

1 **Effect of home-based resistance training performed with or without a high-**  
2 **speed component in adults with severe obesity**

3 *Running title: High-speed vs. slow-speed resistance training*

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17 **Conflict of interest statement**

18 The authors have no conflicts of interest to declare.

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20

21 **ABSTRACT**

22 **Purpose:** 1) To evaluate the effects of walking and home-based resistance training on function,  
23 strength, power, anthropometry and quality of life (QoL) in adults with severe obesity, and 2)  
24 to assess whether performing resistance exercises with maximal concentric velocity provides  
25 additional benefits compared with traditional slow-speed resistance training.

26 **Methods:** Adults with a body mass index of  $\geq 40$  kg/m<sup>2</sup> were randomised to slow-speed  
27 strength training (ST; n = 19) or high-speed power training (PT; n = 19). Both groups completed  
28 a walking intervention and home-based resistance training (2x/week for 6-months). The PT  
29 group performed resistance exercises with maximal intended concentric velocity, whereas the  
30 ST group maintained a slow (2-s) concentric velocity.

31 **Results:** At 6-months, weight loss was ~3 kg in both groups. Both groups significantly  
32 improved function ( $g_z = 1.04$ - $1.93$ ), strength ( $g_z = 0.65$ - $1.77$ ), power ( $g_z = 0.66$ - $0.85$ ),  
33 contraction velocity ( $g_z = 0.65$ - $1.12$ ) and QoL ( $g_z = 0.62$ - $1.54$ ). Between-group differences in  
34 shoulder press velocity ( $-0.09$  m·s<sup>-1</sup>,  $g_s = -0.95$  [- $1.63$ ,  $-0.28$ ]) and six-minute walk test ( $-16.9$   
35 m,  $g_s = -0.51$  [- $1.16$ ,  $0.13$ ]) favoured the PT group.

36 **Conclusions:** Home-based resistance training and walking leads to significant improvements  
37 in functional and psychological measures in adults with severe obesity. In addition, considering  
38 the between-group effect sizes and their uncertainty, performing resistance exercises with  
39 maximal concentric speed is a simple adjustment to conventional resistance training that yields  
40 negligible negative effects but potentially large benefits on walking capacity and upper-limb  
41 contraction velocity.

42 **Keywords:** Severe obesity; resistance training; home-based exercise; power training; physical  
43 function; exercise.

## 44 INTRODUCTION

45 Obesity reduces muscle contractile function and the ability to perform activities of daily living.  
46 <sup>1,2</sup> Severe obesity (i.e. body mass index of  $\geq 40$  kg/m<sup>2</sup>) is associated with even further  
47 reductions in physical functioning and muscle strength relative to body mass.<sup>3</sup> These physical  
48 constraints impair quality of life and to lead to a decreased motivation to exercise.<sup>4</sup> Therefore,  
49 improving physical functioning should be a central tenet in the management of severe obesity  
50 and in the promotion of regular physical activity.

51 Supervised resistance training interventions have been shown improve functional capacity in  
52 adults with severe obesity.<sup>5,6</sup> However, supervised interventions place considerable time and  
53 resource burdens on the service provider and patient, which may not be conducive to sustained  
54 participation. Obese individuals often report feeling too embarrassed to exercise in front of  
55 others and feel uncomfortable wearing exercise clothing in public.<sup>7,8</sup> Home-based exercise is a  
56 convenient alternative to supervised interventions and may promote similar functional  
57 adaptations.<sup>9,10</sup> To date, only one study has evaluated the effects of home-based resistance  
58 training on functionality in adults who are severely obese. This study involved a small sample  
59 size (n = 6) and used a single-group design with historical comparison groups. Given the  
60 therapeutic potential of resistance training, and the ability of home-based exercise to  
61 circumvent many barriers to physical activity, there is an urgent need to extend this evidence-  
62 base.

63 Traditional resistance training typically involves sustained contractions at low to moderate  
64 velocities. While this method of training is effective for augmenting maximal strength  
65 production, which is executed at slow velocities, it may neglect the development of muscle  
66 power. Indeed, studies investigating power adaptations in response to conventional resistance  
67 training have produced equivocal results.<sup>11-13</sup> This is problematic because lower-limb power

68 has recently been shown to be a superior determinant of function compared with strength in  
69 adults with severe obesity.<sup>14</sup> Thus, specifically targeting muscle power, in addition to or instead  
70 of muscle strength, may preferentially enhance physical functioning.

71 Power training integrates a high-speed component into conventional resistance training  
72 exercises. Research in older adults has consistently shown that power training is superior to  
73 conventional slow-speed strength training for improving functionality.<sup>15,16</sup> Preliminary  
74 evidence also exists supporting the superiority of power training in sarcopenic obese adults.<sup>17</sup>  
75 Nevertheless, it is currently unknown whether power training is feasible or effective in adults  
76 who are severely obesity. Therefore, the aim of this study was to evaluate the effects of home-  
77 based resistance training performed with or without a high-speed component on strength,  
78 power, contraction velocity, functional performance, anthropometry and quality of life (QoL)  
79 in adults with a body mass index (BMI) of  $\geq 40$  kg/m<sup>2</sup>. We hypothesized that both groups  
80 would improve outcome measures over time, and that changes in power, contraction velocity  
81 and physical function would be greater in the PT group compared with the ST group.

## 82 **MATERIALS AND METHODS**

### 83 **Participants**

84 Participants were recruited from a Tier 3 specialist weight management service Kingston upon  
85 Hull, United Kingdom, from January 2016 to February 2017. Eligibility criteria for inclusion  
86 were referral from a General Practitioner, an age of  $\geq 18$  years, and a BMI of  $\geq 40$  kg/m<sup>2</sup> or  
87 between 35 and 40 kg/m<sup>2</sup> with a serious comorbidity (such as type II diabetes). Exclusion  
88 criteria included: unstable chronic disease state, prior myocardial infarction or heart failure,  
89 poorly controlled hypertension ( $\geq 180/110$  mmHg), uncontrolled supraventricular tachycardia  
90 ( $\geq 100$  bpm), participation in a structured exercise regime, body mass of over 200 kg, weight  
91 change of  $> 4$  kg in the last 6-months, and pre-existing musculoskeletal or neurological

92 condition that could affect their ability to complete the training and testing. All participants  
93 gave their written informed consent and the study was ethically approved by a relevant  
94 institutional review board. This trial is registered on ClinicalTrials.gov (NCT03900962).

## 95 **Study design**

96 This study was a parallel-groups, prospective, randomised trial. After baseline measurements,  
97 participants were randomly allocated (1:1) to a high-speed power training (PT) group or a slow-  
98 speed strength training (ST) group in block sizes of four using a randomisation sequence  
99 created by an independent researcher (GraphPad QuickCalcs, Graphad Software, La Jolla, CA).  
100 Treatment allocation was concealed in sequentially numbered, opaque, sealed envelopes. Both  
101 groups completed a 6-month home-based resistance training programme with behavioural  
102 support as well as an individualised walking intervention. Outcomes were assessed at baseline,  
103 3-months (mid-intervention), and 6-months (post-intervention).

