The effects of loaded and unloaded high-velocity resistance training on functional fitness among community-dwelling older adults

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Abstract

Background: physical function declines up to 4% per year after the age of 65. High-velocity training is important for maintaining muscular power and ultimately, physical function; however, whether performing high-velocity training without external resistance increases functional fitness among older adults remains unclear.

Objective: the purpose of this investigation was to evaluate loaded and unloaded high-velocity training on lower body muscular power and functional fitness in older adults.

Subjects: fifty-seven community-dwelling older adults (n = 16 males, n = 41 females) participated in this study. Inclusion criteria comprised ≥65 years of age, ≥24 on the Mini-mental state examination and no falls within past year.

Methods: two groups completed a 20-week high-velocity training intervention. The non-weighted group (UNLOAD, n = 27) performed the protocol without external load while the intervention group (LOAD, n = 30) used external loads via exercise machines. Functional fitness was assessed using the Short Physical Performance Battery (SPPB), Senior Fitness Test (SFT), hand-grip and lower body power measures.

Results: multivariate ANOVA revealed that both groups had significant improvements for average (17.21%) and peak (9.26%) lower body power, along with the SFT arm curl (16.94%), chair stand (20.10%) and 8 ft. up-and-go (15.67%). Improvements were also noticed for SPPB 8 ft. walk (25.21%). However, improvements for all functional fitness measures were independent of training group.

Conclusions: unloaded high-velocity training increased functional fitness and power the same as loaded training. The ability of high-velocity movements to elicit gains in functional fitness without external loads may help health professionals develop fitness programs when time/space is limiting factor.

Keywords: power, independence, activities of daily living, older people

Introduction

Within the next 25 years, the population of adults aged 65 years and older is expected to double, reaching 72 million individuals [1]. Among older adults, mobility disability is prevalent, affecting 20% of adults older than 70 and 80% of adults over 90 years [2]. Physical function is the ability to perform activities of daily living (ADLs) such as standing from a chair [3, 4] declining up to 4% per year after the age of 65 [5, 6, 7]. As the number of older adults continues to rise, so will the incidence of mobility disability.

Resistance training is recommended as the most effective and cost-efficient intervention for increasing muscle mass and strength in older individuals [8]. Although resistance training is an important factor for maintaining muscle mass [9, 10, 11], high-velocity training appears to be more relevant to maintenance of ADLs and decreasing mortality rates [12, 13, 14]. High-velocity training increases muscular power [15] and with age, power decreases at a faster rate than strength [16]. Therefore, training programs focused on improving power may be more effective for reducing age-related disabilities [17]. Compared with muscular strength in older adults, muscular power more significantly relates to performance on multi-functional tests such as the Short Physical Performance Battery (SPPB) [18, 19] and individual measures of physical function such as climbing stairs [20].

Commonly, low-velocity resistance exercise is used as a comparison to high velocity to understand differences between
training types [21, 22]. Other studies evaluating the effects of high-velocity training utilise habitually active controls such as performing regular ADLs [15, 23] or walking-based interventions with no resistance training [24]. Different intensities of high-velocity training have also been compared based on 1-repetition maximum (1-RM) performance. Individuals training at 80, 50 and 20% of 1-RM increased power compared with untrained controls (14, 15 and 14%, respectively); however, no differences existed between training groups [15]. This indicates that power may increase independent of intensity (as low as 20% 1-RM) as long as quick concentric/slow eccentric movements are maintained. Although the aforementioned designs indicated that muscular power could be increased compared with traditionally resistance-trained controls, power increases were not different when performing high-velocity training at different loads. As such, it is unclear whether these increases in functional power can be obtained without the use of resistance-based equipment.

Muscular power is important for maintaining longitudinal physical and functional health; however, whether or not performing these movements without additional resistance will improve functional fitness in older adults remains unclear. Based on previous results, performing power-based movements increases muscular power in older adults even at very low loads, but even low-load training requires access to facilities and equipment. Older adults may not always have access to these facilities, ultimately hindering their ability to maintain functional fitness. Therefore, the purpose of this investigation was to evaluate the effects of loaded and unloaded high-velocity resistance training on lower body muscular power and parameters of functional fitness among older adults. It was hypothesised that loaded high-velocity training would further increase lower body muscular power compared with unloaded controls. It was also hypothesised that loaded high-velocity training would significantly increase scores on functional fitness measures compared with individuals performing unloaded power movements.

