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

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

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Conflict of interest statement

The authors have no conflicts of interest to declare.

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ABSTRACT

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

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

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

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

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

INTRODUCTION

Obesity reduces muscle contractile function and the ability to perform activities of daily living.[1,2] Severe obesity (i.e. body mass index of ≥ 40 kg/m^2) is associated with even further reductions in physical functioning and muscle strength relative to body mass.[3] These physical constrains impair quality of life and to lead to a decreased motivation to exercise.[4] Therefore, improving physical functioning should be a central tenet in the management of severe obesity and in the promotion of regular physical activity.

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

Traditional resistance training typically involves sustained contractions at low to moderate velocities. While this method of training is effective for augmenting maximal strength production, which is executed at slow velocities, it may neglect the development of muscle power. Indeed, studies investigating power adaptations in response to conventional resistance training have produced equivocal results.[11-13] This is problematic because lower-limb power has recently been shown to be a superior determinant of function compared with strength in adults with severe obesity.[14] Thus, specifically targeting muscle power, in addition to or instead of muscle strength, may preferentially enhance physical functioning.

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

MATERIALS AND METHODS

Participants

Participants were recruited from a Tier 3 specialist weight management service Kingston upon Hull, United Kingdom, from January 2016 to February 2017. Eligibility criteria for inclusion were referral from a General Practitioner, an age of ≥18 years, and a BMI of ≥ 40 kg/m^2 or between 35 and 40 kg/m^2 with a serious comorbidity (such as type II diabetes). Exclusion criteria included: unstable chronic disease state, prior myocardial infarction or heart failure, poorly controlled hypertension (≥ 180/110 mmHg), uncontrolled supraventricular tachycardia (≥ 100 bpm), participation in a structured exercise regime, body mass of over 200 kg, weight change of > 4 kg in the last 6-months, and pre-existing musculoskeletal or neurological condition that could affect their ability to complete the training and testing. All participants gave their written informed consent and the study was ethically approved by a relevant institutional review board. This trial is registered on ClinicalTrials.gov (NCT03900962).

Study design

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

Resistance training intervention

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

The training programme was delivered online via individual, private playlists on Youtube (YouTube, San Bruno, California, USA), with each playlist involving an individually-prescribed series of pre-recorded exercise videos. Participants also received an exercise package that included three colour-coded resistance bands offering three incremental levels of resistance (Iron Woody Fitness, Onley, MT), a heart rate monitor (FT1, Polar Electro, Kempele, Finland), a training diary, a 10-point rating of perceived exertion (RPE) scale,[18] and a pedometer (Yamax Digiwalker SW-200, YAMAX, Bridgnorth, Shropshire, UK).

Slow-speed strength training

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

High-speed power training

All training variables were the same between groups apart from repetition velocity. During the first three weeks of training, the PT completed the concentric and eccentric phases over two seconds. Thereafter, the PT group completed the concentric phase of five exercises (squat, press-up, incline chest press, seated row and push-press) as fast as possible whilst still taking two seconds to complete the eccentric phase. The exercise videos continuously encouraged participants to perform these resistance exercises with maximal concentric intended velocity.

Walking intervention

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

Weight management service

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

Outcome measures

Anthropometric measurements

Body mass and height were measured with a calibrated digital scale and a free-standing stadiometer, respectively (SECA, Birmingham, UK). Waist and hip circumferences were assessed using standard techniques.[20]

