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RESEARCH

Effects of a 16-week high-speed resistance training program on physical and cognitive function in community-dwelling independent older adults: a clinical trial

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Abstract

Purpose This study investigated the effects of a 16-week high-speed resistance training (HSRT) program on physical and cognitive function in independent older adults.

Methods Seventy-nine participants were assigned to an intervention group (IG, $N = 40$, 68.50 ± 3.54 years) or a control group (CG, $N = 39$, 72.08 ± 5.89 years). The IG completed 60–70 min of supervised HSRT three times weekly for 16 weeks. All concentric actions were continuously monitored with a BEAST™ sensor. Physical function was evaluated by five tests: chair-stand, timed up and go (TUG), seated medicine ball throw (SMBT), six-minute walk (6MWT), and handgrip strength. General cognitive function was assessed with the mini-mental state examination (MMSE).

Results The intervention could induce significant improvements in favor of the IG ($p < 0.001$) for chair-stand ($\eta^2_p = 0.736$), TUG test ($\eta^2_p = 0.635$), SMBT ($\eta^2_p = 0.331$), 6MWT ($\eta^2_p = 0.386$), and handgrip strength test for dominant ($\eta^2_p = 0.448$) and non-dominant side($\eta^2_p = 0.388$), as well as in general cognitive function (MMSE, $p = 0.001$, $\eta^2_p = 0.146$).

Conclusions The 16-week HSRT program led to substantial enhancements in both physical and cognitive function. Interestingly, the HSRT program, tailored to general velocity zones, proved to be a safe and motivational approach to physical exercise within this population.

Keywords Velocity-based training · Strength training · Aged · Exercise · Cognition · Physical fitness

Introduction

The global aging population presents significant challenges, including heightened risks of chronic disease, declines in physical and cognitive function, and rising healthcare costs [1]. These age-related changes reduce independence, quality of life, and increase fall risk, underscoring the need for strategies to promote healthy aging [2].

Exercise interventions, particularly high-speed resistance training (HSRT) interventions, which emphasizes explosive

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concentric muscle actions with low-to-moderate loads [3], have proven more effective than traditional resistance training (RT) at improving fall-related physical function and cognition in older adults [4–8]. However, limited evidence exists on using commercial devices (e.g., accelerometers) to monitor the relationship between relative load and mean concentric velocity (MCV) during RT programs [9, 10]. Previously, Dorrell et al. [11] advocated for the prescription and monitoring of MCV in RT as a means of controlling fatigue and reducing reliance on 1 repetition maximum (1RM) protocol, an approach especially useful for older adults. Given that neuromuscular responses are influenced by both the magnitude of the external load and the intent to move it explosively [12], this may help explain the growing support for velocity-based training (VBT) in this population.

In load-velocity-based HSRT, maximal concentric actions are essential to maintain the inverse linear relationship between load and MCV, which tends to decrease as muscular fatigue increases [9, 11]. While the early findings in young adults have confirmed the effectiveness of VBT, using the MCV method, in promoting strength and power adaptations [11, 13–15], optimal training velocities for functional performance improvements in older adults remain unclear [3]. Although different multi-joint RT exercises are associated with different MCV values [16, 17], Mann and colleagues [18, 19] proposed general velocity zones to help guide loading decisions and to provide objective metrics for training. For instance, these zones suggest that specific MCV values target different elements of the strength–velocity continuum [3, 18].

Moreover, this approach enables real-time feedback on concentric movement velocity for each repetition, which may also enhance engagement and performance during RT exercises [20]. Therefore, this exploratory study is the first to implement a HSRT protocol using velocity zones and continuous MCV monitoring in older adults. The primary aim was to examine the effects of a 16-week HSRT program on physical function, while a secondary objective was to evaluate changes in global cognitive function using the mini-mental state examination (MMSE).