Methodology

The methodology has been abridged based on length requirements. For expanded details, refer to Supplementary data, Appendix S1, available in Age and Ageing online.

Participants

This study consisted of 57 community-dwelling older adults. The Institutional Review Board at the University of Arkansas approved this project, and informed consent was obtained from all interested participants prior to participation.

Mini-Mental state exam

The Mini-Mental state exam (MMSE) [25] was administered prior to testing [26, 27]. Participants were required to score ≥24 out of 30 to be considered eligible [28].

Body composition assessment

Height and weight were measured using a Detecto Physician’s Scale (Webb City, MO, USA); measurements were recorded to the nearest 0.1 cm and 0.1 kg, respectively. Body composition and bone density data were obtained using dual-energy x-ray absorptiometry (DXA, General Electric, Medical Systems; Madison, WI, USA).

Strength testing

Maximal strength (1-RM) testing established maximal muscular strength at baseline and was re-evaluated every 4 weeks throughout the training program. Strength testing comprised the following exercises: seated row, chest press, shoulder press, biceps curl, triceps extension, knee extension and knee curl.

Exercise programs

Participants were randomised into two groups and completed a 20-week high-velocity training intervention. Each group was instructed to perform the concentric phase of all movements as quickly as possible. For the purposes of this study, the non-weighted group (UNLOAD, n = 27) performed the exercise protocol with no external load while the intervention group (LOAD, n = 30) used an external load, via exercise machines, for all exercises.

As prescribed by the American College of Sports Medicine (ACSM), participants performed three sets of eight repetitions at 70% of their pre-determined 1-RM [29]. The exercises were the same as the 1-RM measures with the addition of the power chair stand. For LOAD, the power chair stand was performed with a loaded vest beginning at 10% of the participants’ mass and increased 1% per week until 20% was attained. The UNLOAD group also reported to the fitness centre 2 days/week and performed the same exercises without any external load. Every 4 weeks, 1-RM testing was conducted to ensure progression of exercise intensity. Individualised adjustments were completed when necessary.

Functional fitness measures

Functional fitness was assessed using the SPPB [30], Senior Fitness Test (SFT) [31], hand-grip [32] and lower body power measures. The Short Physical Performance Battery consists of balance, timed 8 ft. walk and chair stands. Reliability of the Short Physical Performance Battery has been reported as ICC = 0.75–0.89 for all measures [33].

The SFT was completed based on the previously established protocols by Rikli and Jones [31]. The SFT has previously established test–retest reliability (0.93–0.97) for all measures [34].

Hand-grip testing determined overall grip strength [32, 35, 36]. High test–retest reliability (ICC = 0.95) for the hand-grip test has been previously recorded [32].

Lower body power was assessed using the Tendo Weightlifting Analyzer (Trencin, Slovak Republic). The Tendo was attached to the side of each participant by securing a belt around...
the subject’s waist. From a seated position, with the arms placed across opposing shoulders, the participant was instructed to stand as quickly as possible before slowly returning to the initial seated position. (For visual, refer to Supplementary data, Figure S1a and b (Appendix S2), available in Age and Ageing online.) Five repetitions were recorded with 60 s rest between each repetition. Average power was calculated as the mean power generated among all five repetitions, and peak power was the highest power recorded during any of the five repetitions.

