf S&C literature  
4003 and offer a realistic framework for integrating RT within the practical constraints of  
4004 competitive golf.

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4790

4791 **APPENDIX A**

Dear All,

In attempts to understand players training habits in and out of season and how this may influence players performance in tournament, a 5-10 minute survey will be distributed by the player relations team at both the Valderrama (Spain) and St. Andrews (Scotland) European tour events. Although the survey will be distributed at multiple events, each player will only be required to complete the survey once. If you would like to complete this survey prior to the distribution at the stated tournaments, an attachment can also be found in the link below...

[https://essex.eu.qualtrics.com/jfe/form/SV\\_eQCy5JRbqv1G03H](https://essex.eu.qualtrics.com/jfe/form/SV_eQCy5JRbqv1G03H)

If you would like further information on how your training habits could improve your performance please drop in and speak to the Strength & Conditioning team from the European Tour Performance Institute, or contact Daniel Coughlan directly via email: [dan@fortiusperformance.com](mailto:dan@fortiusperformance.com) or phone: 07794360151.

Kind Regards,

4792 ...|



## How Do You Train?

Access the survey by following the QR code above!

For further information on how your training habits could improve your performance, please drop in and speak to the Strength & Conditioning team from the European Tour Performance Institute or contact Daniel Coughlan directly via email: [dan@fortiusperformance.com](mailto:dan@fortiusperformance.com) or phone: 07794380151.

Follow the QR code to the survey using your iPhone camera or a QR reading App.

---

4795 **APPENDIX C**

4796 **Participant information sheet**

4797

4798 **Study Title:** *how do you train?*

4799 **How have I been selected?**

4800 Participants have been selected as elite standard golf players participating in tournaments including European tour events and other tournaments of a  
4801 similar standard

4802 **Do I have to take part?**

4803 You are under no obligation to take part in this study and are free to leave the study at any point in time during the study without explanation if you choose  
4804 to take part.

4805 **What will I have to do?**

4806 Participants in this study will be required to complete a digital or hard copy survey with questions relating to their training habits throughout the season  
4807 and off-season.

4808 **What if there is a problem?**

4809 If any problems regarding the study arise, please contact the supervisor for this study who will be able to assist you; Sean White, email:  
4810 swhitee.st@outlook.com, tel. 07496638495. If you feel it more appropriate to speak to the Head of the School of Sport, Rehabilitation and Exercise Sciences  
4811 (Tel 01206 87-2410; e-mail i.w.maynard@essex.ac.uk), or to Sarah Manning-Press, Research Governance and Planning Manager, Research and Enterprise  
4812 Office (tel 01206 87-3561; e-mail sarahm@essex.ac.uk).

4813 **Will my taking part in the study be kept confidential?**

4814 Participants privacy will be respected if they chose to partake in this study. The personal data recorded by participants will be aggregated after two weeks  
4815 of the study finishing. Any information concerning a participant's personal identification will be securely destroyed by administrators within the School of  
4816 Sport, Rehabilitation, and Exercise Sciences following this two-week period. The dataset will only include the participant's identification number and will be  
4817 stored on a password protected PC only accessible by the PI, Sean White, and in very rare cases, a member of the academic governance team at the  
4818 University of Essex. Personal identity data and written consent documents will be stored digitally under a password protected PC. Any identifying  
4819 information will be securely destroyed by administrators within the School of Sport, Rehabilitation, and Exercise Sciences within two-weeks of the  
4820 conclusion of the data collection phase. Only the aforementioned individuals will have access to any identifiable data collected and we appreciate that a  
4821 failure to achieve this will likely results in a violation of the Data Protection Act. Once data collection has finished, the dataset will be anonymised and  
4822 aggregated so to maintain confidentiality and may be stored under the aforementioned conditions by the studies supervisors for up to six-years. Data may  
4823 also be used for publishing purposes.

4824

4825

4826 **CONSENT FORM FOR PARTICIPANTS**

4827

4828 Materials gathered during this research will be treated as confidential and securely stored.

4829 Please answer each statement concerning the collection and use of the research data.

4830

4831 1. I have read and understood the information sheet

4832 2. I have been given the contact details of the research team, so I can ask questions about the study

4833 3. I know that I am free to choose whether to participate in the project

4834 4. I understand that I can withdraw from the research at any time

4835 5. I agree to participate in this study

4836  Yes4837  No4838 **Q1 - How many years have you followed a structured resistance training plan for?**4839  I Haven't  1-2 Years  3-4 Years4840  0-1 Year  2-3 Years  4+ Years