Methods

Study design

Ethical approval was obtained from the local university's Ethics Committee with clearance number 22030. The study was conducted in compliance with the Declaration of Helsinki and according to the Consolidated Standards of Reporting Trials guidelines. All participants were informed about the study's aims, potential benefits and risks and gave their written informed consent to be enrolled in the study. Finally, the present longitudinal study, which began in March 2022, was registered on *clinicaltrials.gov* (ID: NCT05586087).

Participants

The project was publicized through local newspapers and outreach efforts targeting daycares, health centers, and older adult associations. As a result, 89 older adults expressed interest in participating. Each prospective participant was subsequently contacted and underwent a face-to-face interview as part of the initial screening process. The interviews aimed to confirm eligibility based on the following inclusion criteria: (a) age of at least 65 years, (b) independent walking ability, and (c) ability to perform daily living tasks. Exclusion criteria included: (a) diabetes or cardiac disease, (b) surgery within the last 6 months, and (c) active oncological disease. Then, ten participants were excluded based on these criteria (Fig. S1 in the supplementary file).

During the individual interviews, the participants who met the criteria were asked about their ability to take part in the exercise sessions. When participants were not available, they were placed in the control group (CG) and put on a waiting list to take part in other research projects.

At the conclusion of the screening process, 79 independent older adults, both males and females, were divided into two groups: intervention group (IG) [$N = 40$, age, 68.50 ± 3.54 years; weight, 68.65 ± 11.36 kilograms (kg); and height, 157.15 ± 6.42 centimeters (cm)] and CG [$N = 39$, age, 72.08 ± 5.89 years; weight, 67.04 ± 10.69 kg; and height, 158.79 ± 9.63 cm]. The CG were instructed to maintain their usual activities without engaging in any new RT or exercise programs.

After the 16-week intervention, three participants from the IG (due to muscular discomfort, loss of contact, and participation in another exercise program at the same time) and two from the CG (due to a diagnosis of cancer and loss of contact) dropped out of the study.

Procedures

Assessments were conducted pre- and post-intervention over two consecutive days. On the first day (08:30 a.m. – 10:30 a.m.), anthropometric measurements were taken following an eight-hour fast, with participants abstaining from exercise, alcohol, and coffee for 24 hours. On the second day (09:00 a.m. – 01:00 p.m.), cognitive and physical function assessments were conducted in a consistent sequence by the same researcher to minimize errors. To monitor physical activity and dietary habits throughout the 16-week intervention, participants completed the international physical activity questionnaire–short form (IPAQ-SF) [29, 30] and the food frequency questionnaire [21], respectively. Detailed procedures and findings are described elsewhere [22].

Physical function

Physical function was assessed using five tests: (i) the chair-stand, in which participants' body strength was measured in 30 seconds [23]. A BEAST™ sensor (Beast Technologies, Brescia, Italy) was used to track each participant's movement velocity (chair-stand velocity) [24] (Fig. S2 in the supplementary file); (ii) the time up and go (TUG), which evaluates agility and dynamic balance [23]; (iii) the seated medicine ball throw (SMBT), which assesses upper body strength using a three kg medicine ball [25]; (iv) the handgrip strength (HDS), which was conducted with a hydraulic handgrip dynamometer (JAMAR®, Seahan Corporation, Masan, Korea) to evaluate muscle strength; and (v) the six-minute walk (6MWT), which measures aerobic capacity [23].

For the HDS, measurements were recorded for both dominant and non-dominant sides. The dynamometer was adjusted to fit each participant's hand, and participants stood with feet shoulder-width apart, elbows fully extended (180°), and arms away from the trunk. They were instructed to squeeze the grip with maximum force for at least two seconds. Two attempts were made per side with a one-minute rest between attempts, and the average was recorded [26].

General cognitive function

General cognitive function was assessed using the MMSE [27]. The Portuguese version used in this study was translated and validated by Guerreiro et al. [28]. The questionnaire comprises 30 items categorized as follows: (i) spatial–temporal orientation (ten points); (ii) retention (three points); (iii) attention and calculation (five points); (iv) evocation (three points); and (v) language (nine points, with one point awarded for visual constructive capacity).

