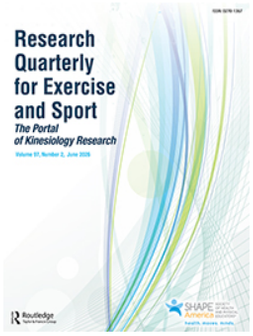

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Effects of a 16-Week High-Speed Resistance Training Program on Isokinetic Muscle Strength Parameters and Health-Related Quality of Life in Independent Older Adults: A Clinical Trial

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ABSTRACT

This study investigated the effects of a 16-week high-speed resistance training (HSRT) program on isokinetic muscle strength parameters and, secondarily, on health-related quality of life (HRQOL). Seventy-nine independent older adults were assigned to an intervention group (IG) and a control group (CG). The IG completed supervised HSRT three times per week, while the CG received no intervention. Each session lasted 60–70 minutes and included 5–6 exercises of 2–3 sets at maximal concentric speed and a controlled eccentric phase (≈2–3 seconds). Isokinetic muscle strength was assessed pre- and post-intervention using isokinetic testing of knee extensors (KE) and flexors (KF) at 60°/s and 180°/s on dominant (DS) and non-dominant sides (NDS). The HRQOL was measured using the SF-36 questionnaire. The IG demonstrated significant improvements in peak torque for KE-DS (Δchange: 14.02 Nm; $p < .001$; $\eta_p^2 = 0.215$), KE-NDS (Δchange: 16.19 Nm; $p < .001$; $\eta_p^2 = 0.290$), KF-DS (Δchange: 8.06 Nm; $p < .001$; $\eta_p^2 = 0.290$), and KF-NDS (Δchange: 8.33 Nm; $p = .002$; $\eta_p^2 = 0.125$), as well as in average muscle power for KE-DS (Δchange: 15.51 W; $p < .001$; $\eta_p^2 = 0.328$), KE-NDS (Δchange: 17.33 W; $p < .001$; $\eta_p^2 = 0.298$), KF-DS (Δchange: 8.21 W; $p < .001$; $\eta_p^2 = 0.284$), and KF-NDS (Δchange: 8.06 W; $p = .005$; $\eta_p^2 = 0.100$). HRQOL improvements were also observed. The present HSRT protocol effectively improves isokinetic muscle parameters and HRQOL measures in older adults.

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Aged; dynamometer; muscle contraction; strength training; velocity-based training

The aging process induces a range of physical and physiological effects, including a progressive decline in muscle strength and power, collectively referred to as muscle function (Keller & Engelhardt, 2014). Among these changes, declines in leg muscle strength and power are particularly critical, as individuals primarily depend on the lower extremities to recover balance following postural disturbances (Benichou & Lord, 2016). These impairments are primarily driven by physiological mechanisms such as the atrophy of type I and II myosin heavy chain isoforms (Frontera et al., 2012), a reduction in total myofibre number (Lexell et al., 1986), and loss of α-motor units with associated denervation (Ling et al., 2009). These neuromuscular changes contribute to the development of sarcopenia and physical frailty (Larsson et al., 2019), conditions strongly associated with increased risk of falls, functional disability, and ultimately higher mortality rates in older adults (Beaudart et al., 2017; Yeung et al., 2019).

Recently, Currier et al. (Currier et al., 2026) provided evidence that resistance training (RT) in older adults can counteract several age-related physiological declines, offering health benefits such improved muscle strength, maintained independence, reduced falls risk, and enhanced quality of life. However, velocity-based training (VBT), commonly implemented as high-speed resistance training (HSRT), has acquired attention due to its emphasis on movement velocity, which presents a critical role in muscle function (Balachandran et al., 2022; Sayers et al., 2016). This protocol requires explosive concentric actions (≤1 seconds) with low-to-moderate loads, coupled with controlled eccentric phases (≈2–3 seconds) (Balachandran et al., 2022; Sayers et al., 2016).

Although most HSRT studies instruct participants to move "*as fast as possible*" (Lopes et al., 2016; Reid et al., 2015; Sayers, 2007; Sayers & Gibson, 2010, 2014), they often lack standardized monitoring of mean concentric velocity (MCV). This oversight limits training precision, especially in older adults, whose self-selected velocities may vary due to age, strength levels, or fatigue (Dorrell et al., 2020; Sayers et al., 2016). Instead, real-time feedback on MCV using commercial kinematic devices (e.g., accelerometers) offers a more precise approach than relying solely on movement duration (González-Badillo & Sánchez-Medina, 2010; Jidovtseff et al., 2011). While this approach has shown promise in younger populations (Dorrell et al., 2020; González-Badillo et al., 2014, 2015), its application in older adults remains limited (Sayers et al., 2016).

To address this gap, Bryan Mann and colleagues (Mann, 2016; Mann et al., 2015) have introduced and described general velocity zones designed for specific training objectives and

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highlighted the potential of real-time MCV feedback for enhancing participant motivation and engagement. These zones, such as 1.30–1.00 m/s or 1.00–0.75 m/s, are strategically aligned with different phases of the strength-velocity continuum and can be incorporated into HSRT protocols.

In parallel, as previously mentioned, RT interventions may help mitigate quality of life issues commonly observed in older adults often linked to the progressive deterioration of muscle function (Trombetti et al., 2016). In addition, a recent study recommends assessing quality of life as a secondary outcome in clinical interventions for older adults (Izquierdo et al., 2025), a relevant consideration given the inconsistent findings reported in previous RT studies (Krčmár et al., 2021; Pietta-Dias et al., 2019).

Given the lack of studies monitoring MCV during HSRT interventions in older adults, and the need to address age-related declines in parameters related to muscle function, this feasibility study aimed to examine the effects of a 16-week HSRT program, structured around general velocity zones, on isokinetic muscle strength parameters [peak torque, average muscle power (muscle power), peak torque ratio, total work, and work fatigue] in independent older adults. Additionally, health-related quality of life (HRQOL) was examined as a secondary aim.