4841

4842 (Only answer Q2 if "I Haven't" was selected for Q1)

4843 **Q2 - Why do you not follow a resistance training plan?** (multiple answers may be selected)4844  Time constraints  Fear of injury4845  Fatigue  Resistance training will worsen golf performance4846  I would rather practice golf  Resistance training will not improve golf performance4847  Lack of facilities Other -

---

4848 (Skip Q3 if Q2 was answered)

4849 **Q3 – Why do you resistance train?** (multiple answers may be selected)

4850  Improve strength     Improve cardiovascular fitness     Improve flexibility

4851  Improve power     Increase muscle mass     Improve balance/co-ordination

4852  Stay healthy     Improve swing technique     Maintain Performance

4853  Decrease body fat     Improve club head speed/

4854 driving distance

Other -

4855 **Q4 - Do you resistance train during the off-season?**

4856  Yes

4857  No

4858  Sometimes

4859

4860 (Skip Q5 if “Yes” was answered for Q4)

4861 **Q5 - Why would you not train during the off-season?** (multiple answers may be selected)

4862  Time constraints     Fear of injury

4863  Fatigue     Resistance training will worsen golf performance

4864  I would rather practice golf     Resistance training will not improve golf performance

4865  Lack of facilities

Other -

4866  I only Resistance train during the season

4867 (Skip Q6 if “No” was answered for Q4)

4868 **Q6 - How many times do you resistance train per week during the off-season?**

1 Time	2 Times	3 Times	4 Times	5 Times	6 Times	7+ Times
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4869 **Q7 - Which of the following fitness activities do you prioritize during off-season training?** (multiple answers may be selected)

4870 (Examples in brackets)

4871

4872  **Heavy load/low volume resistance training**       **Aerobic exercise**

4873 (3x3 back squats at 85% 1RM)      (running/cycling/swimming)

4874  **Low load/high volume resistance training**       **Proprioception**

4875 (3x10-15 lunges)      (balance/ co-ordination/ movement-quality)

4876  **Weighted explosive training**       **Mobility**

4877 (weighted squat jumps/ballistic bench press throws) (Range of motion exercise/stretching)

4878  **Body-weight explosive training**       **Resistance band exercise**

4879 (box jumps / drop jumps)      (shoulder rotation / crab walk)

4880  **Other**

4881

4882 **Q8 – What are your key goals for training during the off-season?**

4883 (multiple answers may be selected)

4884

4885  Improve strength     Improve cardiovascular fitness     Improve flexibility

---

4886  Improve power       Increase muscle mass       Improve balance/co-ordination

4887  Stay healthy       Improve swing technique       Maintain Performance

4888  Decrease body fat       Improve club head speed/  
4889 driving distance

Other -

4890

4891 **Q9 - Do you resistance train during the season?**

4892  Yes

4893  No

4894  Sometimes

4895

4896 (Skip Q10 if “Yes” was answered for Q9)

4897 **Q10 - Why would you not resistance train during the season?** (multiple answers may be selected)

4898  Time constraints       Fear of injury

4899  Fatigue       Resistance training will worsen golf performance

4900  I would rather practice golf       Resistance training will not improve golf performance

4901  Lack of facilities

Other -

4902  I only Resistance train during the off-season

4903 (Skip Q11 if “No” was answered for Q9)

4904 **Q11 - How many times do you resistance train per week during the season?**

1 Time      2 Times      3 Times      4 Times      5 Times      6 Times      7+ Times

4905 **Q12 - Which of the following fitness activities do you prioritize during in-season training?** (multiple answers may be selected)

4906 (Examples in brackets)

4907

4908  **Heavy load/low volume resistance training**       **Aerobic exercise**

4909 (3x3 back squats at 85% 1RM)      (running/cycling/swimming)

4910  **Low load/high volume resistance training**       **Proprioception**

4911 (3x10-15 lunges)      (balance/ co-ordination/ movement-quality)

4912  **Weighted explosive training**       **Mobility**

4913 (weighted squat jumps/ballistic bench press throws) (Range of motion exercise/stretching)

4914  **Body-weight explosive training**       **Resistance band exercise**

4915 (box jumps / drop jumps)      (shoulder rotation / crab walk)

4916  **Other** {

4917 **Q13 - What are your key goals for training during the season?** (multiple answers may be selected)

4918  Improve strength       Improve cardiovascular fitness       Improve flexibility

4919  Improve power       Increase muscle mass       Improve balance/co-ordination

4920  Stay healthy       Improve swing technique       Maintain Performance

4921  Decrease body fat       Improve club head speed/       Other -

4922 driving distance

4923 **Q14 – Which days will you train this week?** (multiple answers may be selected)