Anthropometric

The weights and heights of the participants were measured using an electronic scale (TANITA®, MC 780MA, Amsterdam, Netherlands) and a stadiometer (SECA® 220, Hamburg, Germany) to the nearest 0.01 kg and 0.1 cm, respectively. The participants were required to be dressed in light clothes without shoes during these measurements. Subsequently, body mass index (BMI) values were calculated using the standard formula: BMI = body mass (kg)/height^2 (m^2).

Physical activity

The participants' physical activity levels were assessed using the IPAQ-SF [29, 30] before and after the intervention. The questionnaire captures the frequency (days/week) and duration (minutes/day) of walking, moderate, and vigorous activities, as well as sedentary behavior during the week and weekend. Total physical activity was calculated in MET-minutes/week, including separate scores for walking, moderate-to-vigorous physical activity (MVPA), and sedentary time. The data were processed and analyzed using the scoring spreadsheet provided by Cheng [31].

High-speed resistance training protocol

The full protocol and biweekly prescriptions are available elsewhere [22]. The IG participated in a 16-week supervised HSRT program, with one supervisor per exercise and lead researchers providing pre-session guidance to ensure consistency. Training sessions were held three times weekly (Mondays, Wednesdays, and Fridays), lasting 60–70 min. To accommodate participants' schedules, each day included four sessions with five to ten participants. Each session comprised five to six exercises, with two to three sets of six to ten repetitions per exercise.

Sessions followed a standardized structure: a 10–15-min warm-up, a 45–55-min main phase, and a 5–10-min cool-down. Warm-ups included walking, joint mobilization, and recreational games. The main phase featured exercises like squats (using a smith machine or dumbbells), leg press, leg extension, calf raises, seated row, pec fly, lat pulldown, and incline bench press (Technogym, SPA, Cesena, Italy). Cool-downs included stretching exercises.

This training protocol employs progressively increasing loads, tailored to the participants' MCV for each set across all exercises. Specifically, the training protocol utilized three distinct velocity zones to align with the intervention's objectives [18, 19]: 1st–4th weeks, an average speed over 1.3 m/s was required (*starting strength*); from 5th to 10th weeks, velocities were adjusted to between 1.3 and 1.0 m/s (*speed/strength*); and from the 11th to 16th weeks, velocities ranged from 1.0 to 0.75 m/s (*strength/speed*). If a participant consistently exceeded or fell below the target velocity ranges in two consecutive sessions, the load for the specific exercise was adjusted by 5% in the subsequent session. This individualized strategy ensured adherence to the prescribed velocity ranges for each week and each exercise, tailoring the training to the specific capabilities of each participant.

To monitor performance, participants' MCV for each set and exercise was tracked using the BEAST™ sensor (Beast Technologies, Brescia, Italy) [24]. This device provided real-time MCV feedback to participants and supervisors and recorded the average MCV after each set. The training sessions utilized at least six accelerometers connected via Bluetooth to six separate cell phones. Supervisors also gave verbal instructions, encouraging participants to perform the concentric phase explosively while maintaining control during the eccentric phase, which lasted 2–3 seconds.

Statistical analysis

This clinical trial employed an estimation technique approach to address the limitations associated with traditional N−P hypothesis significance testing [32, 33]. First, the primary analysis was carried out according to an intention-to-treat design, with missing values imputed using the expectation–maximization algorithm.

Second, the baseline characteristics were compared between groups using independent sample tests. Additionally, analysis of covariance (ANCOVA) was conducted to assess the differences between the CG and IG, with pre-intervention values included as covariates. Prior to running the final ANCOVA model for each measure, the potential influence of participants' age at pre-intervention was examined and only retained in the model if it showed a statistically significant effect.

