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Original article

Effects of a 16-week High-Speed Resistance Training program on body composition in community-dwelling independent older adults: A clinical trial

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S U M M A R Y

Background & aims: Aging frequently causes changes in body composition, such as a loss of strength and muscular mass and an increase in fat mass. Exercise training programs have been suggested as effective strategies to mitigate or prevent age-related declines in body composition. Therefore, this study examined the effects of a sixteen-week High-Speed Resistance Training (HSRT) program on body composition parameters in community-dwelling independent older adults.

Methods: The present clinical trial included 79 older adults, who were divided into two groups: intervention group (IG, N = 40, age, 68.50 ± 3.54 years; weight, 68.65 ± 11.36 kg) and control group (CG, N = 39, age, 72.08 ± 5.89 years; weight, 67.04 ± 10.69 kg). IG performed the supervised HSRT for 16 weeks, with 3 sessions per week of 60–70min, each session of 5–6 exercises, 2–3 sets, and 6–10 reps/exercise, while CG did not perform any exercise training program. Body composition parameters were assessed using a multifrequency tetrapolar bioelectrical impedance analyzer (InBody® S10). The level of physical activity and the dietary intake were evaluated by the International Physical Activity Questionnaire (IPAQ-SF) and the Food Frequency Questionnaire, respectively. Statistical analyses were performed using the analysis of covariance (ANCOVA), and effect size (Cohen's $d_{unbiased}$).

Results: The analysis showed significant effects of the group factor for IG on phase angle ($F_{(1)} = 14.39$, $p < 0.001$, $\eta^2_p = 0.159$). Additionally, results from Δ changes (post-minus pre-values) revealed small and medium effects in favor to IG for body cell mass ($t_{(77)} = 1.21$, $p = 0.230$, $d_{unb} = 0.27$ [-0.17, 0.71]) and phase angle ($t_{(77)} = 2.82$, $p = 0.006$, $d_{unb} = 0.63$ [0.18, 1.08]), respectively.

Conclusions: The HSRT could effectively prevent the decline in cellular health and cell integrity in older adults, as evidenced by the significant improvements in the phase angle.

Registration: Clinicaltrial.gov (ID: NCT05586087).

1. Introduction

Aging commonly induces alterations in body composition, marked by diminished strength and muscular mass alongside increased fat mass [1]. Furthermore, aging often leads to reduced body fluids, impacting hydration and nutritional status [2]. A sedentary lifestyle significantly contributes to these age-related

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changes, potentially resulting in muscle loss, a sluggish metabolism, and increased fat storage [3].

Assessing body composition in older adults is crucial for gaining insights into their overall health and nutritional status [4]. It provides clinicians and researchers with the means to monitor changes in muscle mass, fat mass, and hydration levels, which are vital indicators of overall health. Bioelectrical impedance analysis (BIA), a portable, non-invasive, user-friendly tool, is considered a viable, cost-effective method for measuring body composition without exposing technicians to radiation [5]. BIA assesses both whole-body and appendicular segments by measuring impedance, further dividing it into bioelectrical resistance (R) and reactance (Xc) [6].

Exercise training programs are recommended to mitigate or prevent age-related declines in body composition [7]. High-speed resistance training (HSRT) is proposed as an effective approach to counteract the detrimental effects of aging [8–10]. HSRT involves performing concentric actions of resistance exercises at a higher velocity than traditional strength training methods [9,10]. A recent systematic review with meta-analysis by Martins et al. [11] revealed significant effects of HSRT on cognitive function (large effects), neuromuscular function (moderate effects), and physical function (moderate effects). However, its impact on body composition parameters is not fully understood. Out of the 14 studies in the review [11], only one assessed body composition, showing significant improvements after a 12-week elastic band-based HSRT program [9]. Furthermore, no studies have compared the effects of an HSRT program performed on machines monitoring the velocity of the concentric phase using an accelerometer concerning body composition parameters. The limited number of studies exploring HSRT programs' effects on body composition might be attributed to the predominant focus on neural adaptations stemming from early motor unit activation and increased maximum firing frequencies [12]. In this context, this clinical study aimed to examine the effects of a 16-week HSRT program on body composition parameters in community-dwelling independent older adults, with an ancillary objective to assess physical activity levels following the HSRT program.

2. Methods

2.1. Study design

This clinical trial is a part of the longitudinal research project "*Idade Activa*", which commenced its intervention phase in March 2021. It was a non-randomized clinical trial registered on clinicaltrial.gov (ID: NCT05586087) and adhered to the Declaration of Helsinki guidelines, conducted in accordance with the CONSORT (Consolidated Standards of Reporting Trials) guidelines [13]. Approval for the trial was obtained from the Ethics Committee of the local University (no. 22030). The study employed a parallel two-group clinical trial design spanning 20 weeks, with 16 weeks allocated for the intervention and an additional four weeks for data collection (two weeks before and two weeks after the intervention).