Material and methods

Study design

This clinical trial, recorded on *clinicaltrials.gov* (ID: NCT05586087), is a part of the closed "Active Aging" longitudinal study, which began in March 2022. The study used a parallel two-group trial design over a 20-week period, including 16 weeks of HSRT and four weeks for data collection (two weeks before and after the intervention).

Anthropometric measurements, isokinetic muscle strength parameters, and HRQOL measures were assessed both before and after the intervention. The timing of participant evaluations was carefully planned to coincide with the pre- and post-intervention periods to maintain consistency and enhance internal validity. To avoid the immediate impacts of the last HSRT session, post-training assessments were carried out no sooner than 72 hours following the final session.

Participants

Prior to recruitment, a priori sample size calculation was performed on G*power software (University of Dusseldorf, Germany) (Faul et al., 2009) based on conditions outlined by Vieira et al (Vieira et al., 2022): ANCOVA with fixed effects, main effects and interaction: effect size $f = 0.32$, $\alpha = 0.05$, power (1-β err prob)=0.80, number of groups = 2 and number of covariates = 1. The actual power output showed that this clinical trial should have a minimum of 79 participants with an 80% chance of successfully rejecting the null hypothesis.

Participants were recruited through local newspaper advertisements and invitations distributed to daycares and health centers. Initially, 89 older adults expressed interest in participating. Each candidate underwent a personal interview to screen eligibility based on the following inclusion criteria: (i) age ≥ 65 years; (ii) independent walking ability; and (iii) capacity to perform daily living tasks independently. Exclusion criteria included diabetes, cardiac disease, recent surgery (within six months), or active oncological conditions. Based on these criteria, ten participants were excluded.

During the interview, participants who met all criteria were further assessed for their availability to attend the exercise sessions. Those unavailable for these sessions were assigned to the control group (CG) and simultaneously placed on a waiting list for participation in other research projects.

As a result, the study included 79 independent older adults, both males and females, who were divided into two groups: the intervention group (IG) and the CG. The IG consisted of 40 participants (8 males and 32 females; age: 68.50 ± 3.54 years; and weight: 68.65 ± 11.36 kg), while the CG comprised 39 participants (16 males and 23 females; age: 72.08 ± 5.89 years; and weight: 67.04 ± 10.69 kg). Overall, females represented 80% of the IG and 59% of the CG. Considering the total sample, the mean age for males and females was 70.58 ± 6.19 and 70.13 ± 4.67 years, respectively. The flow chart of the study is depicted in the supplementary file as Figure A.

The CG participants were asked to continue their normal physical activities (PA) but avoid starting any new strength training or exercise programs throughout the 16-week intervention. Their PA levels were monitored using the *International Physical Activity Questionnaire—Short Form* (IPAQ-SF), with results published elsewhere (Duarte Martins et al., 2024). The groups differ significantly only in terms of moderate-to-vigorous physical activity.

Following the intervention, five participants discontinued the study: three from the IG, due to muscle discomfort, loss of contact, and concurrent participation in another exercise program, and two from the CG, due to a cancer diagnosis and loss of contact.

Ethical approval

Ethical approval was obtained from the local Ethics Committee with clearance number 22,030. The study was conducted in compliance with the Declaration of Helsinki and according to the CONSORT (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.

Procedures

All assessments were conducted both pre- and post-intervention over two consecutive days. On the first day, anthropometric measurements and the HRQOL questionnaire were completed in the morning, between 08:30 a.m. to 10:30 a.m. Participants were instructed to arrive in a fasted state (at least 8 hours), with an empty bladder, and to refrain from PA, alcohol, or caffeine consumption for 24 hours prior to testing.

On the second day, participants completed the isokinetic muscle function assessments and were asked to fill out the HRQOL questionnaire. All measurements were conducted by the same researcher to minimize potential sources of error, and

the order of the assessments was standardized across all participants.

Isokinetic muscle strength assessment

Isokinetic muscle strength parameters were assessed using an isokinetic dynamometer (Biodex System 3, Biodex® Medical Systems, Shirley, NY, USA), calibrated and configured according to the manufacturer's guidelines. Specifically, participants were seated with the knee joint aligned to the axis of the dynamometer. The dynamometer was set at 0º (full extension), with the seat orientation and dynamometer arm at 90º, and both the seat tilt and range of motion set to 85º. Straps were used to stabilize the hips and shoulders, and the test leg was secured to the lever arm. After these procedures, participants were instructed to relax momentarily to register the passive effect of gravity on the limb.

The warm-up included a ten-minute walk at the participant's fastest comfortable pace. After that, participants performed ten submaximal repetitions at 210º/s to reduce variability in test performance and familiarize them to the equipment. Next, maximal unilateral concentric isokinetic strength of the knee extensors (KE) and flexors (KF) (concentric/concentric mode) was then assessed at two angular velocities: 60º/s (three maximal trials) and 180º/s (twenty maximal trials), for both the dominant (DS) and non-dominant side (NDS). A one-minute rest period was provided between sets.

The following isokinetic muscle strength parameters were quantified: peak torque (Nm), average muscle power (muscle power) (W), KF/KE ratio (%), all were assessed at 60º/s. Additionally, total work (J) and work fatigue (%) were assessed at 180º/s. Work fatigue was calculated using the ratio of the first third of work (Wk1) to the last third of work (Wk2) according to the formula: $[(Wk1-Wk2)/Wk1]\times100$). Verbal encouragement was provided during the assessment to motivate participants to exert maximal effort.