Additionally, to complement the study results, changes from pre- to post-intervention for each group, as well as delta (Δ) changes (post- minus pre-intervention values) across groups, were calculated for all measures using the aforementioned spreadsheet [32, 33]. Gardner−Altman estimation plots, which visually represent mean differences between pre- and post-intervention values along with 95% confidence intervals (CIs), were created in a specific spreadsheet [32, 33]. Finally, effect sizes (ESs) were expressed as η_p^2 values for ANCOVA results (*small*: 0.010–0.059, *medium*: 0.060–0.140, or *large*: > 0.140) [34], and Cohen's $d_{unbiased}$ (d_{unb}) with 95% CI, an unbiased estimate with a sampling distribution whose mean equals the population parameter being estimated, was applied to identify pairwise differences [33] (*small*: 0.20–0.49, *medium*: 0.50–0.80, or *large*: > 0.80) [34, 35]. Data analysis was conducted using IBM SPSS Statistics for Windows, Version 26 (IBM Corp., Armonk, NY, USA). All tests were statistically significant at a $p \leq 0.050$ (two-tailed).

Results

Participants

At baseline, there was a significant difference in age between the groups (Table A in the supplementary file). The adherence rate during the intervention period was 97.60%.

Physical and general cognitive function

At baseline, the CG exhibited significantly greater values than IG in chair-stand $_{unb}$ ($p = 0.003$, $d_{unb} = 0.68$ [0.23, 1.14]), HDS for the dominant side ($p = 0.010$, $d_{unb} = 0.59$ [0.15, 1.05]), HDS for the non-dominant side ($p = 0.026$, $d_{unb} = 0.51$ [0.07, 0.96]), and MMSE score ($p = 0.002$, $d_{unb} = 0.71$ [0.26, 1.17]). The IG presented significantly greater TUG values than CG ($p = 0.020$, $d_{unb} = -0.53$ [−0.98, −0.09]).

The ANCOVA results, summarized in Table 1, demonstrated highly significant effects of the group factor in favor of the IG after the intervention program. For the MMSE, the ANCOVA model was adjusted for participants' age at pre-intervention, which showed a significant influence ($F = 6.308$, $p = 0.014$, $\eta_p^2 = 0.078$).

To complement the study results, Fig. 1 displays Cohen's d_{unb} for the Δ changes (post- minus pre-intervention values) between groups for physical and cognitive function. The IG exhibited significant improvements in MMSE ($p < 0.001$, $d_{unb} = 1.24$ [0.77, 1.73]), chair-stand ($p < 0.001$, $d_{unb} = 3.50$ [2.82, 4.24]), chair-stand velocity ($p < 0.001$, $d_{unb} = 3.28$ [2.63, 3.99]), TUG ($p < 0.001$, $d_{unb} = -2.72$ [−3.37, −2.13]), SMBT ($p < 0.001$, $d_{unb} = 1.44$ [0.95, 1.95]), 6MWT ($p < 0.001$, $d_{unb} = 1.58$ [1.08, 2.09]), HDS for the non-dominant ($p < 0.001$, $d_{unb} = 1.65$ [1.15, 2.18]) and dominant side ($p < 0.001$, $d_{unb} = 1.79$ [1.28, 2.33]).

Following the intervention, there were significant within-IG increases in MMSE ($p < 0.001$, $d_{unb} = 0.86$ [0.46, 1.29]), chair-stand ($p < 0.001$, $d_{unb} = 2.58$ [1.96, 3.29]), chair-stand velocity ($p < 0.001$, $d_{unb} = 2.30$ [1.76, 2.92]), SMBT ($p < 0.001$, $d_{unb} = 0.76$ [0.53, 1.00]), 6MWT ($p < 0.001$, $d_{unb} = 0.89$ [0.59, 1.23]), and HDS for the dominant ($p < 0.001$, $d_{unb} = 0.66$ [0.45, 0.89]), and non-dominant side ($p < 0.001$, $d_{unb} = 0.63$ [0.44, 0.84]). Conversely, significant decreases were observed in TUG values ($p < 0.001$, $d_{unb} = -1.71$ [−2.20, −1.28]).