2.2. Subjects

Participants were recruited through various sources, including advertisements in local newspapers and invitations sent to daycares, health centers, and associations of older adults in the middle-south areas of Portugal. The recruitment period lasted from October 2020 to January 2021, during which 89 older adults expressed interest in participating. Individual interviews were conducted to ensure participants met the inclusion criteria: (a) age of at least 65 years, (b) able to walk independently, and (c) ability to perform daily living tasks. The exclusion criteria were: (a) having diabetes or/and cardiac diseases, (b) having undergone surgery in the last six months, and (c) having an active oncology disease. Based on these criteria, ten participants were excluded from the study (Fig. 1).

During the individual interviews, eligible participants were asked about their availability for exercise sessions. Those who were unavailable were assigned to the Control Group (CG) and/or placed on a waiting list for other research projects. As a result, 79 older adults were included in the study and divided into two groups: Intervention Group (IG, $N = 40$, age: 68.50 ± 3.54 years; weight: 68.65 ± 11.36 kg (kg)) and CG (CG, $N = 39$, age: 72.08 ± 5.89 years; weight: 67.04 ± 10.69 kg). Participants in the CG maintained their usual activities without incorporating strength training or starting a new exercise program during the study. Following the 16-week intervention, three participants from the IG withdrew due to muscular discomfort, loss of contact, and concurrent participation in another exercise program. Additionally, two participants from the CG withdrew due to a cancer diagnosis and loss of contact. All participants received detailed information about the study's objectives, potential benefits, and risks, and provided written informed consent for enrollment in the study.

2.3. Procedures

Anthropometric and body composition measurements were taken during the morning period between 08:30 a.m. to 10:30 a.m. Participants were instructed to be in a fasted state (minimum of 8 h) with an empty bladder and without engaging in exercise, drinking alcohol, or consuming coffee in the 24 h prior to the measurements. All measurements were conducted by the same researcher to minimize possible errors and the order of the measurements was the same for all participants.

2.3.1. Body composition

A multifrequency tetrapolar bioelectrical impedance analyzer (InBody® S10, Model JMW140, Biospace Co, Ltd., Seoul, Korea) was used to measure body composition parameters in accordance with the manufacturer's instructions and comprehensive guidelines outlined elsewhere [14]. Measurements were performed at a frequency of 50 kHz, as per the approach described in a previous study [15]. The following parameters were obtained: (i) fat mass as a percentage (%); (ii) fat mass (kg); (iii) fat-free mass (kg); (iv) muscle mass (kg); (v) lean mass (kg); (vi) body cell mass (kg); (vii) phase angle (°); (viii) total body water (L); (ix) intracellular water (ICW) (L); and (x) extracellular water (ECW) (L).

2.3.2. Anthropometric and Blood pressure

The first measurements enclosed the weight and height of the participants through an electronic scale (TANITA®, MC 780 MA, Amsterdam, Netherlands) and stadiometer (SECA® 220, Hamburg, Germany) to the nearest 0.01 kg and 0.1 cm, respectively. It was a mandatory requirement that each participant had to be dressed in light clothes and no shoes during the measurements. Afterwards, the body mass index (BMI) values were assessed using the standard formula: BMI = body mass (kg)/height^2 (m^2). Blood pressure was assessed by averaging two measurements obtained with appropriately sized automated cuffs through the Omron HEM-907 (Omron Healthcare Co. Ltd., Kyoto, Japan), each taken 1 min apart following a 5-min period of rest and tranquility.

2.3.3. Physical activity

The participants' level of physical activity was evaluated with the short form of the International Physical Activity Questionnaire