## 104 **Resistance training intervention**

105 Both groups completed the resistance training intervention unsupervised in their homes. Two  
106 weekly sessions were completed on non-consecutive days for 24-weeks. During weeks 1 to 12,  
107 the same member of the research team provided all participants with telephone support once  
108 per week and face-to-face behaviour change counselling every 3 weeks. Behaviour change  
109 techniques included self-regulation, motivational interviewing, goal setting, and online peer  
110 support (Appendix 1). During weeks 13 to 24, there was no contact from the research team but  
111 participants were instructed to continue with their exercise programme.

112 The training programme was delivered online via individual, private playlists on Youtube  
113 (YouTube, San Bruno, California, USA), with each playlist involving an individually-  
114 prescribed series of pre-recorded exercise videos. Participants also received an exercise  
115 package that included three colour-coded resistance bands offering three incremental levels of

116 resistance (Iron Woody Fitness, Onley, MT), a heart rate monitor (FT1, Polar Electro,  
117 Kempele, Finland), a training diary, a 10-point rating of perceived exertion (RPE) scale,<sup>18</sup> and  
118 a pedometer (Yamax Digiwalker SW-200, YAMAX, Bridgnorth, Shropshire, UK).

### 119 ***Slow-speed strength training***

120 A detailed description of the training intervention is provided in Appendix 1 in accordance  
121 with the Consensus on Exercise Reporting Template.<sup>19</sup> Briefly, participants completed a  
122 dynamic warm-up followed by 1-2 sets of 5-12 repetitions of 4 body weight (bilateral glute  
123 bridge, squat, press-up, standing strides) and 5 resistance band exercises (incline chest press,  
124 deadlift, seated row, push-press, core rotation), that were based on primary resistance training  
125 movement patterns (Appendix 2). Fifteen seconds of rest separated each exercise. The intensity  
126 of exercise was performed at 4-7 RPE, and progression of training intensity/volume was based  
127 on the participant's RPE rating. If RPE was below four or above seven, the exercise was  
128 progressed or regressed for the next workout, respectively. The resistance band exercises were  
129 progressed by changing from the current band to the next colour in the scale. Body weight  
130 exercises were progressed using exercises of similar movement patterns with a higher degree  
131 of technical difficulty (e.g. biped stance to split stance). Participants in the ST group completed  
132 the concentric phase of each repetition over two seconds, paused at full extension/flexion for  
133 one second, and then performed the eccentric phase for two seconds. The exercise videos  
134 audibly and visually reinforced the need for a controlled lifting tempo.

### 135 ***High-speed power training***

136 All training variables were the same between groups apart from repetition velocity. During the  
137 first three weeks of training, the PT completed the concentric and eccentric phases over two  
138 seconds. Thereafter, the PT group completed the concentric phase of five exercises (squat,  
139 press-up, incline chest press, seated row and push-press) as fast as possible whilst still taking

140 two seconds to complete the eccentric phase. The exercise videos continuously encouraged  
141 participants to perform these resistance exercises with maximal concentric intended velocity.

### 142 **Walking intervention**

143 After the initial baseline assessment, participants recorded the number of steps they walked  
144 daily for seven days using their pedometer whilst maintaining their usual physical activity  
145 levels. Participants were then encouraged to increase their total steps walked each day by 5%  
146 each week during the intervention.

### 147 **Weight management service**

148 Participants continued to receive usual care from the specialist weight management service.  
149 This involved individual 30-minute counselling sessions every 4-8 weeks with a weight  
150 management clinician, which consisted of physical activity, dietary and lifestyle advice. The  
151 programme involved the promotion of healthy eating rather than the prescription of specific  
152 diets.

### 153 **Outcome measures**

#### 154 *Anthropometric measurements*

155 Body mass and height were measured with a calibrated digital scale and a free-standing  
156 stadiometer, respectively (SECA, Birmingham, UK). Waist and hip circumferences were  
157 assessed using standard techniques.<sup>20</sup>

#### 158 *Functional performance*

159 The timed up-and-go (TUG), six-minute walk test (6MWT) and 30-s chair sit-to-stand (STS)  
160 were administered using methods described in detail previously.<sup>14</sup>

#### 161 *Muscle strength*

162 Lower-limb strength was measured with the isometric mid-thigh pull using an analogue  
163 dynamometer (Takei Scientific Instruments Co. Ltd., TTK 5002 Back-A, Tokyo, Japan). The  
164 height of the handle was individually adjusted so that the bar rested midway up the thigh, then  
165 participants maximally extended their knees and trunk for three seconds without bending their  
166 back. Two trials were performed and the maximum value used for analysis. One repetition  
167 maximums were also determined in the shoulder press and seated row using resistance  
168 machines (Life Fitness, Ely, Cambridgeshire, UK). Participants performed a warm-up  
169 consisting of five repetitions at 3 RPE, three repetitions at 5 RPE, and two repetitions at 8 RPE,  
170 followed by 1RM attempts with 5-10% increased loads. A maximum of five attempts were  
171 permitted and the last successful lift was taken as the 1RM.

#### 172 *Muscle power*

173 Muscle power and contraction velocity were measured in the STS and shoulder press.  
174 Participants began the STS power test sat in a firm bariatric chair (height, 48cm; depth 56 cm,  
175 width 69 cm) with their arms crossed against their chest. Upon the researcher's instruction,  
176 participants stood up straight as quickly as possible, stayed standing upright for at least two  
177 seconds, then sat back down at a comfortable pace. The shoulder press power test was  
178 performed with 50% of the load achieved in the 1RM test. Participants completed the  
179 concentric phase with maximal intentional velocity, before returning back to the starting  
180 position in a controlled manner. For both tests, participants performed three repetitions  
181 separated by 60 seconds of rest, with the highest values used for analysis. A wearable inertial  
182 sensor (PUSH<sup>TM</sup>, PUSH Inc., Toronto, Canada) was worn on the participant's forearm, 1-2 cm  
183 distal to the elbow crease, and measured mean power and mean velocity in the concentric phase  
184 of each repetition.<sup>21</sup>

#### 185 *Health-related quality of life*



186 The EQ-5D-5L and EQ-visual analogue scale (EQ-VAS) assessed general QoL,<sup>22</sup> whilst the  
187 17-item Obesity and Weight Loss Quality of Life Instrument (OWLQOL) and 20-item Weight-  
188 Related Symptom Measure (WRSM) were used to assess obesity specific QoL.<sup>23</sup> Higher scores  
189 in the EQ-5D-5L, EQ-VAS and OWLQOL questionnaires indicated better QoL, whereas lower  
190 scores in the WRSM indicated a better experience of symptoms.

### 191 *Exercises responses*

192 Compliance to the resistance training intervention and sessional duration, RPE, and training  
193 volume (total number of repetitions) were recorded and averaged across the intervention  
194 period.