Finally, the CG showed significant reductions in MMSE score ($p = 0.004$, $d_{unb} = -0.43$ [−0.74, −0.14]), chair-stand ($p = 0.001$, $d_{unb} = -0.25$ [−0.41, −0.11]), 6MWT ($p = 0.013$, $d_{unb} = -0.19$ [−0.35, −0.04]), and the HDS for the dominant side ($p = 0.017$, $d_{unb} = -0.11$ [−0.20, −0.02]). Finally, there was a significant increase in TUG values ($p < 0.001$, $d_{unb} = 0.32$ [0.16, 0.49]). Fig. S3 in the supplementary file illustrates Cohen's d_{unb} before and after the intervention for all measures in both groups.

Physical activity

At pre-intervention, the only significant difference between groups was observed in MVPA ($p = 0.031$, $d_{unb} = 0.49$ [0.05, 0.94]). Furthermore, ANCOVA results, presented in Table B (Supplementary File), revealed significant group effects across several physical activity parameters, favoring the IG.

Discussion

This study examined the effects of a 16-week HSRT program on both physical and cognitive function in community-dwelling independent older adults. In this sense, this

Table 1 Analysis of covariance (ANCOVA) results considering the group factor for cognitive and physical function

Measures	Control Group			Intervention Group			ANCOVA Effects		
	Pre	Post	M_{diff} (95% CI)	Pre	Post	M_{diff} (95% CI)	F	p	η_p^2
Cognitive function									
MMSE (score)[a]	28.79 ± 1.49	$28.10 \pm 1.64^{*}$	−0.69 [− 1.15 − 0.23]	27.03 ± 3.15	$29.07 \pm 0.98^{*,§}$	2.05 [1.17 – 2.29]	12.802	0.001	0.146[d]
Physical function									
Chair-stand (rep)	15.33 ± 4.16	$14.23 \pm 4.36^{*}$	−1.10 [− 1.70 – 0.50]	12.83 ± 3.09	$24.32 \pm 5.36^{*,§}$	11.50 [10.0 – 12.99]	212.061	< 0.001	0.736[d]
Chair-stand Vel. (m/s)	0.59 ± 0.17	0.58 ± 0.17	−0.02 [− 0.04 – 0.01]	0.49 ± 0.11	$0.77 \pm 0.12^{*,§}$	0.27 [0.24 – 0.31]	183.315	< 0.001	0.707[d]
TUG (sec)	6.10 ± 1.39	$6.60 \pm 1.64^{*}$	0.49 [0.26 – 0.73]	6.75 ± 0.98	$5.28 \pm 0.68^{*,§}$	−1.47 [− 1.69 – 1.25]	132.081	< 0.001	0.635[d]
SMBT (m)	2.29 ± 0.70	2.19 ± 0.73	−0.09 [− 0.23 – 0.05]	2.05 ± 0.56	$2.51 \pm 0.62^{*,§}$	0.46 [0.36 – 0.56]	37.575	< 0.001	0.331[d]
6MWT (m)	501.93 ± 90.32	$483.81 \pm 94.19^{*}$	−18.12 [− 32.18 − 4.07]	483.71 ± 60.89	$541.49 \pm 65.52^{*,§}$	57.77 [41.26 – 74.29]	47.779	< 0.001	0.386[d]
HDS, DS (kg)	27.87 ± 9.53	$26.79 \pm 9.75^{*}$	−1.08 [− 1.96 – 0.20]	22.99 ± 6.37	$27.95 \pm 8.16^{*,§}$	4.96 [3.73 – 6.19]	61.656	< 0.001	0.448[d]
HDS, non-DS (kg)	25.90 ± 9.67	25.50 ± 9.50	−0.40 [− 1.21 – 0.41]	21.63 ± 6.69	$26.15 \pm 7.42^{*,§}$	4.53 [3.46 – 5.59]	48.215	< 0.001	0.388[d]

Abreviations: MMSE, mini mental score examination; *rep,* repetitions *Vel,* velocity; *m/s,* meters per second; *sec,* seconds; *m,* meters; *kg,* kilograms; *TUG,* time up and go test; *SMBT,* seated medicine ball throw; *6MWT,* six-minute walking test; *HDS,* handgrip strength test; *DS,* dominant side.