Lastly, the reliability of the main isokinetic muscle strength parameters (peak torque and muscle power) were assessed using the Intraclass Correlation Coefficient (ICC), Standard Error of Measurement (SEM), and Smallest Real Difference (SRD), following the methodology proposed by Parraca et al (Parraca et al., 2022). The detailed reliability results are presented in the supplementary material (Table C).

Health-related quality of life

The HRQOL was assessed using the *Medical Outcomes Study 36-Item Short Form Survey* (SF-36) (McHorney et al., 1993; Ware & Sherbourne, 1992) validated and translated into Portuguese language by Ferreira (Ferreira, 2000). The domains evaluated were the following: physical function; role—physical, pain; general health, energy/vitality, social functioning, role—mental and mental health. The questionnaire was applied by the same evaluator pre- and post-intervention.

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 instructions from the principal researchers regarding the specific feedback to provide participants during exercise execution.

The program lasted 16 weeks, with three sessions per week (Mondays, Wednesdays, and Fridays) of 60–70 min. To offer more flexibility, each day included four sessions with five to ten participants, giving participants more scheduling options. Each session typically consisted of five to six exercises, with each exercise comprising two to three sets of six to ten repetitions (Fragala et al., 2019). Detailed biweekly prescriptions are provided in the supplementary file, specifically in Table A.

The exercise sessions followed a standardized format, which included a warm-up phase (10 to 15 min), incorporating activities such as brisk walking, joint mobilization exercises utilizing sand bottles, and engaging in recreational games at a moderate-to-high-intensity level; the main phase, which encompassed 45 to 55 minutes of the HSRT program in the machines; and a cool-down phase, a 5 to 10-minute cool-down period, involving stretching exercises. The main phase included the following upper- and lower-body exercises: squats on smith machine or with dumbbells (depending 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 training protocol for older adults employs progressively increasing loads, tailored to the participants' mean concentric phase velocity for each set across all exercises. Specifically, the training protocol utilized three distinct velocity ranges to align with the intervention's objectives (Mann, 2016; Mann et al., 2015): during the 1st to 4th weeks, an average speed over 1.3 m/s was required (*starting strength*); from the 5th to 10th weeks, speeds were adjusted to between 1.3 and 1.0 m/s (*speed/strength*); and in the 11th to 16th weeks, speeds 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. The initial two weeks of the intervention were dedicated to familiarizing the participants with the exercises. This involved teaching proper postures, movement patterns, and breathing techniques for each exercise.

The participants' mean concentric phase velocity for every set and exercise was monitored using a BEAST™ sensor (Beast Technologies, Brescia, Italy) (Vallejo et al., 2020). This device not only provided real-time feedback on instantaneous velocity to both participants and supervisors but also delivered the mean velocity value at the end of each set. Each session featured at least six accelerometers connected via Bluetooth to six separate cell phones. Additionally, supervisors verbally encouraged participants to perform rapid and explosive repetitions during the concentric phase of each exercise, while maintaining a controlled eccentric phase lasting two-three seconds.

The Borg Rating of Perceived Exertion (RPE) scale, established by Borg (Borg, 1982) was utilized to measure participants' effort, with values ranging from 6 to 20. This subjective assessment asks participants to rate their exertion from "*moderate*" to "*somewhat hard*," which corresponds to RPE scores of 11 to 13. Before the intervention, all participants participated in an orientation session to familiarize themselves with the scale, ensuring they could accurately assess their exertion levels during exercise. Additionally, participants wore Polar M200 heart rate monitors to track their heart rates throughout the training sessions. The predicted maximum heart rate (HRmax) was determined using the formula HRmax = 206.9–(0.67 × Age), as suggested by Gellish et al (Gellish et al., 2007). Importantly, there were no adverse events reported during the intervention, and participant attendance was monitored throughout.

Statistical analysis

This clinical trial employed an estimation technique approach to address the limitations associated with traditional N-P null hypothesis significance testing (Cumming & Calin-Jageman, 2017; Ho et al., 2019). First, the primary analysis was carried out according to an intention-to-treat design, with missing values imputed using the expectation—maximization algorithm. Second, baseline characteristics between groups were compared using an *independent samples t-test* and a chi-square test was performed to examine differences in sex distribution between the IG and CG.

Subsequently, analysis of covariance (ANCOVA) was performed with pre-intervention values entered as a covariate and with group (IG and CG) and sex (male and female) included as fixed factors, allowing us to estimate the adjusted effect of the intervention while accounting for baseline imbalances and sex differences. This approach is recommended in pre-to-post intervention studies as it provides an adjusted estimate of the treatment effect while accounting for baseline imbalances (Lemay, 2017).

To enhance the main results, the Δ changes (post- minus pre-intervention values) for each group were calculated for all measures, along with the comparative differences between the groups. This analysis was conducted using a specific spreadsheet (Cumming & Calin-Jageman, 2017). Additionally, the pre-to-post intervention changes within each group were analyzed using *paired samples t-tests* via the same spreadsheet. Additionally, these individual variations are shown in the Gardner–Altman estimation plots, which graphically displays individual and group mean values at pre- and post-intervention, as well as the mean differences with 95% confidence intervals (CIs) (Cumming & Calin-Jageman, 2017; Ho et al., 2019).

The effect sizes (ESs) were expressed as η_p^2 values for ANCOVA results: small: 0.010–0.059; medium: 0.060–0.140; and large: >0.140 (Cohen, 1988), and as Cohen's $d_{unbiased}$ (d_{unb}) with 95% CI (an unbiased estimate with a sampling distribution whose mean equals the population parameter being estimated) (Cumming & Calin-Jageman, 2017) for interpreting the pairwise differences: small: 0.20–0.49; medium: 0.50–0.80; and large: >0.80 (Cohen, 1988; Hopkins et al., 2009).