Statistical analyses

Statistical Package for the Social Sciences (SPSS, version 20) was used to conduct all analyses. Normal distribution at baseline was assessed using histograms and descriptive statistics. Independent t-tests were used to determine initial differences between groups for demographic, functional fitness and lower body power measures. The repeated-measures multivariate analysis of variance (MANOVA) procedure was used to examine significant differences between variables pre- and post-training, and the Bonferroni correction was applied when significance was observed within the analyses. The training groups were used as the independent variable and dependent variables included: body fat percentage, lean tissue mass, all functional fitness measures, hand-grip strength and lower body muscular power. Significance required for changes in demographic variables (body fat percentage and lean tissue mass) was set at $\alpha < 0.025$ (0.05/2 variables). Significance for the SFT was set at $\alpha < 0.008$ (0.05/6 variables) while significance for the SPPB was set at $\alpha < 0.01$ (0.05/5 variables). Power and strength assessments (average power, peak power, hand-grip strength) composed the final MANOVA analysis ($\alpha < 0.017; 0.05/3$ variables). For each analysis, effect size ($\eta^2$) and power ($\beta$) were also calculated based on the recommendations by Cohen [37]. All data are presented as mean ± SE.

Results

No adverse events were recorded as a result of either training load or compliance for the intervention was similar between groups (LOAD = 77%; UNLOAD = 80%). No initial group differences ($P > 0.05$) were observed prior to the training intervention for demographic, functional fitness or power/grip strength measures. (For initial group data, refer to Supplementary data, Table S1 (Appendix S3), available in Age and Ageing online.) No significant changes were observed between groups for body fat percentage [$F(1,40) = 2.62, P = 0.14$] or lean tissue mass [$F(1,40) = 0.49, P = 0.49$] after the intervention. After completion of the training programs, both LOAD and UNLOAD had significant improvements for average [$F(1,40) = 42.99, P < 0.007, \eta^2 = 0.52, \beta = 1.00$] and peak [$F(1,40) = 18.73, P < 0.017, \eta^2 = 0.32, \beta = 0.99$] lower body power, but not in hand-grip strength ($P > 0.017$). However, improvements were independent of training intervention. When combining the scores from the groups, average power increased 17.21% (Figure 1a) while peak power increased 9.26% (Figure 1b).

Similar results were observed during the senior fitness test for arm curl [$F(1,37) = 24.58, P < 0.008, \eta^2 = 0.40, \beta = 1.00$] and chair stand [$F(1,36) = 19.41, P < 0.008, \eta^2 = 0.35, \beta = 0.99$] measures, where training protocols equally increased testing scores independent of training group (Figure 2a and b, respectively). Scores increased 16.94 and 20.10% for the arm curl and chair stand, respectively. Although the significant group × time interaction ($P = 0.046$) for the 8 ft. up-and-go disappeared when applying the Bonferroni correction, a significant effect of time still remained and both groups improved significantly independent of training protocol [$F(1,34) = 8.44, P < 0.008, \eta^2 = 0.20, \beta = 0.81$]. Distances covered during the 6-min walk test were not significantly different as an effect of time or training intervention, nor were results for the chair sit-and-reach or back-scratch flexibility tests ($P > 0.008$ for all variables).

![Figure 1](image-url)
During the SPPB, training independent performance increases were observed for the 8 ft. walk \([F(1,36) = 19.78, P < 0.01, \eta^2 = 0.36, \beta = 0.99]\) with participants (regardless of group) completing the test 25.21% faster compared with baseline measures (Figure 3b). No significant changes were documented for 5-time sit-to-stand time, side-by-side, tandem and semi-tandem balance measures (all \(P > 0.01\)).

Discussion

The purpose of this study was to evaluate the effects of loaded and unloaded high-velocity training on lower body muscular power and parameters of functional fitness among older adults. LOAD and UNLOAD groups significantly increased average and peak power from baseline with no differences between groups. Certain measures of functional fitness (arm curl, chair sit-to-stand, 8 ft. up-and-go and 8 ft. walk) were also increased from baseline in both groups with no additional benefits from loaded high-velocity training. Increases in performance measures were independent from changes in body composition, indicating improvements may have been associated with neural adaptations as opposed to changes in lean or fat mass \([38]\). Although no significant increases were observed in 6-min walk, chair sit-and-reach and back-scratch scores, the training protocol utilised in this study did not place a direct focus on aerobic capacity or flexibility. Hand-grip strength was also unaffected.
by the training protocol; however, based on age-related normative data [39], the participants in the current investigation scored on the upper end of reported ranges, indicating a ceiling effect may have prevented additional improvements.