### 195 **Sample size**

196 The primary outcome was difference in lower-limb power at 3-months. Balachandran et al<sup>17</sup> is  
197 the only previous study to have compared strength training versus power training in obese  
198 adults, reporting a Hedge's  $g$  effect size in lower-limb power of 0.9, which converts to  $d =$   
199  $0.95$ .<sup>24</sup> Therefore 37 participants (19 per group) were required to detect an effect of  $d = 0.95$  ( $f$   
200  $= 0.475$ ) in an analysis of covariance (ANCOVA) given  $\alpha = 0.05$ ,  $1 - \beta = 0.8$ , and numerator  $df$   
201  $= 1$ , which was calculated using G\*Power version 3.1.<sup>25</sup>

### 202 **Statistical analysis**

203 Analyses were performed by intention to treat using SPSS version 24.0 (IBM SPSS, Chicago,  
204 IL). Descriptive statistics were used to characterise participants at baseline. We used traditional  
205 two-sided significance tests to examine changes over time and determine differences between  
206 groups, where the null hypothesis for each test was that the true effect size was zero. Between-  
207 group differences in outcomes at 3-months and 6-months were assessed by ANCOVA with  
208 baseline values, age and sex as covariates. Homogeneity of regression slopes were confirmed  
209 with scatter plots, and the adjusted mean difference with 95% confidence intervals (CI) from

210 the model are presented. Within-group changes from baseline were examined with one-way  
211 repeated-measures ANOVAs and subsequent Bonferroni-corrected planned contrasts. The  
212 assumption of sphericity was assessed with Mauchly's test, and in the case of significant  
213 violations, the Greenhouse-Geisser epsilon correction was applied. Hedges'  $g$  was calculated  
214 as a measure of effect size within-groups (mean change / SD of change;  $g_z$ ) and between-groups  
215 (adjusted mean difference / SD of difference;  $g_s$ ), which adjusts for sample bias by multiplying  
216 the effect estimate by  $(1 - \frac{3}{4Ni-9})$ .<sup>24</sup> The SD of the adjusted means were derived from their  
217 95% CIs:  $\sqrt{N} \times (\frac{upper\ limit - lower\ limit}{2t-value})$ .<sup>26</sup> Between-group differences of 0.5 SDs were used to  
218 denote a minimum important difference.<sup>27</sup> Effect sizes in favour of ST are reported as a positive  
219  $g_s$  and effect sizes in favour of PT as a negative  $g_s$ . Effect sizes were rated as trivial ( $< 0.2$ ),  
220 small (0.2-0.49), moderate (0.5-0.79) or large ( $\geq 0.8$ ).<sup>28</sup> Statistical significance was set at a two-  
221 tailed  $p < 0.05$ . Missing data at 3- and 6-months were replaced via multiple imputation  
222 (Appendix 3). Data files and scripts are available online.<sup>29</sup>

## 223 **RESULTS**

### 224 **Participants**

225 Thirty-eight participants entered the study and were randomised (Figure 1). Participant  
226 characteristics and outcomes at baseline were well balanced between the two groups (Table 1  
227 and 2). Overall retention of participants was 74% at 6-months. Compliance to the resistance  
228 training intervention from weeks 1 to 12 was 92% (ST group) and 90% (PT group). From  
229 weeks 13 to 24, compliance was 69% and 58% in the respective study groups. No adverse  
230 events occurred during any exercise training or testing sessions (Appendix 1).

### 231 **Exercise responses**

232 On average, daily step counts were  $6739 \pm 516$  in the ST group and  $7181 \pm 379$  in the PT group,  
233 which represents 22% and 13% increases from baseline, respectively (Table 1). Average  
234 session duration was  $26 \pm 3$  min during ST and  $25 \pm 3$  min during PT. Average sessional heart  
235 rate was 30% and 32% of heart rate reserve in the respective ST and PT groups. Participants  
236 completed an average of  $102 \pm 25$  (ST group) and  $101 \pm 26$  (PT group) repetitions each training  
237 session.

### 238 **Within-group changes**

239 From baseline to 6-months, the PT significantly decreased body mass by 3.2 kg ( $g_z = 0.86$ ).  
240 The ST group also reduced body mass by 3.1 kg ( $g_z = 0.45$ ), although this did not reach  
241 statistical significance ( $p = 0.057$ ; Table 3). Both groups significantly improved function ( $g_z =$   
242  $1.04$ - $1.93$ ), strength ( $g_z = 0.65$ - $1.77$ ), power ( $g_z = 0.66$ - $0.85$ ), contraction velocity ( $g_z = 0.65$ -  
243  $1.12$ ) and QoL ( $g_z = 0.62$ - $1.54$ ).

### 244 **Between-group differences**

245 At 3-months, differences in shoulder press power ( $-26$  W,  $g_s = -0.52$ ) and shoulder press  
246 contraction velocity ( $-0.09$  m·s<sup>-1</sup>,  $g_s = -0.64$ ) exceeded 0.5 SDs in favour of the PT group (Table  
247 4), whereas differences in EQ-VAS favoured the ST group ( $6.0$ ,  $g_s = 0.50$ ). At 6-months, the  
248 improvement in shoulder press contraction velocity was significantly greater following PT  
249 compared with ST ( $-0.09$  m·s<sup>-1</sup>,  $g_s = -0.95$ ), and the difference in 6MWT distance also favoured  
250 the PT group ( $-16.9$  m,  $g_s = -0.51$ ).

## 251 **DISCUSSION**

252 The main finding of this study was that home-based walking and resistance training  
253 significantly improved physical function, strength, power, contraction velocity and QoL in  
254 adults with severe obesity. Our findings also suggest that performing resistance exercises with

255 maximal intended concentric velocity is a simple and safe adjustment to conventional slow-  
256 speed resistance training that yields negligible negative effects but potentially large benefits on  
257 walking capacity and upper-limb movement speed.

258 Home-based resistance training, performed with or without a high-speed component, led to  
259 robust improvements in lower-limb strength and physical function. From baseline to 6-months,  
260 the improvements were ~12% for TUG ( $g_z = 1.04-1.64$ ), 9-12% for 6MWT ( $g_z = 1.30-1.93$ )  
261 and 34-38% in the chair STS test ( $g_z = 1.35-1.87$ ). Similar magnitudes of change have been  
262 reported following supervised resistance training studies with obese adults. For instance,  
263 Bouchard and colleagues<sup>30</sup> reported a 29% and 6% improvement in STS and 6MWT  
264 performance, respectively, following 12-weeks of supervised strength exercise in obese  
265 women. Improvements in the Short Physical Performance Battery (SPPB) of 5-20% have also  
266 been reported following various other supervised interventions.<sup>13,31-33</sup> The comparative  
267 improvements in function between our unsupervised protocol and supervised programmes may  
268 be due to how our intervention was delivered. We used online-based playlists on YouTube,  
269 with each playlist involving an individually-prescribed series of exercise videos. The instructor  
270 used verbal cues throughout each video to reinforce correct technique and participants  
271 anecdotally mentioned that they felt like they were receiving one-to-one personal training.  
272 Thus, the tailored video-system appeared to create a quasi-supervised environment. Recently,  
273 Baillot and colleagues<sup>34</sup> showed that delivering aerobic and resistance training via online-based  
274 Telehealth improved physical function in pre-bariatric surgery patients. Therefore, home-based  
275 resistance training delivered via an online platform can increase functionality in adults who are  
276 obese, and the magnitude appears to be similar to traditional supervised programmes.