Lastly, the formulas for the relative and absolute reliability should be acknowledge. The relative reliability was assessed using the ICC (Jenkins & Cramer, 2017), based on the following parameters: (i) model: two-way random effects; (ii) type: single measures; and (iii) definition: consistency. ICC values above 0.90 were considered excellent, while values between 0.75 and 0.90 were considered good (Portney & Watkins, 2009). The absolute reliability was assessed using the SEM and the SRD, following the methodology described by Gray et al (Gray et al., 2014). The formulas used were: SEM (absolute): SEM= $SD \times \sqrt{1 - ICC}$, where SD represents the average standard deviation of the two repetitions; SRD (absolute): SRD= $1.96\left(\text{SEM} \times \sqrt{2}\right)$. The SEM in percentage was calculated by the following the formula: SEM (%) $=\frac{SD\times\sqrt{1-ICC}}{Meanofrepetitions} \times 100$, and the SRD in percentage was calculated through the formula: SRD (%)$=\frac{1.96(SEM\times\sqrt{2}}{Meanofrepetitions} \times 100$. Data analysis was conducted using IBM SPSS Statistics for Windows, Version 26 (IBM Corp., Armonk, NY, USA). All tests were considered statistically significant at a *p*-value less than 0.05, using a two-tailed approach.

Results

Participants

The baseline characteristics of the study sample can be found in the supplementary file as Table B. There was a significant difference in age between the groups ($p = .002$, $d_{unb} = 0.73$ [0.28, 1.19]). The attendance rate during the intervention period was established at 97.60%.

Isokinetic muscle strength parameters

At baseline, significant differences were observed between groups in peak $\text{torque}_{\text{KF-DS}}$, $\text{muscle power}_{\text{KF-DS}}$, and $\text{total work}_{\text{KF-DS,}}$ as well as in $\text{total work}_{\text{KF-NDS}}$. The ANCOVA results, detailed in Table 1, indicate significant group effects that favored the IG across multiple measures following the program. Moreover, additional ANCOVA outputs for the sex main effect and the Group × Sex interaction are presented in Table D (supplementary file). Only $\text{total work}_{\text{KE-NDS}}$ revealed a significant Group × Sex interaction ($p = .015$; $\eta_p^2 = 0.077$), indicating that the intervention effect differed between male and female for this specific parameter.

To complement the study results, Figure 1, which displays Cohen's d_{unb} for the Δ changes between groups, revealing several significant differences favoring the IG.

Lastly, Figure 2 presents the within-group changes. The IG demonstrated significant increases ($p < .001$) in $\text{peak torque}_{\text{KE-DS}}$, $\text{muscle power}_{\text{KE-DS}}$, $\text{total work}_{\text{KE-DS}}$, $\text{peak torque}_{\text{KE-NDS}}$, $\text{muscle power}_{\text{KE-NDS}}$, and $\text{total work}_{\text{KE-NDS}}$. Moreover, the IG also exhibited significant increases in $\text{peak torque}_{\text{KF-DS}}$, $\text{muscle power}_{\text{KF-DS}}$, $\text{total work}_{\text{KF-DS}}$, $\text{work fatigue}_{\text{KF-DS}}$ ($p = .044$), $\text{peak torque}_{\text{KF-NDS}}$, $\text{muscle power}_{\text{KF-NDS}}$, and $\text{total work}_{\text{KF-NDS.}}$

In contrast, the CG exhibited a significant increase in $\text{total work}_{\text{KE-DS}}$ ($p = .002$), and declines in $\text{work fatigue}_{\text{KE-DS}}$ ($p = .046$), and $\text{peak torque}_{\text{KF-DS}}$ ($p = .009$). Finally, visual

Table 1. Analysis of covariance (ANCOVA) results considering the group factor for isokinetic muscle strength parameters.