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	I Won't Train
Training Days	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4924

4925 (Only Answer Q15 if “I Won’t Train” was answered for Q14)

4926 **Q15 – Why would you not resistance train this week?** (multiple answers may be selected)

4927  Time constraints  Fear of injury

4928  Fatigue  Resistance training will worsen golf performance

4929  I would rather practice golf  Resistance training will not improve golf performance

4930  Lack of facilities  Other -

4931  I only Resistance train during the off-season

4932 (Skip Q16 if Q15 was answered)

4933 **Q16 - Which of the following fitness activities will you include in these training sessions?**

4934 (multiple answers may be selected)

4935 (Examples in brackets)

4936

- 4937  **Heavy load/low volume resistance training**       **Aerobic exercise**  
 4938 (3x3 back squats at 85% 1RM)      (running/cycling/swimming)
- 4939  **Low load/high volume resistance training**       **Proprioception**  
 4940 (3x10-15 lunges)      (balance/ co-ordination/ movement-quality)
- 4941  **Weighted explosive training**       **Mobility**  
 4942 (weighted squat jumps/ballistic bench press throws) (Range of motion exercise/stretching)
- 4943  **Body-weight explosive training**       **Resistance band exercise**  
 4944 (box jumps / drop jumps)      (shoulder rotation / crab walk)
- 4945  **Other** {
- 4946
- 4947 **Q17 - If you had a 1 pm tee time, would you train on the morning of the first round of golf?**
- 4948  Definitely yes
- 4949  Probably yes
- 4950  Might or might not
- 4951  Probably not
- 4952  Definitely not
- 4953
- 4954 (Skip Q18 if “Definitely yes” was answered for Q15)
- 4955 **Q18 - Why would you not train on the morning of the first round of golf?**
- 4956 (multiple answers may be selected)
- 4957
- 4958  Time constraints       Fear of injury

4959  Fatigue  Resistance training will worsen golf performance

4960  I would rather practice golf  Resistance training will not improve golf performance

4961  Lack of facilities  Other -

4962  I only Resistance train during  I will train another time  
4963 the off-season

4964

4965

4966 (Skip Q19 if Q18 was answered)

4967 **Q19 - Which of the following fitness activities would you include in this training session?** (multiple answers may be selected)

4968 (Examples in brackets)

4969

4970  **Heavy load/low volume resistance training**  **Aerobic exercise**

4971 (3x3 back squats at 85% 1RM) (running/cycling/swimming)

4972  **Low load/high volume resistance training**  **Proprioception**

4973 (3x10-15 lunges) (balance/ co-ordination/ movement-quality)

4974  **Weighted explosive training**  **Mobility**

4975 (weighted squat jumps/ballistic bench press throws) (Range of motion exercise/stretching)

4976  **Body-weight explosive training**  **Resistance band exercise**

4977 (box jumps / drop jumps) (shoulder rotation / crab walk)

4978  **Other**

4979 **Q20 - Would you train a weighted explosive fitness activity on the morning of the first round of golf, if the evidence supported improved**  
4980 **golf performance?**

- 4981  Definitely yes  
4982  Probably yes  
4983  Might or might not  
4984  Probably not  
4985  Definitely not

4986

4987 (Skip Q21 if “Definitely yes” was answered for Q20)

4988 **Q21 - Why would you not train a weighted explosive fitness activity on the morning of the first round of golf?** (multiple answers may be  
4989 selected)

- 4990  Time constraints  Fear of injury  
4991  Fatigue  Training will worsen golf performance  
4992  I would rather practice golf  Training will not improve golf performance  
4993  Lack of facilities  Other -

4994

4995 **Q22 - Would you train a heavy load/low volume strength-based fitness activity on the morning of the first round of golf, if the evidence**  
4996 **supported improved golf performance?**

- 4997  Definitely yes  
4998  Probably yes

---

4999  Might or might not

5000  Probably not

5001  Definitely not

5002

5003 (Skip Q23 if “Definitely yes” was answered for Q22)

5004 **Q23 – Why would you not train a heavy load/low volume fitness activity on the morning of the first round of golf?** (multiple answers may  
5005 be selected)

5006  Time constraints  Fear of injury

5007  Fatigue  Resistance training will worsen golf performance

5008  I would rather practice golf  Resistance training will not improve golf performance

5009  Lack of facilities  Other -

5010

5011

5012

5013 **Q24 - Will you warm-up before the first round of golf?**

5014  Definitely yes

5015  Probably yes

5016  Might or might not

5017  Probably not

5018  Definitely not

5019

5020 (Skip Q25 if “Definitely Not” was answered for Q24)