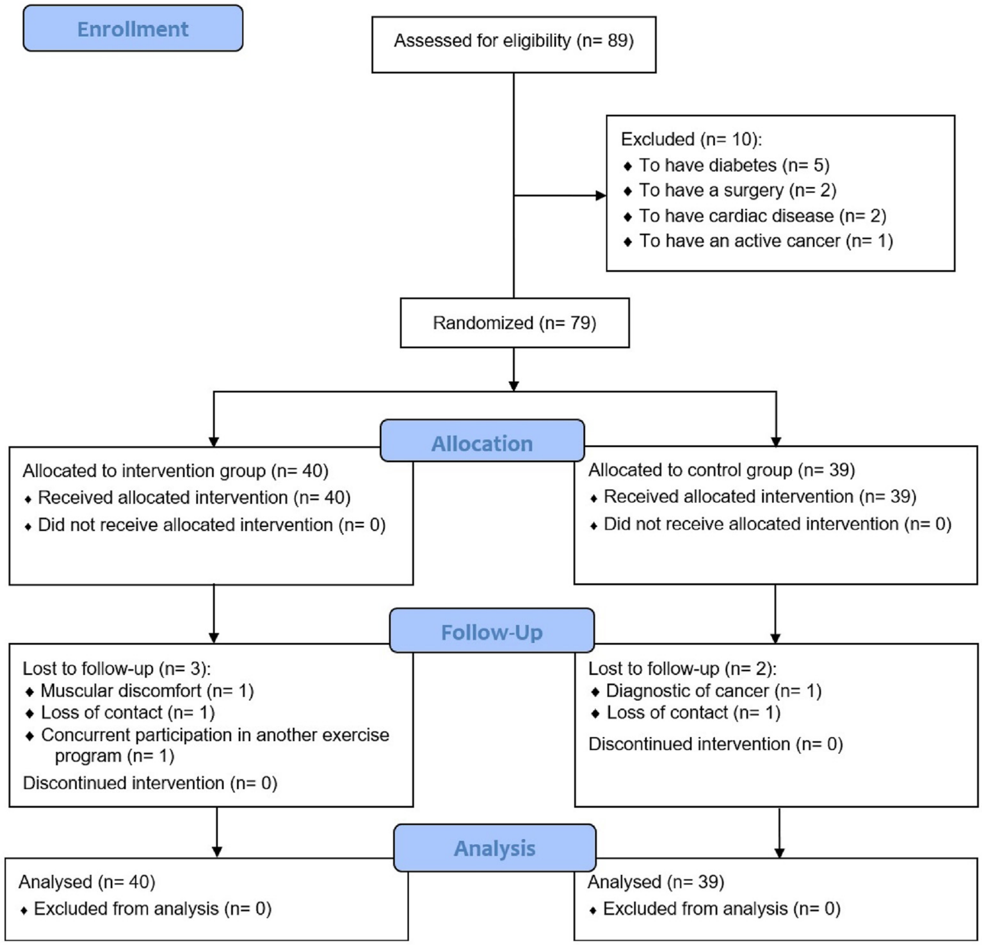

Fig. 1. Flow chart of the present study.

(IPAQ-SF) [16] at pre- and post-intervention. The data collected from the IPAQ-SF included the following measures: total activity in days and in min per week; total physical activity (sum of walking, moderate and vigorous MET-min/week scores), moderate and vigorous physical activity (MVPA) (sum of moderate and vigorous MET-min/week scores), walking, moderate and vigorous activity in MET/minute/week, and the time spent sitting over the week or weekend. Participants are also asked to report the number of days per week they engage in each type of activity and the average duration of those activities on those days. Finally, collected data were processed using a scoring spreadsheet developed by Cheng [17].

2.3.4. Dietary intake

Dietary intake of the participants was evaluated using the semi-quantitative Food Frequency Questionnaire (FFQ) administered in a traditional pen-and-paper format both before and after the intervention, following the methodology described before [18,19]. This FFQ comprises eight food groups, with respondents indicating their frequency of consumption using nine qualitative options, ranging from “never or less than once a month” to “6 or more times per day”. The conversion of food consumption data into nutrient values was conducted by qualified nutritionists. The Food Processor Plus software (version 11.1) by ESHA Research, Salem, Oregon, served as the primary tool for this process, utilizing nutritional data from food composition tables sourced from the US Department of Agriculture.

2.4. High-speed resistance training protocol

The participants in the IG underwent supervised training, with one supervisor assigned per exercise. To ensure uniformity, all supervisors received prior instruction from the principal investigators regarding the specific feedback to provide participants during exercise execution. HSRT program lasted 16 weeks, with 3 sessions per week (Mondays, Wednesdays, and Fridays) of 60–70min, each session of 5–6 exercises, 2–3 sets, and 6–10 reps/exercise [20]. The rest period between exercises and sets was 2 min.

The exercise sessions followed a standardized format, commencing with a 10 to 15-min warm-up phase. This warm-up incorporated activities such as brisk walking, joint mobilization exercises utilizing sand bottles, and engaging in recreational games at a moderate to high intensity level. Subsequently, participants engaged in the main phase of the session, which encompassed 45–55 min of the HSRT program. Finally, each session concluded with a 5 to 10-min cool-down period, involving stretching exercises. The main phase included the following upper- and lower-body exercises: squats on smith machine or with dumbbells (depended on each participant's ability); leg press, leg extension; calf raise; seated row; peck fly; lat pull down; and incline bench press (Technogym, SPA, Cesena, Italy).

This innovative training protocol for older adults used progressively increased loads based on participants' movement velocity on concentric phase of the different exercises. The specified velocity range of >1.3–0.75 m/s, representing approximately 10%–

65% of 1RM [21,22], which correspond to a range of velocities that participants were expected to maintain during their exercises. Individualized load adjustments for each exercise were made, tailoring the weight to the specific capabilities of each participant to ensure adherence to the designated velocity ranges for each week (see Table A in the supplementary file).

If a participant consistently exceeded or fell below these ranges in two consecutive sessions, the load for that exercise was modified in the next session. This approach ensures that participants are training at an appropriate intensity level based on their capabilities. The initial two weeks of the intervention were dedicated to familiarizing participants with the exercises. This involved teaching proper posture, movement patterns, and breathing techniques for each exercise. Ensuring that participants perform exercises with correct form is crucial for safety and effectiveness.

Participants were verbally encouraged to perform repetitions in a rapid and explosive manner during the concentric phase of each exercise, while the eccentric phase was controlled, lasting 2–3 s. The velocity of the concentric phase in each exercise was monitored using a BEAST™ sensor (Beast Technologies, Brescia, Italy) [23], which provided real-time feedback to participants and supervisor about the movement speed. The rating of perceived exertion (RPE) scale [24] was used to assess how hard participants felt the exercises were. This is a subjective measure where participants rate their effort on a scale from 6 to 20, with a target RPE of 11–13, indicating a moderate to somewhat hard level of perceived exertion. Participants also used heart rate monitors to record their heart rate during the training sessions. Predicted maximum heart rate (HRmax) was calculated using a formula based on age: HRmax = 206.9–(0.67*Age), proposed by Gellish et al. [25].