	Control Group			Intervention Group			ANCOVA Effects		
Parameters	Pre	Post	M_{diff} (95% CI)	Pre	Post	M_{diff} (95% CI)	F	p	η_p^2
Extension at 60º/sec									
Peak Torque (Nm), DS	98.56 ± 41.29	94.99 ± 48.15	−3.57 [−8.90 to 1.77]	90.79 ± 42.75	104.82 ± 39.22*,§	14.02 [8.58 to 19.47]	25.423	**<0.001**	0.256$^{£}$
Peak Torque (Nm), NDS	88.04 ± 30.83	88.43 ± 33.35	0.39 [−3.82 to 4.59]	88.08 ± 27.74	104.26 ± 30.53*,§	16.19 [12.32 to 20.05]	26.526	**<0.001**	0.264$^{£}$
Avg. Muscle Power (W), DS	58.45 ± 20.48	57.51 ± 25.57	−0.95 [−4.73 to 2.83]	50.39 ± 18.98	65.89 ± 21.23*,§	15.51 [11.67 to 19.36]	38.434	**<0.001**	0.342$^{£}$
Avg. Muscle Power (W), NDS	54.87 ± 21.14	56.13 ± 25.25	1.26 [−2.48 to 5.01]	49.22 ± 18.73	66.55 ± 20.31*,§	17.33 [13.21 to 21.45]	35.858	**<0.001**	0.326$^{£}$
Flexion at 60º/sec									
Peak Torque (Nm), DS	48.05 ± 16.18‡	44.40 ± 18.08*	−3.65 [−6.33 to −0.98]	40.94 ± 12.36	48.99 ± 13.35*,§	8.06 [5.17 to 10.95]	30.511	**<0.001**	0.292$^{£}$
Peak Torque (Nm), NDS	47.30 ± 16.72	48.98 ± 18.66	1.67 [−0.79 to 4.14]	43.43 ± 13.53	51.76 ± 13.13*,§	8.33 [5.36 to 11.29]	14.903	**<0.001**	0.168$^{£}$
Avg. Muscle Power (W), DS	31.64 ± 13.34‡	30.04 ± 13.74	−1.60 [−3.56 to 0.36]	25.23 ± 8.47	33.43 ± 10.60*,§	8.21 [5.62 to 10.79]	34.041	**<0.001**	0.315$^{£}$
Avg. Muscle Power (W), NDS	29.81 ± 12.82	31.75 ± 14.65	1.94 [−0.22 to 4.10]	26.77 ± 9.91	34.83 ± 10.86*,§	8.05 [4.76 to 11.35]	9.866	**0.002**	0.118$^{#}$
Flexors/extensors at 60º/sec									
Peak Torque Ratio (%), DS	50.78 ± 10.63	48.39 ± 10.89	−2.39 [−5.18 to 0.39]	48.13 ± 14.26	49.28 ± 11.53	−0.64 [−5.06 to 3.78]	1.322	0.254	0.018$^{&}$
Peak Torque Ratio (%), NDS	55.33 ± 12.19	56.42 ± 9.72	1.09 [−2.36 to 4.56]	50.59 ± 11.04	50.99 ± 10.04	0.41 [−2.79 to 3.61]	1.281	0.261	0.017$^{&}$
Extension at 180º/sec									
Total Work (J), DS	835.78 ± 302.91	907.67 ± 382.87*	71.89 [11.99 to 131.79]	785.71 ± 285.28	1050.69 ± 379.89*,§	264.98 [159.82 to 370.14]	20.859	**<0.001**	0.220$^{£}$
Total Work (J), NDS	845.13 ± 356.09	880.97 ± 384.54	35.85 [−18.49 to 90.19]	770.23 ± 302.99	1064.53 ± 337.19*,§	294.30 [195.98 to 392.62]	39.345	**<0.001**	0.347$^{£}$
Work Fatigue (%), DS	36.23 ± 18.56	24.67 ± 42.52*	−11.56 [−22.91 to −0.20]	26.95 ± 26.85	34.55 ± 9.76§	7.59 [−1.21 to 16.40]	3.203	0.078	0.041$^{&}$
Work Fatigue (%), NDS	25.36 ± 32.87	29.87 ± 24.59	4.51 [−5.02 to 14.04]	28.88 ± 19.91	33.72 ± 11.90	4.84 [−2.28 to 11.96]	0.371	0.544	0.005
Flexion at 180º/sec									
Total Work (J), DS	550.11 ± 292.09‡	519.53 ± 267.43	−30.59 [−72.75 to 11.57]	402.48 ± 123.54	557.58 ± 171.36*,§	155.11 [102.33 to 207.89]	24.315	**<0.001**	0.247$^{£}$
Total Work (J), NDS	554.25 ± 287.50‡	566.79 ± 355.22	12.54 [−43.25 to 68.32]	407.47 ± 145.39	585.93 ± 184.34*,§	178.47 [111.31 to 245.61]	10.362	**0.002**	0.123$^{#}$
Work Fatigue (%), DS	22.02 ± 55.15	18.36 ± 61.60	−3.66 [−24.88 to 17.55]	20.02 ± 51.18	36.58 ± 11.61*	16.55 [0.49 to 32.61]	3.049	0.085	0.040$^{&}$
Work Fatigue (%), NDS	10.73 ± 70.07	22.45 ± 61.12	11.72 [−7.22 to 30.66]	26.37 ± 41.69	34.83 ± 12.85	8.46 [−4.48 to 21.40]	0.068	0.794	0.001

Abbreviations: DS, dominant side; NDS, non-dominant side; Avg, average; Nm, newton meter; sec, seconds; W, watts; %, percent; J, joules. Pre- and post-intervention 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 $p \leq .05$. ‡, $p \leq .05$ *vs*. Intervention Group's pre-intervention values. *, $p \leq .05$ *vs*. pre-intervention values. §, $p \leq .05$ *vs*. Control Group's Δ. η_p^2 values thresholds: &, small effect: $\eta_p^2 = 0.010$ to 0.059; #, medium effect: $\eta_p^2 = 0.060$ to 0.140; £, large effect large: $\eta_p^2 > 0.140$.

representations of variations and differences in mean values for peak torque before and after the intervention are depicted in supplementary file as Figure B.

Health-related quality of life

At baseline, significant differences in some HRQOL measures were observed, namely physical function, energy/vitality, social functioning, role—mental, and mental health. Moreover, the ANCOVA results (Table 2) reveal significant group effects in favor of the IG for several HRQOL measures.

To further illustrate the study's findings, Figure 3 presents Cohen's d_{unb} for Δ changes between the groups. The HRQOL measures reveal several large ESs: role—physical, pain, general health, energy/vitality, social functioning, role—mental, and mental health.

Lastly, the within-group analyses at post-intervention showed that the IG exhibited significant increases ($p < .001$) in physical function ($p = .002$, $d_{unb} = 0.46$), role—physical ($d_{unb} = 1.18$), pain ($d_{unb} = 0.84$), general health ($d_{unb} = 0.65$), energy/vitality ($d_{unb} = 1.26$), social functioning ($d_{unb} = 1.37$), role—mental ($d_{unb} = 1.21$), and mental health ($d_{unb} = 1.27$). In contrast, the CG showed significant declines in general health ($d_{unb} = -0.69$), energy/vitality ($p = .011$, $d_{unb} = -0.53$), role—mental ($p = .001$, $d_{unb} = -0.73$), and mental health ($p = .008$, $d_{unb} = -0.51$).