Functional performance

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

Muscle strength

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

Muscle power

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

Health-related quality of life

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

Exercises responses

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

Sample size

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

Statistical analysis

Analyses were performed by intention to treat using SPSS version 24.0 (IBM SPSS, Chicago, IL). Descriptive statistics were used to characterise participants at baseline. We used traditional two-sided significance tests to examine changes over time and determine differences between groups, where the null hypothesis for each test was that the true effect size was zero. Between-group differences in outcomes at 3-months and 6-months were assessed by ANCOVA with baseline values, age and sex as covariates. Homogeneity of regression slopes were confirmed with scatter plots, and the adjusted mean difference with 95% confidence intervals (CI) from the model are presented. Within-group changes from baseline were examined with one-way repeated-measures ANOVAs and subsequent Bonferroni-corrected planned contrasts. The assumption of sphericity was assessed with Mauchly's test, and in the case of significant violations, the Greenhouse-Geisser epsilon correction was applied. Hedges' g was calculated as a measure of effect size within-groups (mean change / SD of change; g_z) and between-groups (adjusted mean difference / SD of difference; g_s), which adjusts for sample bias by multiplying the effect estimate by $(1 - \frac{3}{4Ni-9})$.[24] The SD of the adjusted means were derived from their 95% CIs: $\sqrt{N}$ x $(\frac{upper\ limit - lower\ limit}{2t - value})$.[26] Between-group differences of 0.5 SDs were used to denote a minimum important difference.[27] Effect sizes in favour of ST are reported as a positive g_s and effect sizes in favour of PT as a negative g_s. Effect sizes were rated as trivial (< 0.2), small (0.2-0.49), moderate (0.5-0.79) or large (≥ 0.8).[28] Statistical significance was set at a two-tailed $p < 0.05$. Missing data at 3- and 6-months were replaced via multiple imputation (Appendix 3). Data files and scripts are available online.[29]

RESULTS

Participants

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

Exercise responses

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

Within-group changes

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

Between-group differences

At 3-months, differences in shoulder press power (-26 W, g_s = -0.52) and shoulder press contraction velocity (-0.09 $m \cdot s^{-1}$, g_s = -0.64) exceeded 0.5 SDs in favour of the PT group (Table 4), whereas differences in EQ-VAS favoured the ST group (6.0, g_s = 0.50). At 6-months, the improvement in shoulder press contraction velocity was significantly greater following PT compared with ST (-0.09 $m \cdot s^{-1}$, g_s = -0.95), and the difference in 6MWT distance also favoured the PT group (-16.9 m, g_s = -0.51).

DISCUSSION

The main finding of this study was that home-based walking and resistance training significantly improved physical function, strength, power, contraction velocity and QoL in adults with severe obesity. Our findings also suggest that performing resistance exercises with maximal intended concentric velocity is a simple and safe adjustment to conventional slow-speed resistance training that yields negligible negative effects but potentially large benefits on walking capacity and upper-limb movement speed.

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

The improvement in 6MWT distance favoured the PT group (adjusted mean difference = -16.9 m, g_s = -0.52). This finding suggests that PT improves walking capacity to a greater extent than ST, which partially agrees with the only other study to compare power and strength training in obese individuals. Balachandran and colleagues[17] found that modified SPPB performance favoured PT in a sample of 17 sarcopenic obese adults (g_s = 0.6). The authors attributed this finding to improved gait speed based on the reasoning that gait speed explains most of the variance in SPPB.[17] Unlike our study though, neither ST nor PT improved 6MWT performance, nor were any between-group differences reported (adjusted mean difference = 5.4 m, g_s = 0.1). It is also important to consider that a range of differences in 6MWT distance are compatible with our data, from a large difference in favour of PT to a trivial difference favouring ST (effect size 95% CI: -1.16 to 0.13). Hence, the data suggest that the potential negative effects of PT compared to ST are negligible, but the potential benefits are large. On the basis that power training is a simple and safe adjustment to conventional resistance training, it is therefore reasonable to recommend that severely obese adults perform resistance exercises with maximal concentric velocity to confer further improvements in walking capacity.

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

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

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

Weight loss slightly exceeded 3 kg in both groups (-2.4%). This is likely to be clinically meaningful because a weight loss of ≥ 2.5 kg reduces the risk of developing type II diabetes.[45] In obese adults with type II diabetes, reductions in body mass of ≥ 2% results in decreased fasting glucose concentrations and HbA1c.[45] Previous studies that have added resistance training to specialist weight management programmes have reported similar magnitudes of weight loss (2.4-2.8%).[5,6] Participants in our study were receiving usual care for the duration of the training intervention, which includes specialist treatments designed to aid weight loss (.e.g. counselling, dietary advise, pharmacotherapy). As a consequence, it is not possible to determine which components of the weight management service were responsible for weight loss, but it is likely a combination of these factors.