Values in bold represent significant differences at $p < 0.05$. Pre- and post-intervention values data are presented as the mean and standard deviation, whereas mean difference as the mean and 95% confidence interval

[a] ANCOVA was adjusted for age at pre-intervention values

[*] $p < 0.05$ *vs.* pre-intervention values

[§] $p < 0.05$ *vs.* control group's delta (Δ)

η_p^2 values thresholds

[b] Small effect: 0.010 to 0.059

[c] Medium effect: 0.060 to 0.140;

[d] Large effect: > 0.140

exploratory clinical trial underscore that the 16-week HSRT program, which was designed around general velocity zones [18, 19], demonstrated substantial enhancements in physical function performance. In relation to the secondary aim, the intervention also significantly improved the general cognitive function. Additionally, it important to highlight that the high adherence rate and low dropout due to intervention-related issues suggest that the HSRT program was both safe and well-received by participants.

As both groups exhibited similar lifestyle patterns at baseline (Table B in the supplementary file), despite the CG's significantly higher MVPA levels, the post-intervention results (Table 1) highlight the clinical relevance of the findings. These results suggest that the 16-week MCV-based HSRT program effectively induced functional and physiological improvements, which may translate to enhanced capacity for daily living activities [36].

These findings are consistent with previous studies involving HSRT programs in older adults [3, 37, 38] and those exclusively focusing on older women [6–8, 39]. An analysis of studies included in a recent systematic review with meta-analysis, Lopez et al. [40] revealed that the effects observed in the present study surpassed those reported in earlier research. For instance, in the chair-stand, the present study demonstrated an enhancement of 89.6%, which contrasted with the 17.7% reported by Pereira et al. [6] and the