Discussion

This study investigated the impact of a 16-week HSRT program on isokinetic muscle strength parameters in independent older adults. In addition, the intervention effect on HRQOL was assessed. The findings demonstrated that the HSRT program, structured around general

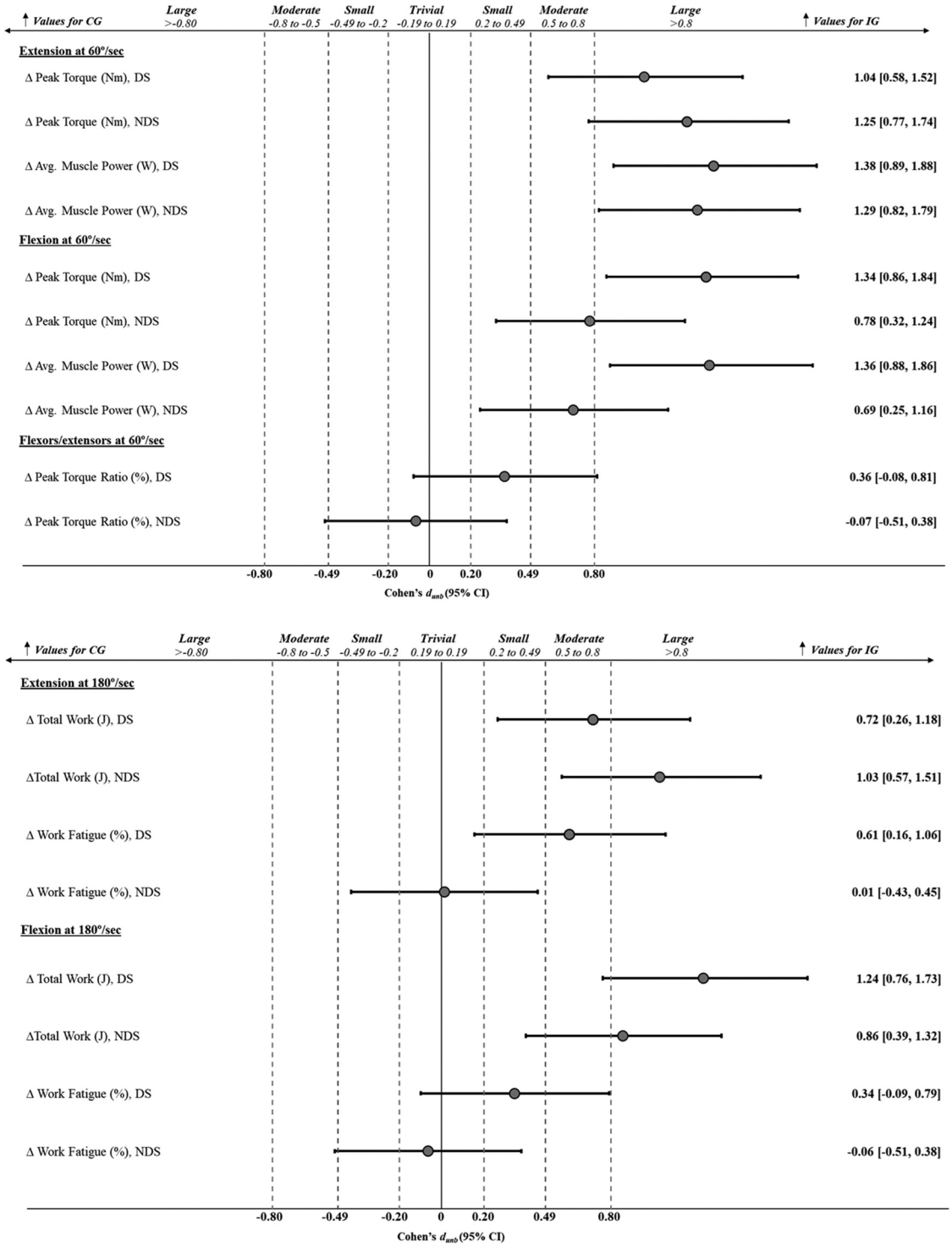

Figure 1. Cohen's d_{unb} for comparison of the delta changes (post- minus pre-intervention values) occurred for isokinetic muscle strength parameters between groups. The error bars indicate the uncertainty in the true mean changes with 95% confidence intervals. Abbreviations: DS, dominant side; NDS, non-dominant side; sec, seconds; Nm, newton meter; Avg, average; %, percentage; J, joule.

velocity zones, led to significant improvements in peak torque and muscle power. These results warrant clinical attention, given the reported annual declines in muscle strength of 2–4% (Frontera et al., 2008) and a reduction in muscle power of approximately 8–9% over a three-year period (Reid et al., 2014). Despite the absence of a comparator RT group and the unequal sex distribution between groups, these findings provide important preliminary evidence supporting the feasibility and effectiveness of a velocity-oriented HSRT protocol in independent older adults.

Previous studies have demonstrated that HSRT programs can mitigate or even reverse age-related declines in muscle strength and power and physical function (Balachandran et al., 2022; El Hadouchi et al., 2022; Monteiro et al., 2020). This benefit is likely due to the stimulus provided