5021 **Q25 - Which of the following fitness activities will you include in this warm-up?** (multiple answers may be selected) (Examples in brackets)

5022

5023  **Heavy load/low volume resistance training** **Aerobic exercise**

5024 (3x3 back squats at 85% 1RM)

(running/cycling/swimming)

5025  **Low load/high volume resistance training** **Proprioception**

5026 (3x10-15 lunges)

(balance/ co-ordination/ movement-quality)

5027  **Weighted explosive training** **Mobility**

5028 (weighted squat jumps/ballistic bench press throws) (Range of motion exercise/stretching)

5029  **Body-weight explosive training** **Resistance band exercise**

5030 (box jumps / drop jumps)

(shoulder rotation / crab walk)

5031  **Other** {  **Hitting golf balls**5032 **Q26 - Would you include an explosive fitness activity in your warm-up if the evidence supported improved golf performance?**5033  Definitely yes5034  Probably yes5035  Might or might not5036  Probably not5037  Definitely not

5038 (Skip Q27 if “Definitely yes” was answered for Q26)

5039 **Q27 - Why would you not include an explosive fitness activity in your warm-up?**

5040 (multiple answers may be selected)

5041  Time constraints  Fear of injury

5042  Fatigue  Training will worsen golf performance

5043  I would rather practice golf  Training will not improve golf performance

5044  Lack of facilities

Other -

5045 **Q28 - Would you include a heavy load/low volume strength-based fitness activity in your warm-up, if the evidence supported improved**  
5046 **golf performance?**

5047  Definitely yes

5048  Probably yes

5049  Might or might not

5050  Probably not

5051  Definitely not

5052 (Skip Q29 if “Definitely yes” was answered for Q28)

5053 **Q29 - Why would you not include a heavy load/low resistance fitness activity in your warm-up?**

5054 (multiple answers may be selected)

5055  Time constraints  Fear of injury

5056  Fatigue  Training will worsen golf performance

5057  I would rather practice golf  Training will not improve golf performance

5058  Lack of facilities

Other -

5059 **APPENDIX D**

To whom it may concern,

We grant the express permission for the anonymised data collected at the Portrush Irish Open 2019 on player usage at the onsite gym to be distributed to Sean White and the University of Essex for research purposes.

Yours Sincerely,

Simon Brearley

Strength & Conditioning Coach  
European Tour Performance Institute

5060

5061 **APPENDIX E**

5062 **Observation Time: 13.00 PM – 21.00 PM**

5063

	<b>Tally</b>	<b>Total</b>
Number of players entering the gym		
Number of top 20 players entering the gym		

5064

<b>Conditioning Activity</b>	<b>Example</b>	<b>Tally</b>	<b>Total</b>
Heavy load/low volume resistance training	3x3 back squats at 85% 1RM		
Low load/high Volume resistance training	3x10-15 lunges		
Weighted explosive training	weighted squat jumps/ballistic bench-press throws		

Body-weight explosive training	box jumps / explosive press-ups		
Resistance band exercise	shoulder rotations / crab walk		
Aerobic Exercise	Running / Cycling / Swimming		
Proprioception	Balance / Co-ordination / Movement quality		
Mobility	Range of motion exercise / Stretching		

5065

5066 **APPENDIX F**

Participant number:	Date/Time:
---------------------	------------

5067

5068 **Short Recovery Scale:** *Below you find a list of expressions that describe different aspects of*  
 5069 *your current state of recovery. Rate how you feel **right now** in relation to your best ever*  
 5070 *recovery state.*

---

<b>Physical Performance</b>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
<b>Capability</b>	<b>Does not</b> <b>Fully</b> <b>apply at all</b> <b>applies</b>
<i>e.g.</i>	<b>0</b> <b>1</b> <b>2</b> <b>3</b> <b>4</b> <b>5</b> <b>6</b>
<i>strong,</i>	
<i>physically capable,</i>	
<i>energetic,</i>	
<i>full of power</i>	

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<b>State</b>	<b>Does not</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>Fully</b>
<i>e.g.</i>	<b>apply at all</b>								<b>applies</b>
<i>feeling down,</i>									
<i>stressed,</i>									
<i>annoyed,</i>									
<i>short-tempered</i>									

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<b>Overall stress</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<i>e.g.</i>	<b>Does not</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>Fully</b>
<i>tired,</i>	<b>apply at all</b>								<b>applies</b>
<i>worn-out,</i>									
<i>overloaded,</i>									
<i>physically exhausted</i>									