2.5. Statistical analysis

A priori sample size calculation was conducted using G-power software (University of Dusseldorf, Germany) [26] under the following conditions for *F* tests through analysis of covariance (ANCOVA) with fixed effects, main effects, and interaction: effect size f = 0.40, α err prob = 0.10, power (1-β err prob) = 0.95, number of groups = 2, and number of covariates = 1. The actual power output indicated that this clinical trial required more than 70 participants with a 95.23% chance of successfully rejecting the null hypothesis. All statistical analyses were performed using Statistical Package for the Social Sciences for Windows version 26 (IBM Corp., Armonk, NY, USA). The level of significance was set at $p < 0.05$ (two-tailed). An estimation technique approach was employed to address the limitations associated with traditional N–P null hypothesis significance testing [27–29].

Initially, the primary analysis followed an intention-to-treat design, with missing values imputed using the expectation–maximization algorithm. Subsequently, the independent sample *t*-test compared general characteristics between groups at baseline. Estimation plots for body composition parameters and physical activity levels from IPAQ-SF served as descriptive statistics for CG and IG using a specific spreadsheet [27,29]. This graphical representation illustrated individual and mean group values for pre- and post-test measures, along with the difference in means with 95% confidence intervals (CI). Additionally, data (body composition parameters, physical activity levels, and dietary intake measures) were processed for analysis of covariance (ANCOVA, group effect: CG *vs.* IG), with post-test values as the dependent variable and pre-test values as the covariate. Furthermore, differences between pre-post scores for each group and differences between Δ changes (post-minus pre-values) among groups were computed for all measures using a specific spreadsheet [30].

Finally, effect sizes (ES) were expressed as partial eta-squared for ANCOVA measures, with interpretations based on established thresholds: 0.01 to 0.059 classified as small, 0.06 to 0.14 as medium, and values exceeding 0.14 considered large [31]. Cohen's $d_{unbiased}$ (d_{unb}) with 95% CI as ES (an unbiased estimate has a sampling distribution whose mean equals the population parameter being estimated) was applied to identify pairwise differences [27] among all previous comparisons, according to the following thresholds: 0.2 to 0.49 are considered small, 0.5 to 0.8 are considered medium, and greater than 0.8 are considered large [31].

3. Results

3.1. Participants

Table B in the supplementary file presents a summary of the baseline characteristics of the study sample. A statistically significant difference was observed between groups in terms of age ($p = 0.002$, d_{unb}=0.73 [0.28, 1.19]).

3.2. Adherence and safety

Among the 37 participants who completed the intervention program, the mean adherence rate was 97.72%, with adherence rates ranging from 80% to 100%. Finally, 25 out of the 37 participants (67.5%) did not miss any exercise sessions over the entire 16-week intervention period. Importantly, no adverse events were reported during the intervention period.

3.3. Body composition

At baseline, a significant intergroup difference was observed only in the phase angle ($p = 0.024$, d_{unb}=-0.53 [−0.98, −0.08]).

Following the intervention, no significant differences were observed for weight and BMI. The CG exhibited increases in various body composition parameters: fat-free mass (IG, $t_{(39)} = 1.71$, $p = 0.096$, $d_{unb} = 0.07$ [−0.01, 0.15]; CG, $t_{(38)} = 2.98$, $p = 0.005$, d_{unb}=0.07 [0.02, 0.12]); muscle mass (IG, $t_{(39)} = 1.84$, $p = 0.074$, $d_{unb} = 0.07$ [−0.01, 0.16]; CG, $t_{(38)} = 2.78$, $p = 0.008$, $d_{unb} = 0.06$ [0.02, 0.11]); lean mass (IG, $t_{(39)} = 1.60$, $p = 0.117$, $d_{unb} = 0.06$ [−0.02, 0.14]; CG, $t_{(38)} = 2.94$, $p = 0.006$, $d_{unb} = 0.07$ [0.02, 0.11]); ICW (IG, $t_{(39)} = 1.91$, $p = 0.064$, $d_{unb} = 0.08$ [−0.01, 0.16]; CG, $t_{(38)} = 2.67$, $p = 0.011$, $d_{unb} = 0.06$ [0.01, 0.11]); and in ECW (IG, $t_{(39)} = 1.84$, $p = 0.073$, $d_{unb} = 0.08$ [−0.01, 0.16]; CG, $t_{(38)} = 2.73$, $p < 0.001$, $d_{unb} = 0.08$ [0.02, 0.14]).