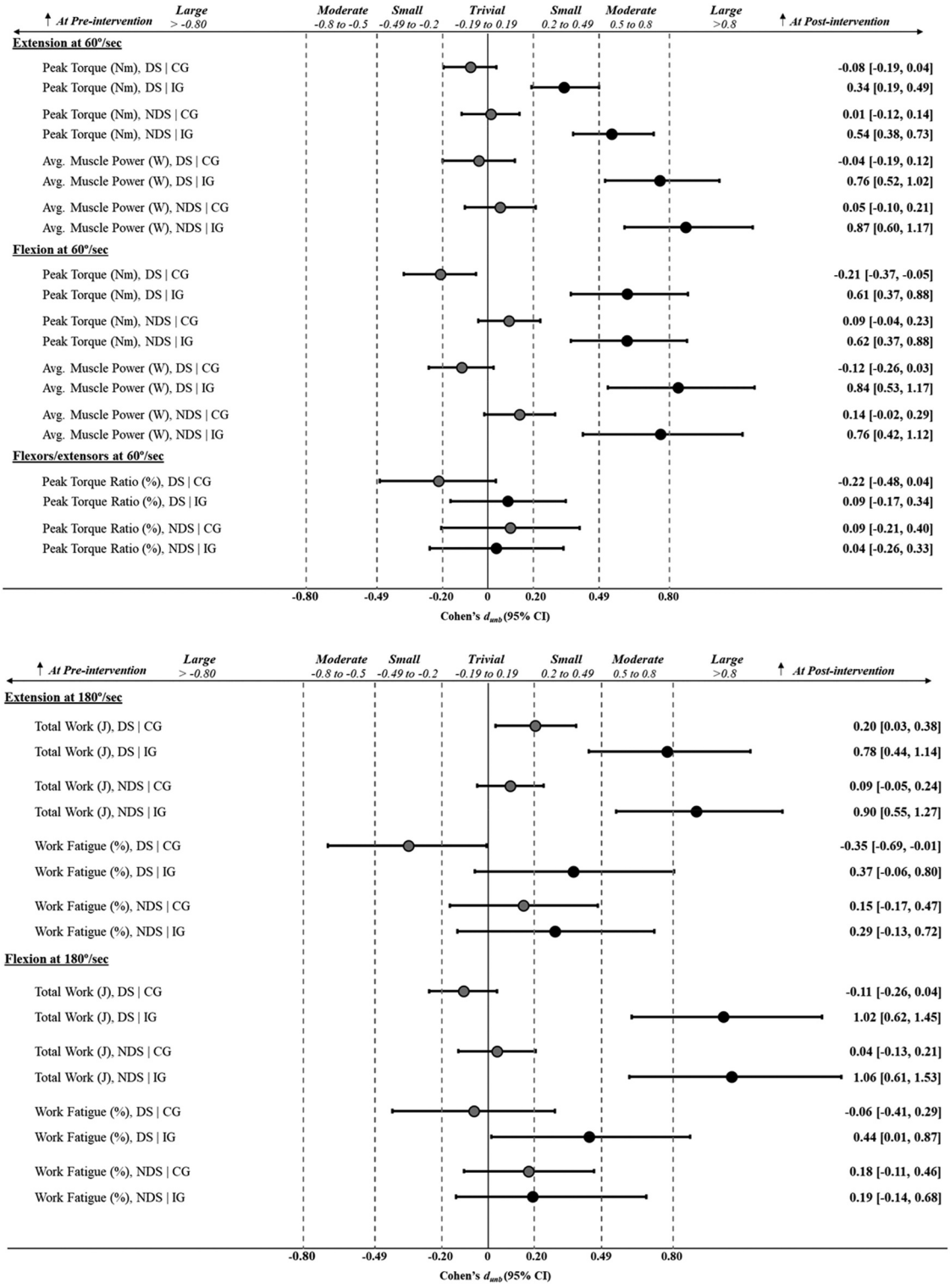

Figure 2. Cohen's d_{unb} differences for all pre-to-post-intervention changes across all parameters are presented for both groups, with error bars representing the level of uncertainty in true mean changes, depicted as 95% confidence intervals. Abbreviations: CG, control group; IG, intervention group; DS, dominant side; NDS, non-dominant side; sec, seconds; Nm, newton meter; Avg, average; %, percentage; J, joule.

by the high-velocity concentric actions, followed by a controlled eccentric phase (Balachandran et al., 2022). In this study, significant enhancements in peak torque were observed in the IG compared to the CG after intervention, namely on peak $\text{torque}_{\text{KE-DS}}$ (15% *vs.* −4%), peak $\text{torque}_{\text{KE-NDS}}$ (18% *vs.* 0.5%), peak $\text{torque}_{\text{KF-DS}}$ (20% *vs.* −8%), and peak $\text{torque}_{\text{KF-NDS}}$ (19% *vs.* 4%). These findings are visually supported by the *large* ESs illustrated in Figure 1, highlighting the magnitude of muscle adaptations in response to HSRT.

Table 2. Analysis of covariance (ANCOVA) results considering the group factor for health-related quality of life measures.

	Control Group			Intervention Group			ANCOVA Effects		
Measures	Pre	Post	M_{diff} (95% CI)	Pre	Post	M_{diff} (95% CI)	F	p	η_p^2
Physical Function	90.00 ± 13.72[‡]	89.87 ± 15.41	−0.13 [−2.58 to 2.32]	78.38 ± 19.09	86.33 ± 14.33[*,§]	7.95 [3.11 to 12.79]	0.670	0.416	0.009
Role—Physical	76.95 ± 22.09	71.67 ± 23.41	−5.28 [−12.42 to 1.85]	68.50 ± 19.42	89.13 ± 14.39[*,§]	20.63 [14.64 to 26.61]	20.932	**<0.001**	0.220[£]
Pain	63.95 ± 19.26	58.89 ± 22.25	−5.05 [−12.04 to 1.93]	56.73 ± 21.42	75.20 ± 21.81[*,§]	18.48 [10.22 to 26.73]	11.288	**0.001**	0.132[#]
General Health	63.74 ± 13.45	54.49 ± 13.02[*]	−9.26 [−12.88 to −5.64]	59.05 ± 12.69	68.45 ± 15.41[*,§]	9.40 [5.89 to 12.90]	45.293	**<0.001**	0.380[£]
Energy/Vitality	70.64 ± 16.55[‡]	62.49 ± 13.18[*]	−8.15 [−14.32 to −1.99]	51.98 ± 15.954	72.60 ± 16.22[*,§]	20.63 [15.30 to 25.95]	16.785	**<0.001**	0.185[£]
Social Functioning	69.64 ± 22.10[‡]	66.13 ± 16.13	−3.51 [−10.33 to 3.31]	58.02 ± 20.91	85.18 ± 17.80[*,§]	27.15 [20.63 to 33.67]	26.660	**<0.001**	0.265[£]
Role—Mental	81.85 ± 17.82[‡]	68.33 ± 18.46[*]	−13.51 [−20.76 to −6.27]	66.28 ± 23.68	90.15 ± 13.79[*,§]	23.88 [17.14 to 30.61]	17.115	**<0.001**	0.188[£]
Mental Health	67.95 ± 13.56[‡]	61.15 ± 12.48[*]	−6.79 [−11.64 to −1.95]	57.50 ± 17.94	78.63 ± 14.54[*,§]	21.13 [14.92 to 27.33]	12.842	**<0.001**	0.148[£]

