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Citation: Orange, Sam, Marshall, Phil, Madden, Leigh A. and Vince, Rebecca V. (2020) Effect of home-based resistance training performed with or without a high-speed component in adults with severe obesity. *Translational Sports Medicine*, 3 (1). pp. 34-45. ISSN 2573-8488

Published by: UNSPECIFIED

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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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13 **Acknowledgements**

14 The authors would like to thank H. Henrickson, M. Doughty, K. Russell, and S. Pender for
15 their help supporting the study and in the recruitment of participants. We would also like to
16 thank all the participants whom volunteered to take part in this study.

17 **Conflict of interest statement**

18 The authors have no conflicts of interest to declare.

19 **ClinicalTrials.gov Identifier:** NCT03900962

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 ≥ 40 kg/m² 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⁻¹, $g_s = -0.95$ [-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 ^{1,2} Severe obesity (i.e. body mass index of ≥ 40 kg/m²) is associated with even further
47 reductions in physical functioning and muscle strength relative to body mass.³ These physical
48 constraints impair quality of life and to lead to a decreased motivation to exercise.⁴ 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.^{5,6} 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.^{7,8} Home-based exercise is a
56 convenient alternative to supervised interventions and may promote similar functional
57 adaptations.^{9,10} 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.¹¹⁻¹³ 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.¹⁴ 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.^{15,16} Preliminary
74 evidence also exists supporting the superiority of power training in sarcopenic obese adults.¹⁷
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 ≥ 40 kg/m². 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 ≥ 18 years, and a BMI of ≥ 40 kg/m² or
87 between 35 and 40 kg/m² 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 (≥ 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,¹⁸ 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.¹⁹ 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.²⁰

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.¹⁴

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., TKK 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 (PUSHTM, 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.²¹

185 *Health-related quality of life*

186 The EQ-5D-5L and EQ-visual analogue scale (EQ-VAS) assessed general QoL,²² 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.²³ 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 al¹⁷ 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 .²⁴ 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 3.1.²⁵

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 $(1 - \frac{3}{4Ni-9})$.²⁴ The SD of the adjusted means were derived from their
217 95% CIs: $\sqrt{N} \times (\frac{upper\ limit - lower\ limit}{2t-value})$.²⁶ Between-group differences of 0.5 SDs were used to
218 denote a minimum important difference.²⁷ 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 (≥ 0.8).²⁸ 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.²⁹

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 ± 516 in the ST group and 7181 ± 379 in the PT group,
233 which represents 22% and 13% increases from baseline, respectively (Table 1). Average
234 session duration was 26 ± 3 min during ST and 25 ± 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 ± 25 (ST group) and 101 ± 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⁻¹, $g_s = -0.64$) 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⁻¹, $g_s = -0.95$), 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 colleagues³⁰ 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.^{13,31-33} 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 colleagues³⁴ 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 colleagues¹⁷ 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.¹⁷ 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.^{35,36} 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.³⁷ Sayers and colleagues³⁸ 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,³⁹ greater early phase neural drive,⁴⁰ and better
304 coordination.⁴¹

305 Despite this, we were unable to demonstrate a difference in STS power between groups. Whilst
306 the single STS power test is reliable¹⁴ 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,⁴² 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,¹⁷ 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.⁴³ 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°.⁴⁴ 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.¹⁴

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 ≥ 2.5 kg reduces the risk of developing type II diabetes.⁴⁵
329 In obese adults with type II diabetes, reductions in body mass of $\geq 2\%$ results in decreased

330 fasting glucose concentrations and HbA1c.⁴⁵ 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%).^{5,6} 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, $d = 0.73$).²³ 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,^{46,47} whereas those showing no change in
346 QoL did not report the use of behaviour change methods.^{48,49} 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.

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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 ²)	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
Function						
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
Strength						
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
Anthropometry						
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
Power						
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
QoL						

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

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>
Function						
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
Strength						
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
Anthropometry						
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
Power						
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

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
Function						
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
Strength						
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
Anthropometry						
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
Power						
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
QoL						

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

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.

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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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