Decreases in functional fitness relate to declines in physical health and ultimately independence in older adults [40]. Performing ADLs requires muscular strength and power; however, power has been suggested to be more important for maintaining functional fitness [21, 22]. High-velocity resistance training increases muscular power and is also associated with increased performance of functional activities [23, 24, 40, 41]. In older adults, high-velocity training has been suggested as a more effective method for maintaining longitudinal health compared with other forms of exercise, such as low-velocity resistance training [21, 22] or walking-based interventions [24]. Compared with low velocity, high-velocity resistance training has significantly increased scores on the arm curl and chair stand tests with subsequent increases in lower body muscular power [42]. This is similar to the current study in which high-velocity resistance training increased functional fitness measures from the SFT and SPPB along with lower body muscular power. However, to date, it is unclear what level of intensity is required to elicit these increases in power and functional fitness scores. In older adults, it has been previously suggested that participation in power-based exercises at intensities as low as 20% 1-RM can provide significant performance benefits to the same extent as training at higher intensities (50 and 80% of 1-RM) [15]. In this study, we demonstrate that the use of external loads is not necessarily required to generate increases in power after a 20-week exercise intervention among independent living older adults.

De Vos and colleagues [15] suggested that a 16-week intervention averaging 50 sets per exercise may not be enough to observe between group differences and a longer design/greater exercise volume may be necessary. Although, the current design utilised a longer intervention (20 weeks) and greater exercise volume (3 sets/2 days/20 weeks; 120 sets per exercise), there were still no differences between training interventions. These results indicate that even with a longer, more intensive training program, external loads are not required for improvements in functional fitness and lower body when performing high-velocity movements among older adults.

The ability to maintain and potentially increase functional power is important for preserving physical health in older adults, yet loaded power-based exercises typically require specialised equipment to be performed properly. This can become an issue as older adults are not always capable of commuting to fitness facilities [43]. Even when proper transportation is available, older adults may feel intimidated by fitness center settings and personal issues can arise, such as feeling as if they are hindering or obstructing other exercisers [44]. From a safety perspective, previous data indicate no adverse responses to high-velocity resistance training in older adults when performed properly [41]; however, these studies have been traditionally conducted in healthy, community-dwelling older adults and it cannot be assumed that adverse events would not be observed when using a frailer population. Use of unloaded high-velocity movements to increase power indicates that certain barriers to exercise may be alleviated as older adults can exercise in the comfort of their own living arrangements, without the need for expensive equipment or ambulatory capability.

A limiting factor of this investigation is the majority of participants in the current investigation were female (72%), as females seem to adapt more favorably to low-load training compared with males [45]. Therefore, further research extrapolating these findings to community living individuals with a focus on gender specificity is warranted. An additional limitation is that a non-exercise control group was not utilised. Use of a non-exercise control group would rule out a learning effect associated with the functional fitness tests administered before and after training. Finally, in future investigations, dietary intake should be monitored to account for potential group differences affecting outcome results.

We conclude that unloaded high-velocity resistance training can potentially increase parameters of functional fitness and power to the same degree as using loaded training protocols in a mixed cohort of community-dwelling older adults. When developing exercise prescriptions for older adults, it is important to determine ease and feasibility of exercise, leading to increased participation and adherence. Based on previous recommendations for the incorporation of high-intensity training in older adults and the ability of these movements to elicit gains in physical fitness without the need for an external load, it may be easier for health professionals to develop fitness programs when time and space are limiting factors.

Key points
• External resistance is not required for improvements in functional fitness when performing high-velocity resistance training.
• Older adults may not need access to specialised equipment/facilities to maintain physical health.
• Health professionals can use these results to help develop more feasible exercise programs when working with older adults.

Conflicts of interest
None declared.

Supplementary data
Supplementary data mentioned in the text are available to subscribers in Age and Ageing online.

References
The long list of references supporting this original article has meant that only the most important are listed here and are represented by bold type throughout the text. The full list of
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