277 The improvement in 6MWT distance favoured the PT group (adjusted mean difference = -16.9  
278 m,  $g_s = -0.52$ ). This finding suggests that PT improves walking capacity to a greater extent than  
279 ST, which partially agrees with the only other study to compare power and strength training in

280 obese individuals. Balachandran and colleagues<sup>17</sup> found that modified SPPB performance  
281 favoured PT in a sample of 17 sarcopenic obese adults ( $g_s = 0.6$ ). The authors attributed this  
282 finding to improved gait speed based on the reasoning that gait speed explains most of the  
283 variance in SPPB.<sup>17</sup> Unlike our study though, neither ST nor PT improved 6MWT  
284 performance, nor were any between-group differences reported (adjusted mean difference =  
285 5.4 m,  $g_s = 0.1$ ). It is also important to consider that a range of differences in 6MWT distance  
286 are compatible with our data, from a large difference in favour of PT to a trivial difference  
287 favouring ST (effect size 95% CI: -1.16 to 0.13). Hence, the data suggest that the potential  
288 negative effects of PT compared to ST are negligible, but the potential benefits are large. On  
289 the basis that power training is a simple and safe adjustment to conventional resistance training,  
290 it is therefore reasonable to recommend that severely obese adults perform resistance exercises  
291 with maximal concentric velocity to confer further improvements in walking capacity.

292 The superior effect of high-speed resistance training on 6MWT distance could be underpinned  
293 by the role that muscle power plays in gait performance and in the aetiology of obesity-related  
294 impaired function. Obesity reduces power and strength, which leads to declines in physical  
295 function. However, the obesity-related reduction in power is greater than the reduction in  
296 strength.<sup>35,36</sup> As a result, improvements in functionality may largely rely on increasing muscle  
297 power. Maximal gait speed also requires a greater velocity component of power than force  
298 component.<sup>37</sup> Sayers and colleagues<sup>38</sup> showed that lower-limb velocity explained a greater  
299 proportion of 400-m gait speed variability than muscle strength in community-dwelling older  
300 adults ( $R^2 = 0.18$  vs. 0.06, respectively). Thus, power training may lead to velocity-specific  
301 adaptations and transfer better to tasks that require considerable movement velocity, such as  
302 the 6MWT. Adaptations to high-speed training are likely to be driven by neural factors,  
303 including reduced antagonist coactivation,<sup>39</sup> greater early phase neural drive,<sup>40</sup> and better  
304 coordination.<sup>41</sup>

305 Despite this, we were unable to demonstrate a difference in STS power between groups. Whilst  
306 the single STS power test is reliable<sup>14</sup> and replicates activities of daily living, it may not be  
307 sensitive enough to detect differences in change scores between the two intervention groups.  
308 Given that adults perform ~60 chair-rises every day,<sup>42</sup> the regular execution of STSs might  
309 mask any training-induced differences in the STS power test. This reasoning is supported by  
310 evidence of velocity-specific adaptations in the shoulder press. Adjusted mean differences in  
311 shoulder press power ( $g_s = -0.52$ ) and contraction velocity ( $g_s = -0.64$ ) favoured PT at 3-months,  
312 and the improvement in velocity was significantly greater than ST at 6-months ( $g_s = -0.95$ ).

313 This study found no evidence for between-group differences in strength. In contrast, it has  
314 previously been shown that ST improves leg press 1RM strength more than PT in older obese  
315 adults,<sup>17</sup> presumably because slow-speed resistance training replicates the slow muscle  
316 contractions observed in a 1RM test. We used the isometric IMTP as a proxy for lower-limb  
317 strength, which does not replicate the dynamic muscle contractions involved in resistance  
318 training. Thus, the specificity of the test may have contributed to the lack of between-group  
319 difference. However, many adults with severe obesity cannot achieve the range of motion  
320 required in the leg press exercise due to restrictive abdominal adiposity.<sup>43</sup> Standardisation of  
321 knee flexion is compulsory because leg press 1RM has been shown to improve by 59% when  
322 the starting knee angle increases by 20°.<sup>44</sup> Whilst isokinetic dynamometry is another  
323 laboratory-based method regularly used to measure strength, this test does not replicate the  
324 contraction-type nor the multiarticular movement patterns involved in resistance training.  
325 Therefore, the IMTP may represent the most practical option for assessing lower-limb strength  
326 in adults who are severely obese.<sup>14</sup>

327 Weight loss slightly exceeded 3 kg in both groups (-2.4%). This is likely to be clinically  
328 meaningful because a weight loss of  $\geq 2.5$  kg reduces the risk of developing type II diabetes.<sup>45</sup>  
329 In obese adults with type II diabetes, reductions in body mass of  $\geq 2\%$  results in decreased

330 fasting glucose concentrations and HbA1c.<sup>45</sup> Previous studies that have added resistance  
331 training to specialist weight management programmes have reported similar magnitudes of  
332 weight loss (2.4-2.8%).<sup>5,6</sup> Participants in our study were receiving usual care for the duration  
333 of the training intervention, which includes specialist treatments designed to aid weight loss  
334 (e.g. counselling, dietary advice, pharmacotherapy). As a consequence, it is not possible to  
335 determine which components of the weight management service were responsible for weight  
336 loss, but it is likely a combination of these factors.

337 Beyond the physical improvements, both interventions significantly improved general and  
338 obesity-specific QoL. The changes from baseline to 6-months in the OWLQoL questionnaire  
339 ( $g_z = 1.19-1.54$ ) and the WRSM ( $g_z = 0.62-0.80$ ) are similar to those associated with  $\geq 10\%$   
340 weight loss in obese adults (OWQoL,  $d = 1.63$ ; WRSM,  $d = 0.73$ ).<sup>23</sup> The change in QoL is  
341 ostensibly mediated by factors aside from the weight loss, including motivational strategies  
342 and behaviour change techniques. We included several behaviour change methods that may  
343 have contributed to the marked increase in QoL, such as self-regulation, peer support and goal  
344 setting. Indeed, recent resistance training studies reporting an increase in QoL have employed  
345 behaviour change techniques such as goal setting,<sup>46,47</sup> whereas those showing no change in  
346 QoL did not report the use of behaviour change methods.<sup>48,49</sup> Interestingly, the difference in  
347 EQ-VAS favoured the ST group at 3-months ( $g_s = 0.50$ , [-0.14, to 1.15]), although this  
348 difference was not evident at 6-months ( $g_s = 0.35$  [-0.29 to 0.99]). This finding is difficult to  
349 explain but may be related to a greater initial appreciation of the health benefits to traditional  
350 resistance training, with less understanding of the benefits to power training.

351 There were some study limitations that warrant consideration. Outcome assessors were not  
352 blinded to group allocation, although the same investigator strictly adhered to a pre-determined  
353 protocol. We did not include a non-exercising control group and therefore we examined  
354 changes within-groups, although we interpreted magnitudes of change in relation to their

355 clinical relevance. In addition, the study was only powered to detect large differences in STS  
356 power. As a consequence, we used 0.5 SDs to identify important between-group differences  
357 and considered the range of differences that were compatible with the data. Finally, it is  
358 unknown whether participants in the PT group executed resistance exercises with maximal  
359 intended velocity because training sessions were unsupervised. Even so, exercise videos  
360 visually and audibly instructed participants to perform the exercises as fast as possible, and the  
361 researcher reminded participants of this during each telephone call. Participants also rehearsed  
362 exercise technique under the researcher's supervision during behaviour change counselling  
363 sessions.