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

There were some study limitations that warrant consideration. Outcome assessors were not blinded to group allocation, although the same investigator strictly adhered to a pre-determined protocol. We did not include a non-exercising control group and therefore we examined changes within-groups, although we interpreted magnitudes of change in relation to their clinical relevance. In addition, the study was only powered to detect large differences in STS power. As a consequence, we used 0.5 SDs to identify important between-group differences and considered the range of differences that were compatible with the data. Finally, it is unknown whether participants in the PT group executed resistance exercises with maximal intended velocity because training sessions were unsupervised. Even so, exercise videos visually and audibly instructed participants to perform the exercises as fast as possible, and the researcher reminded participants of this during each telephone call. Participants also rehearsed exercise technique under the researcher's supervision during behaviour change counselling sessions.

PERSPECTIVES

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

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

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Table 2. Outcomes at baseline, 3-months and 6-months (mean ± 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 ± 1.11	6.01 ± 1.33	6.06 ± 0.87	6.40 ± 0.96	5.65 ± 0.78	5.68 ± 0.67
6MWT (m)	504 ± 76	557 ± 77	550 ± 75	504 ± 78	554 ± 80	566 ± 76
Chair STS (reps)	11.1 ± 2.9	15.6 ± 3.5	15.3 ± 4.1	12.4 ± 2.5	16.1 ± 3.1	16.5 ± 3.4
Strength						
IMTP (kg)	81.8 ± 48.9	115 ± 39	115 ± 42	76.1 ± 48.1	108 ± 36	104 ± 50
Shoulder press 1RM (kg)	38.9 ± 18.9	43.2 ± 20.0	41.6 ± 19.1	37.2 ± 17.8	40.8 ± 17.4	39.1 ± 19.4
Seated row 1RM (kg)	52.6 ± 24.3	61.5 ± 22.2	60.3 ± 20.9	52.7 ±16.9	60.8 ± 18.8	61.9 ± 19.2
Anthropometry						
Body mass (kg)	123.3 ± 22.5	120.8 ± 24.7	120.3 ± 25.4	132.3 ± 27.9	131.1 ± 27.6	129.1 ± 28.3
Waist circumference (cm)	127 ± 14	124 ± 16	124 ± 18	129 ± 15	126 ± 16	126 ± 17
Power						
Shoulder press MV ($m \cdot s^{-1}$)	0.49 ± 0.15	0.55 ± 0.15	0.58 ± 0.11	0.54 ± 0.20	0.64 ± 0.16	0.67 ± 0.14
STS MV ($m \cdot s^{-1}$)	0.66 ± 0.18	0.84 ± 0.17	0.83 ± 0.16	0.68 ± 0.16	0.86 ± 0.18	0.84 ± 0.19
Shoulder press MP (W)	133 ± 76	158 ± 86	164 ± 84	134 ± 98	186 ± 96	183 ± 98
STS MP (W)	717 ± 256	949 ± 315	934 ± 312	793 ± 292	1069 ± 409	1004 ± 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.

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)	*p*	Mean change (95% CI)	g_z (95% CI)	*p*
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.

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.