Both groups demonstrated significant improvements in fat mass, indicated as both a percentage (IG, $t_{(39)}$ = -2.57, $p = 0.014$, $d_{unb} = -0.18$ [−0.33, −0.04]; CG, $t_{(38)}$ = -3.47, $p = 0.001$, $d_{unb} = -0.17$ [−0.27, −0.07]);]) and in kg (IG, $t_{(39)}$ = -2.26, $p = 0.029$, $d_{unb} = 0.16$ [−0.30, −0.02]; CG, $t_{(38)}$ = -3.11, $p = 0.004$, $d_{unb} = -0.16$ [−0.27, −0.05]). Additionally, significant improvements were noted in body cell mass (IG, $t_{(39)} = 3.06$, $p = 0.004$, $d_{unb} = 0.11$ [0.04, 0.19]; CG, $t_{(38)} = 2.19$, $p = 0.034$, $d_{unb} = 0.05$ [0.01, 0.09]); and TBW (IG, $t_{(39)} = 2.12$, $p = 0.004$, $d_{unb} = 0.08$ [0.01, 0.17]; CG, $t_{(38)} = 2.98$, $p = 0.005$, $d_{unb} = 0.07$ [0.02, 0.12]). Finally, post-intervention, the CG exhibited substantial reductions in the phase angle (CG, $t_{(38)}$ = -3.79, $p = 0.001$, $d_{unb} = -0.29$ [−0.47, −0.13]), while the IG showed no significant change (IG, $t_{(39)} = 0.07$, $p = 0.94$, $d_{unb} = 0.01$ [−0.16, 0.18]).

Figure 2 illustrates the Cohen's d_{unb} pre-post differences after the intervention for all measures in both groups. Additionally, visual representations of variations and differences in mean values for all measures before and after the intervention are depicted in the supplementary file as Figure A.

The ANCOVA results, summarized in Table 1, reveal a medium-significant effect of the group factor in the phase angle after the intervention period ($F_{(1)} = 14.39$, $p < 0.001$, $\eta^2_p = 0.159$). No

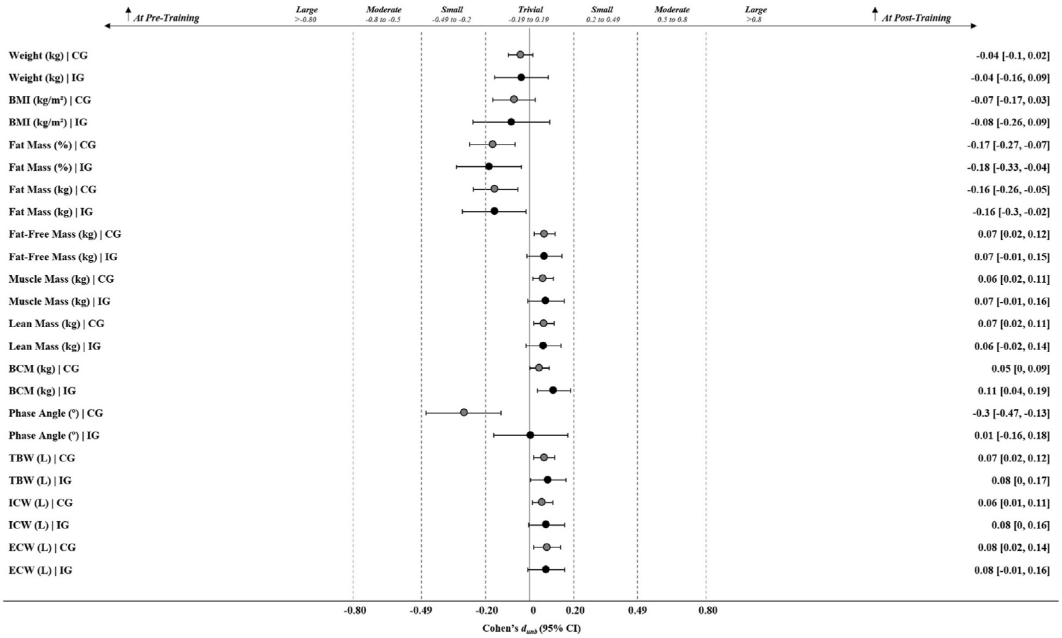

Fig. 2. Cohen's d_{unb} pre-post differences for all measures are presented for both groups, with error bars representing the level of uncertainty in true mean changes, depicted as 95% confidence intervals. Abbreviations: CG, control group; IG, intervention group; BMI, body mass index; Kg, kilograms; m, meters; %, percent; BCM, body cell mass; °, degrees; TBW, total body water; ICW, intracellular water; ECW, extracellular water; L, liters.

significant differences were observed in the other assessed parameters.

To complete the results of this study, Figure D in the supplementary file displays the Δ changes (post-minus pre-values) between groups for body composition parameters. Significantly, only the phase angle ($t_{(77)} = 2.82$, $p = 0.006$, $d_{unb} = 0.63$ [0.18, 1.08]) and body cell mass ($t_{(77)} = 1.21$, $p = 0.230$, $d_{unb} = 0.27$ [−0.17, 0.71]) revealed effects of small magnitude or greater.

3.4. Physical activity

Individual differences and changes in mean values between pre- and post-test measurements for physical activity levels are visually presented in Figure C in the supplementary file. These estimation plots depict effect sizes as bootstrap 95% confidence intervals on separate but aligned axes, providing a clear representation for each variable and group. At baseline, the only significant difference between groups was observed in MVPA ($p = 0.031$, $d_{unb} = 0.49$ [0.05, 0.94]).