## 364 **PERSPECTIVES**

365 This study is the first to show that **6-months of** home-based walking and resistance training  
366 improves function, strength, power and QoL in adults with severe obesity. We also showed  
367 that power training is a safe and simple adjustment to traditional slow-speed resistance training  
368 that leads to significantly greater improvements in shoulder press contraction speed.  
369 Improvements in 6MWT distance also favoured the PT group, with compatible differences  
370 ranging from a large beneficial effect of PT to a trivial difference favouring ST ( $g_s = -0.51$ ,  
371 95% CI: -1.16 to 0.13). Hence, the data suggest that the potential negative effects of PT on  
372 walking capacity compared to ST are negligible, but the potential benefits are large. Therefore,  
373 home-based walking and resistance training should be an option in weight management  
374 services to improve functional and psychological measures in adults with severe obesity, and  
375 resistance exercises should be performed with maximal concentric velocity to confer further  
376 improvements in upper-limb contraction velocity and walking capacity.



377 **REFERENCES**

- 378 1. Tallis J, James RS, Seebacher F. The effects of obesity on skeletal muscle contractile  
379 function. *J Exp Biol.* 2018;221(Pt 13).
- 380 2. Tomlinson DJ, Erskine RM, Morse CI, Winwood K, Onambele-Pearson G. The  
381 impact of obesity on skeletal muscle strength and structure through adolescence to old  
382 age. *Biogerontology.* 2016;17(3):467-483.
- 383 3. Ling C, Kelechi T, Mueller M, Brotherton S, Smith S. Gait and Function in Class III  
384 Obesity. *Journal of obesity.* 2012;2012:257468.
- 385 4. Shultz SP, Byrne NM, Hills AP. Musculoskeletal function and obesity: Implications  
386 for physical activity. *Current obesity reports.* 2014;3(3):355-360.
- 387 5. Herring LY, Wagstaff C, Scott A. The efficacy of 12 weeks supervised exercise in  
388 obesity management. *Clin Obes.* 2014;4(4):220-227.
- 389 6. Baillot A, Mampuya WM, Comeau E, Meziat-Burdin A, Langlois MF. Feasibility and  
390 impacts of supervised exercise training in subjects with obesity awaiting bariatric  
391 surgery: a pilot study. *Obesity surgery.* 2013;23(7):882-891.
- 392 7. Ball K, Crawford D, Owen N. Too fat to exercise? Obesity as a barrier to physical  
393 activity. *Australian and New Zealand journal of public health.* 2000;24(3):331-333.
- 394 8. Wiklund M, Olsen MF, Willen C. Physical activity as viewed by adults with severe  
395 obesity, awaiting gastric bypass surgery. *Physiother Res Int.* 2011;16(3):179-186.
- 396 9. Perri MG, Martin AD, Leermakers EA, Sears SF, Notelovitz M. Effects of group-  
397 versus home-based exercise in the treatment of obesity. *Journal of consulting and*  
398 *clinical psychology.* 1997;65(2):278-285.
- 399 10. Orange ST, Marshall P, Madden LA, Vince RV. The Short-Term Training and  
400 Detraining Effects of Supervised Versus Unsupervised Resistance Exercise in Aging

- 401 Adults. *Journal of strength and conditioning research*. Published Online: March 6,  
402 2018 (doi: 10.1519/JSC.0000000000002536).
- 403 11. Zemkova E, Kyselovicova O, Jelen M, et al. Upper and Lower Body Muscle Power  
404 Increases After 3-Month Resistance Training in Overweight and Obese Men.  
405 *American journal of men's health*. 2017;11(6):1728-1738.
- 406 12. Kraemer WJ, Volek JS, Clark KL, et al. Influence of exercise training on  
407 physiological and performance changes with weight loss in men. *Med Sci Sports*  
408 *Exerc*. 1999;31(9):1320-1329.
- 409 13. Nicklas BJ, Chmelo E, Delbono O, Carr JJ, Lyles MF, Marsh AP. Effects of  
410 resistance training with and without caloric restriction on physical function and  
411 mobility in overweight and obese older adults: a randomized controlled trial. *The*  
412 *American journal of clinical nutrition*. 2015;101(5):991-999.
- 413 14. Orange ST, Marshall P, Madden LA, Vince RV. Can sit-to-stand power explain the  
414 ability to perform functional tasks in adults with severe obesity? *Journal of Sport*  
415 *Sciences*. 2019;37(11):1227-1234.
- 416 15. Steib S, Schoene D, Pfeifer K. Dose-response relationship of resistance training in  
417 older adults: a meta-analysis. *Medicine and science in sports and exercise*.  
418 2010;42(5):902-914.
- 419 16. Tschopp M, Sattelmayer MK, Hilfiker R. Is power training or conventional resistance  
420 training better for function in elderly persons? A meta-analysis. *Age and ageing*.  
421 2011;40(5):549-556.
- 422 17. Balachandran A, Krawczyk SN, Potiaumpai M, Signorile JF. High-speed circuit  
423 training vs hypertrophy training to improve physical function in sarcopenic obese  
424 adults: a randomized controlled trial. *Experimental Gerontology*. 2014;60:64-71.

- 425 18. Carli F, Scheede-Bergdahl C. Prehabilitation to enhance perioperative care.  
426 *Anesthesiol Clin.* 2015;33(1):17-33.
- 427 19. Slade SC, Dionne CE, Underwood M, Buchbinder R. Consensus on Exercise  
428 Reporting Template (CERT): Explanation and Elaboration Statement. *British journal*  
429 *of sports medicine.* 2016.
- 430 20. WHO. *Waist circumference and waist–hip ratio: report of a WHO expert*  
431 *consultation.* Geneva, Switzerland: World Health Organisation; 2008.
- 432 21. Orange ST, Metcalfe JW, Liefieith A, et al. Validity and Reliability of a Wearable  
433 Inertial Sensor to Measure Velocity and Power in the Back Squat and Bench Press. *J*  
434 *Strength Cond Res.* 2019;33(9):2398-2408.
- 435 22. Devlin NJ, Shah KK, Feng Y, Mulhern B, van Hout B. Valuing health-related quality  
436 of life: An EQ-5D-5L value set for England. *Health economics.* 2017.
- 437 23. Patrick DL, Bushnell DM, Rothman M. Performance of two self-report measures for  
438 evaluating obesity and weight loss. *Obesity research.* 2004;12(1):48-57.
- 439 24. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a  
440 practical primer for t-tests and ANOVAs. *Frontiers in psychology.* 2013;4:863.
- 441 25. Faul F, Erdfelder E, Lang AG, Buchner A. G\*Power 3: a flexible statistical power  
442 analysis program for the social, behavioral, and biomedical sciences. *Behav Res*  
443 *Methods.* 2007;39(2):175-191.
- 444 26. Higgins JPT, Green S. Chapter 7: Selecting studies and collecting data. In: Higgins  
445 JPT, Deeks JJ, eds. *Cochrane Handbook for Systematic Reviews of*  
446 *Interventions Version 5.1.0 (updated March 2011).* The Cochrane  
447 Collaboration. Available from [www.handbook.cochrane.org](http://www.handbook.cochrane.org); 2011.