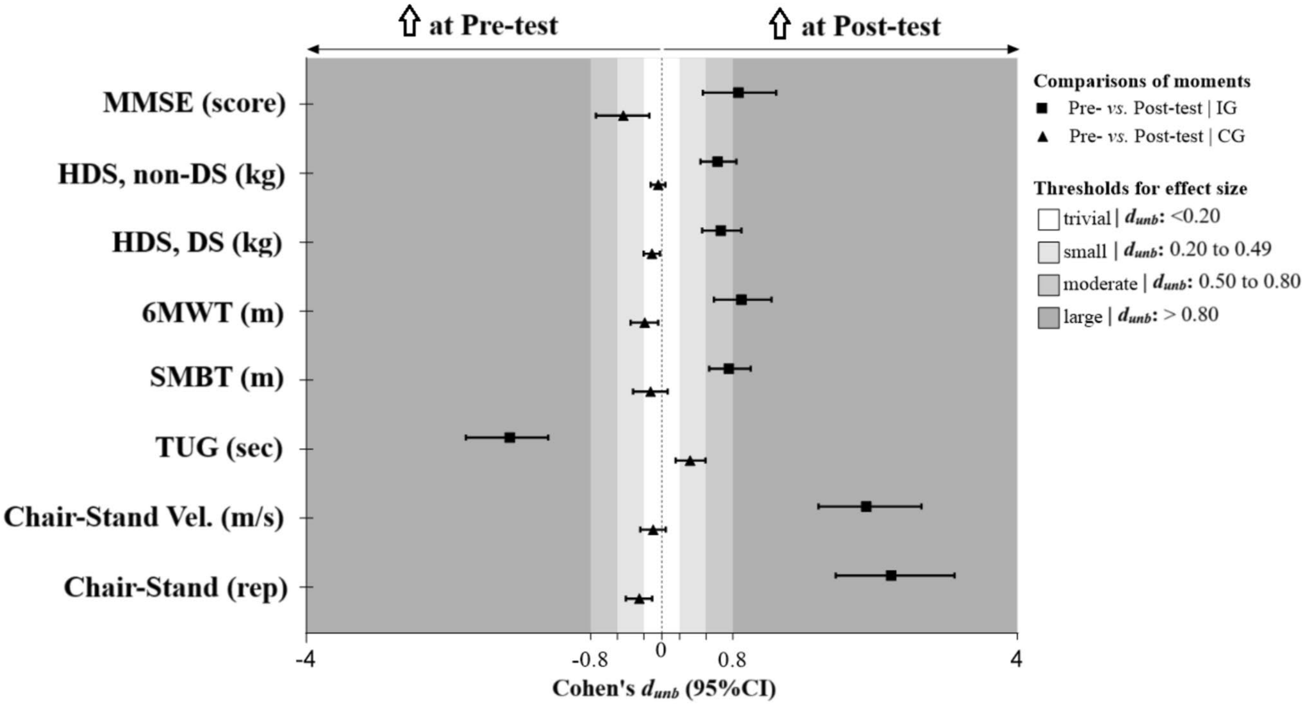

Fig. 1 Cohen's d_{unb} for comparison of the Δ (post- minus pre-intervention values) in physical and cognitive function between groups. Error bars represent 95% confidence intervals around the mean change, indicating the range within which the true mean is likely to lie. *MMSE,* mini-mental state examination; *HDS,* handgrip strength test; *DS,* dominant side; *6MWT,* six-minute walk test; *SMBT,* seated medicine ball throw test; *TUG,* time up and go; *sec,* seconds; *Vel,* velocity; *m,* meters; *m/s*, meters per second; *kg,* kilograms; *rep,* repetitions.

22.0% found by Ramírez-Campillo et al. [8]. In the TUG, this study showed a significant reduction of 21.8%, while the studies by Ramírez-Campillo et al. [8] and [7] reported reductions of 18.1% and 12.9%, respectively. Additionally, the distance covered in the 6MWT increased by 12%, while Coelho-Júnior and Uchida [37] showed decreases of 4%.

The results of the present study suggest that individualized RT prescriptions based on MCV in the context of older adults can optimize improvements in physical function, confirming the findings of Lopez et al. [40]. The utilization of the general velocity zones described before [18, 19] may have contributed to a positive transfer to task performance due to the specific patterns of muscle activation required in each exercise [41]. Additionally, the real-time MCV feedback provided to each participant ensured their continuous motivation and engagement during the RT exercises. Some studies have postulated that HSRT enhances strength and power primarily through neural adaptations rather than muscle hypertrophy [42]. These adaptations encompass increased recruitment of active motor units and firing rates, resulting in enhanced activation of agonist muscles and reduced coactivation of antagonist muscles [42]. Barry and Carson [41] suggested that this improved coordination among muscle groups is critical for the transfer of adaptations from RT to physical function in older adults. Hence, it is plausible to hypothesize that the substantial enhancements can be attributed to the increased coordination and synchronization among various muscle groups, ultimately resulting in positive adaptations that directly impact on an individual's capacity to perform activities of daily living more effectively and efficiently. For example, the significant results observed for chair-stand velocity serve as a clear illustration of the adaptations induced by the intervention.

In terms of the SMBT results, as well as the HDS values for both the dominant and non-dominant sides, the HSRT program demonstrated statistically significant improvements in all these measures, as evidenced by the respective values of 22.4%, 21.5%, and 20.8%, respectively. When comparing these results to those of previous studies that employed the VBT approach, it becomes evident that the results in this study are superior across all measures. For instance, Balachandran et al. [38] showed an increase of 12.1% in the HDS for the dominant side, whereas Pereira et al. [6] reported increases of 5% and 6.9% for the dominant and non-dominant sides, respectively. Additionally, in the studies by Ramírez-Campillo et al. [8] and [7], increases of 8.2% and 8.5%, respectively, in the dominant side, and 9% and 8.5%, respectively, in the non-dominant side were observed. In terms of the SMBT, despite variations in the weight of the ball used (three vs. two kg), the present study also exhibited greater improvements than other studies, such as a 20.8% and 12% increases reported by Ramírez-Campillo et al. [8] and [7], respectively, and a 6.5% increase reported by Filho et al. [39].