Figure Legends

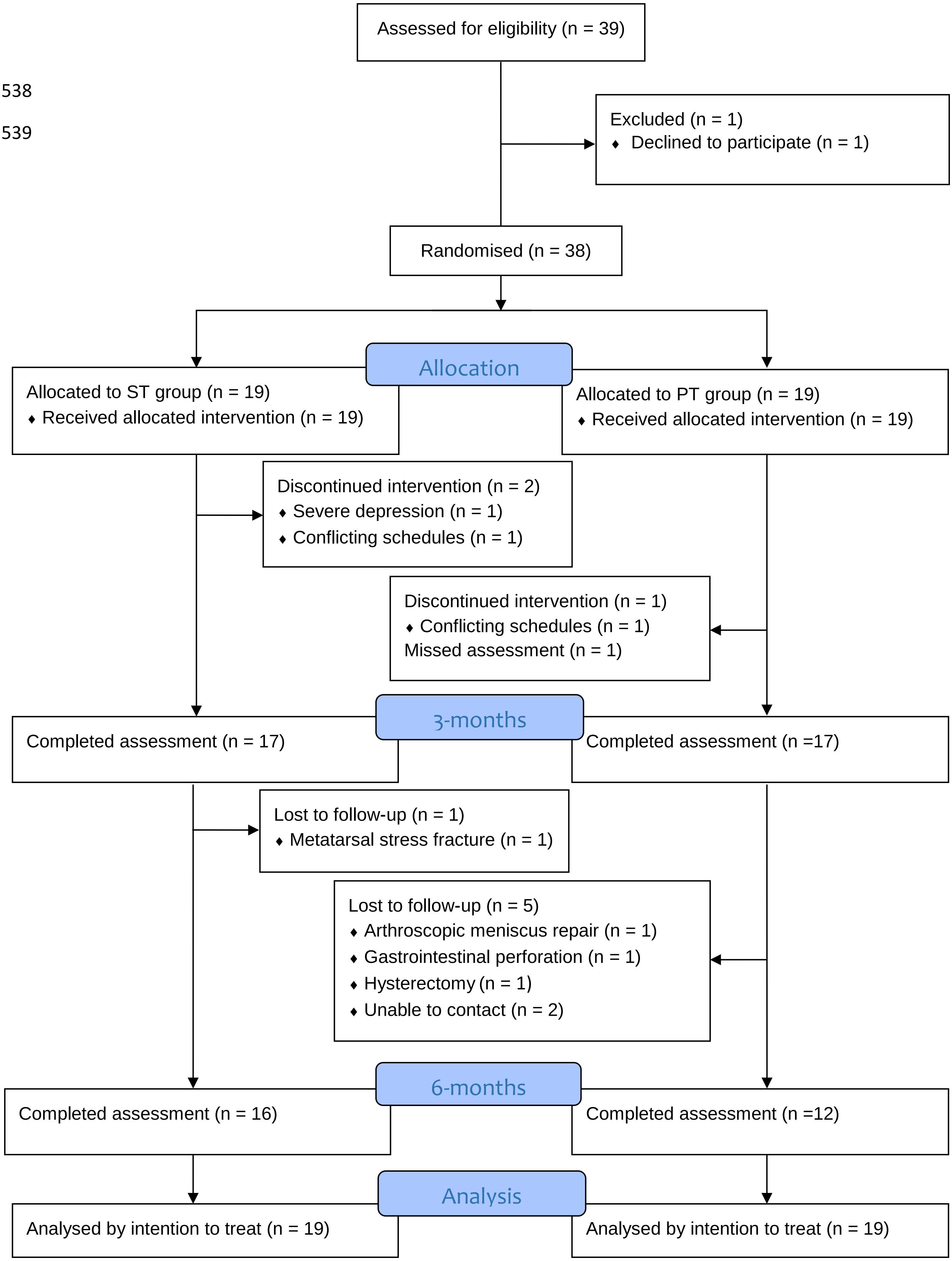
Figure 1. CONSORT participant flowchart. PT = high-speed power training; ST = slow-speed strength training.

Appendices

Appendix 1. Consensus on Exercise Reporting Template (CERT)

Appendix 2. Primary resistance training movement patterns

Appendix 3. Supplementary methods


Assessed for eligibility (n = 39)
Excluded (n = 1)
♦ Declined to participate (n = 1)
Randomised (n = 38)
Allocation
Allocated to ST group (n = 19)
♦ Received allocated intervention (n = 19)
Allocated to PT group (n = 19)
♦ Received allocated intervention (n = 19)
Discontinued intervention (n = 2)
♦ Severe depression (n = 1)
♦ Conflicting schedules (n = 1)
Discontinued intervention (n = 1)
♦ Conflicting schedules (n = 1)
Missed assessment (n = 1)
3-months
Completed assessment (n = 17)
Completed assessment (n =17)
Lost to follow-up (n = 1)
♦ Metatarsal stress fracture (n = 1)
Lost to follow-up (n = 5)
♦ Arthroscopic meniscus repair (n = 1)
♦ Gastrointestinal perforation (n = 1)
♦ Hysterectomy (n = 1)
♦ Unable to contact (n = 2)
6-months
Completed assessment (n = 16)
Completed assessment (n =12)
Analysis
Analysed by intention to treat (n = 19)
Analysed by intention to treat (n = 19)