- 448 27. Norman GR, Sloan JA, Wyrwich KW. Interpretation of changes in health-related  
449 quality of life: the remarkable universality of half a standard deviation. *Medical care*.  
450 2003;41(5):582-592.
- 451 28. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. New York, NY:  
452 Routledge Academic; 1988.
- 453 29. [Dataset] Orange ST, Marshall P, Madden LA, Vince RV; 2019; Home-based  
454 Resistance Training for Adults With Severe Obesity; Open Science Framework; doi:  
455 10.17605/OSF.IO/ABGQC.
- 456 30. Bouchard DR, Soucy L, Senechal M, Dionne IJ, Brochu M. Impact of resistance  
457 training with or without caloric restriction on physical capacity in obese older women.  
458 *Menopause (New York, NY)*. 2009;16(1):66-72.
- 459 31. Chmelo EA, Crotts CI, Newman JC, et al. Heterogeneity of physical function  
460 responses to exercise training in older adults. *Journal of the American Geriatrics*  
461 *Society*. 2015;63(3):462-469.
- 462 32. Anton SD, Manini TM, Milsom VA, et al. Effects of a weight loss plus exercise  
463 program on physical function in overweight, older women: a randomized controlled  
464 trial. *Clinical interventions in aging*. 2011;6:141-149.
- 465 33. Straight CR, Dorfman LR, Cottell KE, Krol JM, Lofgren IE, Delmonico MJ. Effects  
466 of resistance training and dietary changes on physical function and body composition  
467 in overweight and obese older adults. *Journal of physical activity & health*.  
468 2012;9(6):875-883.
- 469 34. Baillot A, Boissy P, Tousignant M, Langlois MF. Feasibility and effect of in-home  
470 physical exercise training delivered via telehealth before bariatric surgery. *Journal of*  
471 *telemedicine and telecare*. 2017;23(5):529-535.

- 472 35. Lafortuna CL, Maffiuletti NA, Agosti F, Sartorio A. Gender variations of body  
473 composition, muscle strength and power output in morbid obesity. *International*  
474 *Journal of Obesity*. 2005;29(7):833-841.
- 475 36. Hilton TN, Tuttle LJ, Bohnert KL, Mueller MJ, Sinacore DR. Excessive adipose  
476 tissue infiltration in skeletal muscle in individuals with obesity, diabetes mellitus, and  
477 peripheral neuropathy: association with performance and function. *Physical therapy*.  
478 2008;88(11):1336-1344.
- 479 37. Sayers SP, Gibson K. High-speed power training in older adults: a shift of the external  
480 resistance at which peak power is produced. *J Strength Cond Res*. 2014;28(3):616-  
481 621.
- 482 38. Sayers SP, Guralnik JM, Thombs LA, Fielding RA. Effect of leg muscle contraction  
483 velocity on functional performance in older men and women. *Journal of the American*  
484 *Geriatrics Society*. 2005;53(3):467-471.
- 485 39. Pousson M, Amiridis IG, Cometti G, Van Hoecke J. Velocity-specific training in  
486 elbow flexors. *European journal of applied physiology and occupational physiology*.  
487 1999;80(4):367-372.
- 488 40. Balshaw TG, Massey GJ, Maden-Wilkinson TM, Tillin NA, Folland JP. Training-  
489 specific functional, neural, and hypertrophic adaptations to explosive- vs. sustained-  
490 contraction strength training. *Journal of applied physiology (Bethesda, Md: 1985)*.  
491 2016;120(11):1364-1373.
- 492 41. Almasbakk B, Hoff J. Coordination, the determinant of velocity specificity? *Journal*  
493 *of applied physiology (Bethesda, Md : 1985)*. 1996;81(5):2046-2052.
- 494 42. Dall PM, Kerr A. Frequency of the sit to stand task: An observational study of free-  
495 living adults. *Applied ergonomics*. 2010;41(1):58-61.

- 496 43. Orange ST. *Home-based resistance training for adults with severe obesity* [PhD  
497 thesis]. Hull, United Kingdom, University of Hull; 2019.
- 498 44. Moura JA, Borher T, Prestes MT, Zinn JL. The influence of different joint angles  
499 obtained in the starting position of leg press exercise and at the end of the frontal pull  
500 exercise on the values of 1RM. *Revista Brasileira de Medicina do Esporte*.  
501 2004;10(4):269-274.
- 502 45. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS guideline for the  
503 management of overweight and obesity in adults: a report of the American College of  
504 Cardiology/American Heart Association Task Force on Practice Guidelines and The  
505 Obesity Society. *Journal of the American College of Cardiology*. 2014;63(25 Pt  
506 B):2985-3023.
- 507 46. Fanning J, Walkup MP, Ambrosius WT, et al. Change in health-related quality of life  
508 and social cognitive outcomes in obese, older adults in a randomized controlled  
509 weight loss trial: Does physical activity behavior matter? *Journal of behavioral  
510 medicine*. 2018;41(3):299-308.
- 511 47. Villareal DT, Aguirre L, Gurney AB, et al. Aerobic or Resistance Exercise, or Both,  
512 in Dieting Obese Older Adults. *The New England journal of medicine*.  
513 2017;376(20):1943-1955.
- 514 48. Vasconcelos KS, Dias J, Araújo MC, Pinheiro AC, Moreira BS, Dias RC. Effects of a  
515 progressive resistance exercise program with high-speed component on the physical  
516 function of older women with sarcopenic obesity: a randomized controlled trial.  
517 *Brazilian Journal of Physical Therapy*. 2016;20(5):432-440.
- 518 49. Heiestad H, Rustaden AM, Bo K, Haakstad LA. Effect of Regular Resistance  
519 Training on Motivation, Self-Perceived Health, and Quality of Life in Previously

520 Inactive Overweight Women: A Randomized, Controlled Trial. *BioMed research*  
521 *international*. 2016;2016:3815976.

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**Table 1.** Baseline characteristics of study participants. Data are presented as mean  $\pm$  SD or number of participants (percentage of participants).

	Total (n = 38)	ST (n = 19)	PT (n = 19)
Age (years)	43.6 $\pm$ 12.3	45.3 $\pm$ 12.5	41.9 $\pm$ 12.2
Male	15 (39)	8 (42)	7 (37)
Body mass (kg)	127.8 $\pm$ 25.4	123.3 $\pm$ 22.5	132.3 $\pm$ 27.9
Height (cm)	167.9 $\pm$ 8.6	165.9 $\pm$ 8.6	169.9 $\pm$ 8.4
BMI (kg/m <sup>2</sup> )	45.2 $\pm$ 7.8	44.8 $\pm$ 7.7	45.7 $\pm$ 8.1
Waist circumference (cm)	128.0 $\pm$ 14.1	127.3 $\pm$ 13.9	128.7 $\pm$ 14.6
Waist to hip ratio	0.94 $\pm$ 0.10	0.95 $\pm$ 0.09	0.94 $\pm$ 0.10
Habitual daily steps	5951 $\pm$ 2754	5528 $\pm$ 2915	6373 $\pm$ 2591
Systolic BP (mmHg)	139.9 $\pm$ 17.0	141.4 $\pm$ 14.4	138.4 $\pm$ 19.5
Diastolic BP (mmHg)	86.1 $\pm$ 9.0	86.8 $\pm$ 9.7	85.4 $\pm$ 8.4
Resting HR (bpm)	71.7 $\pm$ 8.9	72.9 $\pm$ 10.1	70.5 $\pm$ 7.6
Type II diabetes	9 (24)	5 (26)	4 (21)
OSA	14 (37)	6 (32)	8 (42)
Number of medications	3.1 $\pm$ 3.2	3.3 $\pm$ 4.0	2.8 $\pm$ 2.3
Type 2 diabetes	7 (18)	3 (16)	4 (21)
Hypertension	14 (37)	7 (37)	7 (37)
Hyperlipidaemia	5 (13)	2 (11)	3 (16)
PCOS	5 (13)	4 (21)	1 (5)
GERD	8 (21)	4 (21)	4 (21)
Analgesic	6 (16)	4 (21)	2 (11)
Anti-inflammatory	9 (24)	4 (21)	5 (26)
Asthma	10 (26)	4 (21)	6 (32)
Depression	3 (8)	1 (5)	2 (11)