After the intervention period, no significant difference was observed for walking intensity. Additionally, significant improvements were found for the IG and declines for the CG in total days of activity (IG, $t_{(39)} = 4.34$, $p < 0.001$, $d_{unb} = 0.89$ [0.45, 1.36]; CG, $t_{(38)} = -3.04$, $p = 0.004$, $d_{unb} = -0.52$ [−0.88, −0.16]); and in MVPA (IG, $t_{(39)} = 17.85$, $p < 0.001$, $d_{unb} = 3.02$ [2.14, 3.67]; CG, $t_{(38)} = -2.29$, $p = 0.027$, $d_{unb} = -0.35$ [−0.67, −0.04]). Conversely, there were significant reductions in time spent sitting in IG and increases in CG (IG, $t_{(39)} = -6.21$, $p < 0.001$, $d_{unb} = -1.01$ [−1.42, −0.63]; CG, $t_{(38)} = 3.53$, $p = 0.001$, $d_{unb} = 0.43$ [0.17, 0.70]). For total activity and total PA only the IG showed significant enhancements (IG, $t_{(39)} = 8.89$, $p < 0.001$, $d_{unb} = 1.68$ [1.18, 2.25]; CG, $t_{(38)} = 0.35$, $p = 0.730$, $d_{unb} = 0.06$ [−0.29, 0.41]) and (IG, $t_{(39)} = 11.79$, $p < 0.001$, $d_{unb} = 1.95$ [1.43, 2.53]; CG,

Table 1
Analysis of covariance (ANCOVA) results considering the group factor for body composition parameters.

Measures	Control Group			Intervention Group			ANCOVA Effects			
	Pre	Post	Δ (95% CI)	Pre	Post	Δ (95% CI)	*df*	*F*	*p*	η^2_p
Weight (kg)	67.04 ± 10.69	66.60 ± 3.04	−0.44 [-1.05 to −1.76]	68.65 ± 11.36	68.24 ± 11.22	−0.41 [-1.83 to 1.00]	1	0.02	0.890	<0.001
BMI (kg/m^2)	26.53 ± 3.04	26.31 ± 3.06	−0.22 [-0.51 to −1.09]	27.88 ± 4.37	27.53 ± 3.93	−0.35 [-1.09 to 0.39]	1	0.08	0.780	0.001
Fat Mass (%)	36.37 ± 7.32	35.07 ± 7.92[a]	−1.29 [-2.05 to −0.54]	38.97 ± 7.26	37.68 ± 6.52[a]	−1.28 [-2.29 to −0.27]	1	0.12	0.728	0.859
Fat Mass (kg)	24.48 ± 6.42	23.44 ± 6.67[a]	−1.04 [-1.72 to −0.36]	27.13 ± 8.15	25.89 ± 7.28[a]	−1.24 [-2.35 to −0.13]	1	0.04	0.841	0.001
Fat-Free Mass (kg)	42.56 ± 7.98	43.12 ± 8.39[a]	0.56 [0.18 to 0.95]	41.44 ± 6.53	41.89 ± 6.87	0.45 [-0.08 to 0.99]	1	0.05	0.826	0.001
Muscle Mass (kg)	23.03 ± 4.74	23.33 ± 5.01[a]	0.30 [0.08 to 0.52]	22.56 ± 3.97	22.86 ± 4.13	0.31 [-0.03 to 0.65]	1	0.01	0.926	<0.001
Lean Mass (kg)	40.20 ± 7.61	40.72 ± 7.99[a]	0.52 [0.16 to 0.87]	39.14 ± 6.20	39.54 ± 6.54	0.41 [-0.11 to 0.93]	1	0.06	0.812	0.001
BCM (kg)	27.48 ± 5.21	27.73 ± 5.55[a]	0.25 [0.02 to 0.48]	26.91 ± 4.26	27.39 ± 4.44[a]	0.49 [0.16 to 0.81]	1	1.82	0.181	0.023
Phase Angle (°)	5.22 ± 0.69	5.02 ± 0.64[a]	−0.20 [-0.31 to −0.09]	5.56 ± 0.58	5.57 ± 0.56[b]	0.01 [-0.09 to 0.10]	1	14.39	**<0.001**	0.159
TBW (L)	31.41 ± 5.93	31.82 ± 6.24[a]	0.42 [0.13 to 0.69]	30.49 ± 4.83	30.91 ± 5.06[a]	0.42 [0.02 to 0.83]	1	0.02	0.883	<0.001
ICW (L)	19.19 ± 3.63	19.42 ± 3.85[a]	0.22 [0.05 to 0.39]	18.83 ± 3.02	19.07 ± 3.16	0.24 [-0.01 to 0.49]	1	0.05	0.829	0.001
ECW (L)	12.21 ± 2.33	12.40 ± 2.41[a]	0.19 [0.05 to 0.33]	11.68 ± 1.81	11.82 ± 1.92	0.14 [-0.01 to 0.30]	1	0.12	0.728	0.002

Abbreviations: Kg, kilograms; m, meters; %, percent; °, degrees; L, liters; TBW, total body water; ICW; intracellular water; ECW, extracellular water; BCM, body cell mass; CI, confidence interval; Δ, delta difference; df, degrees of freedom.
Pre- and post-values data are presented as mean and standard deviation, whereas mean difference as mean and 95% confidence interval.
Values in bold represent significant differences at $p < 0.05$.
[a] Significant differences at $p < 0.05$ *vs.* pre-values;
[b] Significant differences at $p < 0.05$ *vs.* Control Group's Δ.