These two results have significant clinical implications. The SMBT is recognized as a valuable tool for assessing muscle power and explosive force [25]. Therefore, the intervention may improve the ability to recruit motor units and enhance the capacity for activation and force production in the upper limbs [42]. Additionally, the HDS is widely recognized as the best method for assessing muscle performance in clinical settings. Greater declines are associated with a higher risk of mortality [43] and longer hospital stays [44], making it a valuable indicator of health in older adults. Improvements observed in this study may have mitigated issues like mobility limitations, frailty, falls [45], and reduced quality of life [46]. Notably, by the end of the intervention, only a IG participant had a dominant side HDS below the reference values [47], compared with five dominant side and four non-dominant side participants at baseline.

In relation to the second aim, the study demonstrated significant improvements in general cognitive function in the IG, with a 7.5% increase (*large* ES). In comparison, Yoon et al. [5] reported a greater improvement of 20.7% following an elastic band-based HSRT. Similarly, Coelho-Júnior et al. [48] observed comparable positive effects (*large* ESs) from both a combined traditional RT and HSRT program and a traditional RT protocol alone. Although the MMSE is widely used older adults [49], it presents some limitations that warrant acknowledgment. It is particularly sensitivity to age [49], as also observed in this study (Table 1) and it lacks the ability to assess specific cognitive domains, such as executive function. Therefore, while the observed results suggest a beneficial effect of HSRT, they should be interpreted as reflecting general cognitive status rather than domain-specific enhancements. Despite these limitations, the observed cognitive function improvement remains clinically relevant, as preserving cognitive abilities plays a key role in preventing age-related decline in independence and quality of life among older adults [49].

This exploratory study presents some limitations. First, the absence of randomization in participant allocation may have introduced selection bias. Second, neither the assessor nor the intervention technicians, along with the participants, were blinded to the study objectives. These two factors should be considered when interpreting the findings. Third, as the MMSE provides only a brief and general assessment of cognitive function, future studies should incorporate additional cognitive tests to enable a more comprehensive evaluation of the intervention's effects on specific cognitive domains.

Conclusions

In conclusion, the findings from this exploratory clinical trial highlight the positive potential of the HSRT program for significantly enhancing physical function among older adults. Moreover, the results suggest that the HSRT program could be a valuable tool for mitigating age-related declines in cognitive function.

One important finding from this research is that the HSRT program, which is based on individual and targeted velocity zones, was found to be both safe and beneficial for older adults as an exercise regimen and to be effective for all measures evaluated.

Clinical application

To our knowledge, this study is the first to apply the VBT method, which uses general velocity zones originally defined for athletes, to older adults. The results unveiled in this clinical trial underscore the importance of integrating HSRT programs into clinical practice, exercise interventions, and research projects. Moreover, it is imperative to prescribe the load individually based on each person's MCV. By doing so, this intervention holds the potential to significantly enhance vitality and overall well-being in older adults. As such, we encourage clinicians, exercise professionals, and researchers to embrace and implement HSRT programs as part of their holistic approach to improving the lives of older adults.

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Author contributions Alexandre Duarte Martins: Conceptualization, Data curation, Formal analysis, Investi-gation, Methodology, Project administration, Validation, Visualization, and Writing—original draft. Nuno Batalha: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, and Writing—review & editing. Orlando Fernandes: Conceptualization, Methodology, Project administration, Supervision, Validation, Visualization, and Writing—review & editing. Bruno Gonçalves: Formal analysis, Methodology, Validation, Visualization, and Writing—review & editing. Rafael Oliveira: Formal analysis, Methodology, Validation,

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Declarations

Conflict of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

Ethics approval, Informed consent and consent to participate This study was conducted in accordance with the requirements of the Declaration of Helsinki and was approved by the Ethics Committee of Evora University with clearance number 22030. This clinical trial was registered on *clinicaltrial.gov* (ID: NCT05586087).

Consent to publish All participants provided informed consent to participate in the study and authorized the publication of their data.

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