BMI = body mass index; BP = blood pressure; GERD = gastroesophageal reflux disease; HR = heart rate; bpm = beats per minute; OSA = obstructive sleep apnoea; PCOS = polycystic ovary syndrome; PT = high-speed power training; ST = slow-speed strength training.



**Table 2.** Outcomes at baseline, 3-months and 6-months (mean  $\pm$  SD)

	Slow-speed strength training (n = 19)			High-speed power training (n = 19)		
	Baseline	3-months	6-months	Baseline	3-months	6-months
<b>Function</b>						
TUG (s)	6.89 $\pm$ 1.11	6.01 $\pm$ 1.33	6.06 $\pm$ 0.87	6.40 $\pm$ 0.96	5.65 $\pm$ 0.78	5.68 $\pm$ 0.67
6MWT (m)	504 $\pm$ 76	557 $\pm$ 77	550 $\pm$ 75	504 $\pm$ 78	554 $\pm$ 80	566 $\pm$ 76
Chair STS (reps)	11.1 $\pm$ 2.9	15.6 $\pm$ 3.5	15.3 $\pm$ 4.1	12.4 $\pm$ 2.5	16.1 $\pm$ 3.1	16.5 $\pm$ 3.4
<b>Strength</b>						
IMTP (kg)	81.8 $\pm$ 48.9	115 $\pm$ 39	115 $\pm$ 42	76.1 $\pm$ 48.1	108 $\pm$ 36	104 $\pm$ 50
Shoulder press 1RM (kg)	38.9 $\pm$ 18.9	43.2 $\pm$ 20.0	41.6 $\pm$ 19.1	37.2 $\pm$ 17.8	40.8 $\pm$ 17.4	39.1 $\pm$ 19.4
Seated row 1RM (kg)	52.6 $\pm$ 24.3	61.5 $\pm$ 22.2	60.3 $\pm$ 20.9	52.7 $\pm$ 16.9	60.8 $\pm$ 18.8	61.9 $\pm$ 19.2
<b>Anthropometry</b>						
Body mass (kg)	123.3 $\pm$ 22.5	120.8 $\pm$ 24.7	120.3 $\pm$ 25.4	132.3 $\pm$ 27.9	131.1 $\pm$ 27.6	129.1 $\pm$ 28.3
Waist circumference (cm)	127 $\pm$ 14	124 $\pm$ 16	124 $\pm$ 18	129 $\pm$ 15	126 $\pm$ 16	126 $\pm$ 17
<b>Power</b>						
Shoulder press MV ( $\text{m}\cdot\text{s}^{-1}$ )	0.49 $\pm$ 0.15	0.55 $\pm$ 0.15	0.58 $\pm$ 0.11	0.54 $\pm$ 0.20	0.64 $\pm$ 0.16	0.67 $\pm$ 0.14
STS MV ( $\text{m}\cdot\text{s}^{-1}$ )	0.66 $\pm$ 0.18	0.84 $\pm$ 0.17	0.83 $\pm$ 0.16	0.68 $\pm$ 0.16	0.86 $\pm$ 0.18	0.84 $\pm$ 0.19
Shoulder press MP (W)	133 $\pm$ 76	158 $\pm$ 86	164 $\pm$ 84	134 $\pm$ 98	186 $\pm$ 96	183 $\pm$ 98
STS MP (W)	717 $\pm$ 256	949 $\pm$ 315	934 $\pm$ 312	793 $\pm$ 292	1069 $\pm$ 409	1004 $\pm$ 378
<b>QoL</b>						

EQ-5D-5L index value	0.71 ± 0.20	0.75 ± 0.17	0.75 ± 0.14	0.78 ± 0.18	0.79 ± 0.19	0.83 ± 0.10
EQ-VAS	43.3 ± 22.9	70.0 ± 16.0	62.5 ± 16.9	47.4 ± 20.2	64.9 ± 14.5	59.4 ± 19.3
OWLQOL	38.5 ± 19.1	62.4 ± 14.9	66.6 ± 23.2	43.0 ± 26.2	63.0 ± 24.5	66.4 ± 20.6
WRSM	27.4 ± 13.6	13.9 ± 9.4	15.1 ± 9.7	23.9 ± 13.0	15.8 ± 10.3	14.8 ± 7.6

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1RM = one repetition maximum; 6MWT = six-minute walk test; QoL = health-related quality of life; IMTP = isometric mid-thigh pull; MD = mean difference; MP = mean power; MV = mean velocity; OWLQOL = Obesity and Weight Loss Quality of Life Instrument; STS = sit-to-stand; SP = shoulder press; SR = seated row; TUG = timed up-and-go; VAS = visual analogue scale; WRSM = Weight-Related Symptom Measure.

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**Table 3.** Within-group changes from baseline to 6-months

	Slow-speed strength training (n = 19)			High-speed power training (n = 19)		
	Mean change (95% CI)	$g_z$ (95% CI)	<i>p</i>	Mean change (95% CI)	$g_z$ (95% CI)	<i>p</i>
<b>Function</b>						
TUG (s)	-0.83 (-1.1, -0.55)	1.64 (0.90, 2.37)	<0.001	-0.72 (-1.1, -0.34)	1.04 (0.36, 1.72)	<0.001
6MWT (m)	46.3 (26.7, 66.0)	1.30 (0.60, 2.00)	<0.001	62.3 (44.5, 80.0)	1.93 (1.16, 2.70)	<0.001
Chair STS (reps)	4.2 (3.0, 5.4)	1.87 (1.11, 2.64)	<0.001	4.2 (2.5, 5.8)	1.35 (0.65, 2.06)	<0.001
<b>Strength</b>						
IMTP (kg)	33.3 (23.0, 43.6)	1.77 (1.02, 2.52)	<0.001	28.2 (15.1, 41.2)	1.18 (0.49, 1.87)	<0.001
Shoulder press 1RM (kg)	2.7 (0.4, 4.9)	0.65 (0.00, 1.30)	0.010	1.9 (-0.95, 4.7)	0.37 (-0.28, 1.01)	0.12
Seated row 1RM (kg)	7.7 (3.5, 11.9)	1.01 (0.34, 1.69)	<0.001	9.2 (4.7, 13.7)	1.12 (0.44, 1.81)	<0.001
<b>Anthropometry</b>						
Body mass (kg)	-3.1 (-6.7, 0.63)	0.45 (-0.19, 1.09)	0.057	-3.2 (-5.2, -1.1)	0.86 (0.19, 1.52)	0.001
Waist circumference (cm)	-3.2 (-6.7, 0.19)	0.52 (-0.13, 1.17)	0.033	-2.5 (-6.0, 1.0)	0.39 (-0.25, 1.03)	0.10
<b>Power</b>						
Shoulder press MV ( $m \cdot s^{-1}$ )	0.08 (0.01, 0.15)	0.65 (-0.01, 1.30)	0.010	0.13 (0.03, 0.23)	0.71 (0.05, 1.36)	0.006
STS MV ( $m \cdot s^{-1}$ )	0.17 (0.08, 0.25)	1.09 (0.41, 1.77)	<0.001	0.16 (0.08, 0.23)	1.12 (0.44, 1.80)	<0.001
Shoulder press MP (W)	31.6 (7.5, 55.8)	0.72 (0.06, 1.37)	0.005	49.5 (8.1, 90.8)	0.66 (0.00, 1.31)	0.009
STS MP (W)	216 (77, 356)	0.85 (0.19, 1.52)	0.001	211 (36, 385)	0.66 (0.01, 1.32)	0.009