$t_{(38)}$ = -1.47, p = 0.151, d_{unb} = −0.23 [−0.54, 0.08]), respectively. Additionally, Figure B in the supplementary file illustrates the magnitude of the effects in terms of Cohen's d_{unb} following the 16-week intervention period.

A summary of the ANCOVA findings related to the group factor is presented in Table C in the supplementary file. The intervention period revealed substantial effects of the group factor on various physical activity levels. Namely, MVPA exhibited a significant effect ($F_{(1)}$ = 227.86, p < 0.001, η^2_p = 0.750), as did total activity in terms of minutes per week ($F_{(1)}$ = 58.01, p < 0.001, η^2_p = 0.433), and sitting time ($F_{(1)}$ = 68.41, p < 0.001, η^2_p = 0.474) in favor to IG. No significant difference was found for walking intensity.

Figure D in the supplementary file depicts the Δ changes (post-minus pre-values) for physical activity levels between groups. Significant between-group changes were observed in total days of activity ($t_{(77)}$ = 5.23, p < 0.001, d_{unb} = 1.17 [0.69, 1.65]); total activity ($t_{(77)}$ = 6.79, p < 0.001, d_{unb} = 1.52 [1.02, 2.03]); total PA ($t_{(77)}$ = 10.09, p < 0.001, d_{unb} = 2.25 [1.69, 2.83]); MVPA ($t_{(77)}$ = 15.39, p < 0.001, d_{unb} = 3.43 [2.75, 4.16]); sitting time ($t_{(77)}$ = -6.99, p < 0.001, d_{unb} = −1.56 [−2.07, −1.06]).

3.5. Dietary intake

The total daily energy and macronutrient intake at baseline and post-training are detailed in Table D of the supplementary file. After intervention, no significant differences were observed in any measure. Likewise, ANCOVA results did not indicate any significant effects associated with the group factor for these measures. Additionally, the comparison of Δ changes (post-minus pre-values) between the groups revealed no significant differences.

4. Discussion

The presented study examined the effects of a 16-week HSRT program on body composition parameters in community-dwelling independent older adults. A key finding was the program's preventive effect on the decline of cellular health and integrity, as evidenced by a significant impact on the group factor in the phase angle. The intervention also demonstrated effectiveness in reducing sedentary behaviors, particularly the time spent in a seated position within the IG, while this time increased in the CG. This implies that the HSRT program may play a crucial role in averting the decline in cellular health and integrity among older adults. Despite positive effects observed in certain aspects, specifically the phase angle, the HSRT training protocol did not result in significant improvements in body composition parameters, such as muscle and lean mass and body fat.

In general, resistance training has received wide-ranging endorsement for its benefits in older people. Both the American College of Sports Medicine (ACSM) [32] and the National Strength and Conditioning Association (NSCA) [20] have issued comprehensive guidelines, tailoring resistance training recommendations specifically for older adults. In 2011, ACSM recommended utilizing a 10 to 15 RM range [33], while NSCA, in its 2019 guidelines, suggested an RM range of 8–12 or 10 to 15 [20]. However, it is essential to note that despite these guidelines, certain studies, backed by more substantial scientific evidence, have not consistently demonstrated significant improvements in key body composition parameters, including muscle and lean mass, percentage of fat mass, and fat mass in kg [34–36]. While this study employed a distinct protocol from those mentioned above (*i.e.*, the load was prescribed based on participants' movement velocity and continuously monitored in real time for each exercise), it aligns with previous research utilizing similar protocols by confirming the lack of effects on certain body composition parameters. For instance, previous studies have shown no significant effects on BMI and total body mass [8], total body mass, fat mass in kg, lean body mass, and appendicular skeletal-muscle mass [37], as well as percent body fat, lean mass, and skeletal mass index [38].

Interestingly, a recent meta-analysis has described that resistance training protocols only have small-to-moderate effects (SMD = 0.44) on muscle mass, regardless of age, weekly frequency, and intervention length [39]. This review study with meta-analysis also showed that no significant effect was detected for body fat. The present study did not find a significant effect of the group factor for most of the body composition parameters (Table 1). However, it did demonstrate significant increases for CG in various body composition parameters after the intervention period, including fat-free mass, muscle mass, lean mass, ICW, and ECW. Paying attention to the magnitude of the effects (*i.e.*, d_{unb}), it becomes evident that the results for all these parameters were similar for both groups; however, only the CG exhibited statistically significant differences (Fig. 2).

A possible explanation for these results could be attributed to the inherent variability in humans. As biological organisms constantly undergo changes and are exposed to various behavioral influences, it's reasonable to infer that even body composition parameters are, to some extent, subject to fluctuations [40]. In contrast, the present study focused on independent older adults, potentially contributing to elevated baseline values of lean mass. This divergence from previous studies, which often involved older populations with more health issues or institutionalized older people, may explain the higher lean body mass values observed in our participants. For instance, Vieira et al. [41] reported 37.84 ± 3.80 kg, Orsatti et al. [42] found 18.8 ± 3.3 kg, and Cunha et al. [43] measured 17.1 ± 2.6 kg, while our study recorded 39.14 ± 6.20 kg.