**QoL**

EQ-5D-5L index value	0.05 (-0.04, 1.4)	0.28 (-0.36, 0.92)	0.17	0.06 (-0.02, 0.13)	0.40 (-0.25, 1.04)	0.09
EQ-VAS	19.7 (10.7, 28.6)	1.15 (0.47, 1.84)	<0.001	12.0 (2.3, 21.7)	0.68 (0.03, 1.34)	0.007
OWLQOL	28.0 (15.0, 41.0)	1.19 (0.50, 1.87)	<0.001	23.3 (15.0, 31.7)	1.54 (0.81, 2.26)	<0.001
WRSM	-12.4 (-20.7, -4.2)	0.80 (0.14, 1.46)	0.002	-8.9 (-17.0, -0.86)	0.62 (-0.03, 1.27)	0.015

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1RM = one repetition maximum; 6MWT = six-minute walk test;  $g_z$  = Hedges'  $g$ ; QoL = health-related quality of life; IMTP = isometric mid-thigh pull; MD = mean difference; MP = mean power; MV = mean velocity; OWLQOL = Obesity and Weight Loss Quality of Life Instrument;  $p$  =  $p$ -value; STS = sit-to-stand; TUG = timed up-and-go; VAS = visual analogue scale; WRSM = Weight-Related Symptom Measure.

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**Table 4.** Adjusted mean differences (95% CI) in outcomes at 3-months and 6-months

	3-months			6-months		
	Adjusted MD (95% CI)	$g_s$ (95% CI)	$p$	Adjusted MD (95% CI)	$g_s$ (95% CI)	$p$
<b>Function</b>						
TUG (s)	-0.02 (-0.52, 0.48)	0.02 (-0.61, 0.66)	0.94	0.05 (-0.25, 0.35)	-0.12 (-0.75, 0.52)	0.73
6MWT (m)	1.6 (-18.5, 21.6)	0.05 (-0.58, 0.69)	0.88	-16.9 (-5.1, 38.9)	-0.51 (-1.16, 0.13)	0.13
Chair STS (reps)	0.8 (-0.6, 2.2)	0.40 (-0.24, 1.04)	0.24	0.0 (-1.9, 1.9)	0.00 (-0.63, 0.64)	1.0
<b>Strength</b>						
IMTP (kg)	3.9 (-5.3, 13.1)	0.28 (-0.35, 0.92)	0.39	7.9 (-3.5, 19.4)	0.46 (-0.18, 1.11)	0.17
Shoulder press 1RM (kg)	1.0 (2.0, 4.1)	0.23 (-0.41, 0.87)	0.49	0.9 (-2.0, 3.9)	0.21 (-0.43, 0.85)	0.53
Seated row 1RM (kg)	0.7 (-2.9, 4.4)	0.13 (-0.50, 0.77)	0.69	-1.8 (-5.7, 2.2)	-0.30 (0.94, 0.34)	0.37
<b>Anthropometry</b>						
Body mass (kg)	-1.3 (-3.9, 1.3)	0.34 (-0.30, 0.98)	0.32	0.2 (-3.1, 3.7)	-0.06 (-0.69, 0.58)	0.89
Waist circumference (cm)	-1.4 (-4.2, 1.5)	0.32 (-0.32, 0.96)	0.33	-0.7 (-4.5, 3.2)	0.11 (-0.52, 0.75)	0.74
<b>Power</b>						
Shoulder press MV ( $m \cdot s^{-1}$ )	-0.09 (-0.2, 0.01)	-0.64 (-1.29, 0.02)	0.06	-0.09 (-0.15, -0.03)	-0.95 (-1.63, -0.28)	0.007
STS MV ( $m \cdot s^{-1}$ )	-0.01 (-0.1, 0.08)	-0.07 (-0.71, 0.56)	0.83	0.01 (-0.08, 0.10)	0.05 (-0.58, 0.69)	0.88
Shoulder press MP (W)	-26 (-59, 7)	-0.52 (-1.17, 0.13)	0.12	-16 (-45, 13)	-0.38 (-1.02, 0.26)	0.26
STS MP (W)	-45 (-196, 105)	-0.20 (-0.84, 0.43)	0.54	-41 (-218, 135)	-0.16 (-0.80, 0.48)	0.64
<b>QoL</b>						

EQ-5D-5L index value	0.00 (-0.06, 0.06)	0.02 (-0.61, 0.66)	0.93	-0.04 (-0.10, 0.03)	-0.40 (-1.04, 0.25)	0.24
EQ-VAS	6.0 (-2.0, 14.1)	0.50 (-0.14, 1.15)	0.14	4.6 (-4.2, 13.5)	0.35 (-0.29, 0.99)	0.30
OWLQOL	5.2 (-3.6, 14.1)	0.40 (-0.24, 1.04)	0.24	3.4 (-8.5, 15.3)	0.19 (-0.44, 0.83)	0.56
WRSM	-3.2 (-9.4, 3.0)	0.35 (-0.29, 0.99)	0.30	-1.8 (-7.0, 4.6)	0.14 (-0.50, 0.77)	0.68

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1RM = one repetition maximum; 6MWT = six-minute walk test; 95% CI = 95% confidence interval;  $g_s$  = Hedges'  $g$ ; QoL = health-related quality of life; IMTP = isometric mid-thigh pull; MD = mean difference; MP = mean power; MV = mean velocity; OWLQOL = Obesity and Weight Loss Quality of Life Instrument;  $p$  =  $p$ -value; STS = sit-to-stand; TUG = timed up-and-go; VAS = visual analogue scale; WRSM = Weight-Related Symptom Measure.

529 **Figure Legends**

530 **Figure 1.** CONSORT participant flowchart. PT = high-speed power training; ST = slow-speed  
531 strength training.

532

533 **Appendices**

534 **Appendix 1.** Consensus on Exercise Reporting Template (CERT)

535 **Appendix 2.** Primary resistance training movement patterns

536 **Appendix 3.** Supplementary methods

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