The findings involving phase angle are in line with earlier studies using various resistance training programs [7,44,45]. In the present clinical trial, both groups showed significant increases in body cell mass. However, it is noteworthy that the CG exhibited a significant decrease in phase angle from Δ changes result (Figure D in the supplementary file) and from ANCOVA result (Table 1), using the baseline values as covariate to mitigate the impact of this significant difference at baseline between groups. This decrease is in line with previous research [7,45] which emphasizes the importance of older adults participating in exercise programs, particularly resistance training. This result may suggest that the present intervention can mitigate the aging effects on cell integrity, structure, and capacitance [46–48]. The positive effects found in this study align with the results of other studies in which the phase angle increased in the IG and significantly decreased in the CG, where the participants did not engage in any exercise program [44,49].

In summary, our training protocol for older adults, which increased loads based on movement speed, did not significantly improve several body composition parameters. However, other studies with similar methods have shown positive effects on functional capacity and muscle strength [8,50]. A study conducted by Loenneke et al. [51] suggested that improvements in muscle strength do not necessarily imply a causal relationship with increased muscle mass. The reason for this statement is due to the fact the mechanisms responsible for muscle hypertrophy and strength development are different in nature [52,53]. While muscle hypertrophy primarily occurs due to metabolic stress and mechanical tension, which activate intracellular pathways leading to muscle growth [53], initial improvements in strength, before noticeable muscle hypertrophy, are attributed to increased neural impulse. This neural improvement results from an increased firing rate of motor units or agonist-antagonist co-activation [52]. Our study provides insights into the different mechanisms of muscle growth and strength improvements in HSRT for older adults.

Regarding physical activity and dietary intake, the improvements observed were not related to the participants' activity levels or dietary changes. The CG demonstrated decreases in physical activity levels and increased sedentary behavior, as shown by the ANCOVA results and changes in sitting time. Table C and D and Figure B and C in the supplementary file provide valuable insights into the magnitude of the effects.

Finally, it is important to note that the present clinical trial showed high adherence rates, and the absence of fall incidents or severe health problems suggest that the intervention was well-tolerated and safe for the participants. According to Hong et al. [54], 50% of the general population discontinues an exercise program within the first 6 months, and they also noted that exercise programs with high intensities may not be well-tolerated in older populations. In the present study, although adherence rates experienced a slight decrease in the latter part of the intervention (weeks 11–16), as indicated in Table A of the supplementary file, they remained consistently above 95% among participants who did not drop out.

While this study has generated valuable information, it is important to acknowledge certain limitations. including the non-randomized participant group allocation and the lack of blinding for assessors, intervention technicians, and participants. Additionally, the absence of measurements related to strength, muscle hypertrophy, functional capacity, and other physiological measures could have strengthened the findings. These measures were excluded due to the volume of information and are intended for use in future research. It is also worth noting that guidelines for exercise in older adults were not fully adhered to, particularly regarding aerobic exercise [55], which may explain the limited results on body composition parameters.

5. Conclusion

The 16-week HSRT program demonstrated a preventive effect on cellular health and integrity, as indicated by the phase angle. However, when considering the group factor, significant improvements in body composition parameters were not observed. This suggests that interventions with higher loads or alternative approaches, such as cardiorespiratory training, may be necessary for greater gains in muscle and lean mass and reductions in fat mass. Moreover, the high adherence and reduced sedentary habits highlight the feasibility of implementing this intervention for older adults. Recognizing that adherence remains a challenge, program intensity should be carefully tailored to accommodate the tolerance levels of older populations.

6. Practical applications

This study pioneers the application of the Velocity-Based Training (VBT) method, originally designed for athletes, to older adults. This innovative approach has proven to be safe and well-tolerated, serving as a motivating factor for their active participation. Exercise professionals may find compelling reasons to integrate VBT into older adults' training programs. Real-time feedback from an accelerometer encourages swift concentric actions, enhancing engagement and effort. VBT, accommodating preferences to avoid high loads, offers a more appealing and sustainable alternative for long-term adherence among older adults. Moreover, VBT assists in adjusting training loads to account for daily performance fluctuations due to common life stressors in older adults [21]. A previous study [56] estimating daily 1RM using the load-velocity profile found an approximate 18% variation both above and below the established 1RM. This implies a 36% margin around the previously determined 1RM. Managing these daily variations in older adults can be challenging and may involve some risk, as loads that were 65% of 1RM on one day can be 83% of 1RM on another.

Lastly, considering the potential impact of nutritional support on health outcomes, especially in older adults participating in exercise interventions, and considering the results presented in Table D of the supplementary file, we strongly advocate for the integration of comprehensive nutritional assessment and support into clinical practice. This proactive approach can significantly enhance the effectiveness of interventions aimed at improving overall health and well-being in this population.

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CRediT authorship contribution statement

Alexandre Duarte Martins: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, and Writing - original draft. **João Paulo Brito**: 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. **Rafael Oliveira**: Formal analysis, Methodology, Validation, Visualization, and Writing - review & editing. **Bruno Gonçalves**: Formal analysis, Methodology, Validation, Visualization, and Writing - review & editing. **Nuno Batalha**: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, and Writing - review & editing.

Declaration of competing 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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2024.06.010.

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