Abbreviations: HRQOL, health-related quality of life. Pre- and post-intervention 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 $p \leq .05$. ‡, $p \leq .05$ *vs*. Intervention Group's pre-intervention values. *, $p \leq .05$ *vs*. Pre-intervention values. §, $p \leq .05$ *vs*. Control Group's Δ. η_p^2 values thresholds: &, small effect: $\eta_p^2 = 0.010$ to 0.059; #, medium effect: $\eta_p^2 = 0.060$ to 0.140; £, large effect large: $\eta_p^2 > 0.140$.

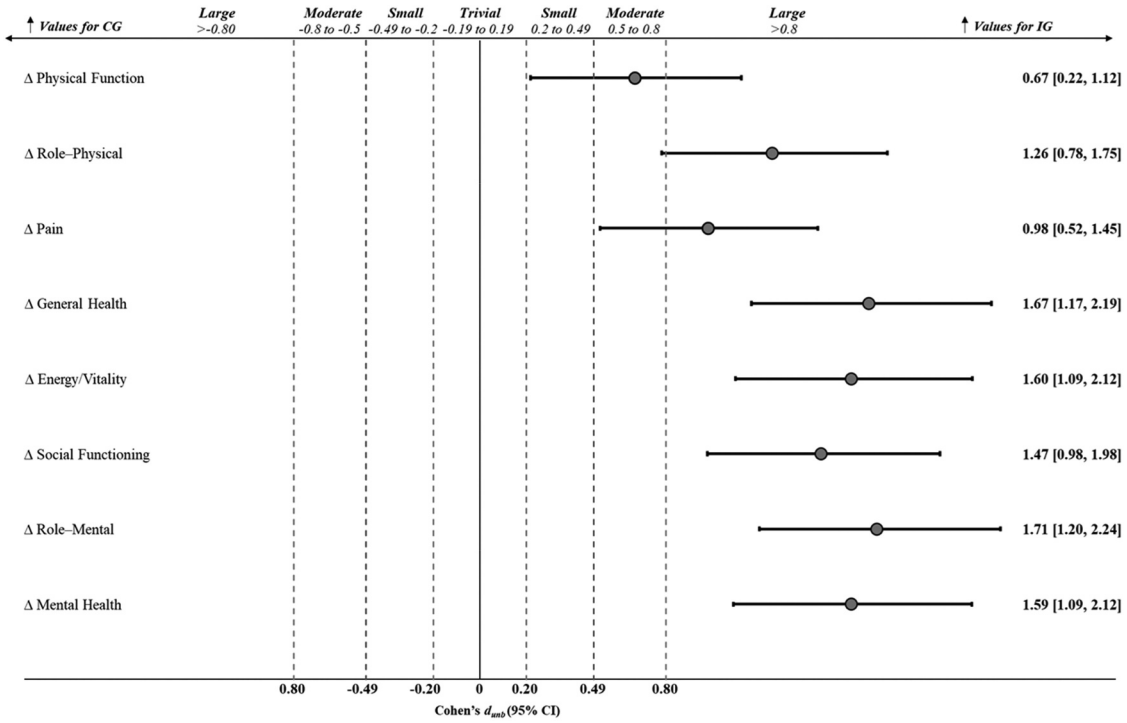

Figure 3. Cohen's d_{unb} for comparison of the delta changes (post- minus pre-intervention values) occurred for health-related quality of life measures between groups. The error bars indicate the uncertainty in the true mean changes with 95% confidence intervals.

These results align with findings from previous studies (Carvalho et al., 2010; Lopes et al., 2016; Monteiro et al., 2020). Specifically for Portuguese older adults, Monteiro et al. (Monteiro et al., 2020) reported increases of 5% and 1% in peak $torque_{KE\text{-}DS}$ and peak $torque_{KE\text{-}ND}$, respectively, and significant improvements of 18% and 12% in peak $torque_{KF\text{-}DS}$ and peak $torque_{KF\text{-}NDS}$ after eight months of HSRT. Similarly, Carvalho et al. (Carvalho et al., 2010) demonstrated significant changes in peak $torque_{KE\text{-}DS}$ (6%), peak $torque_{KE\text{-}NDS}$ (10%), peak $torque_{KF\text{-}DS}$ (14%), and peak $torque_{KF\text{-}NDS}$ (20%) after a 24-week combined program that included RT. From a clinical perspective, Chen et al. (Chen et al., 2022) defined low muscle strength as peak $torque_{KE}$ values below 104.4 Nm for men and 62.6 Nm for women. At post-intervention, only one man and two women in the IG had values below these thresholds, compared to 14 participants in the CG. While caution is advised when extrapolating these thresholds due to cultural differences (Europeans *vs*. Americans), the present findings support the implementation of HSRT to enhance muscle strength in older adults.

Likewise, significant improvements in muscle power were observed in the IG following the HSRT program. Specifically, muscle $power_{KE\text{-}DS}$ increased by 31%, and muscle $power_{KE\text{-}NDS}$ by 35%. Similarly, muscle $power_{KF\text{-}DS}$ and muscle $power_{KF\text{-}NDS}$ enhanced by 33% and 30%, respectively. These changes, detailed in Figures 1 and 2, underscore the effectiveness of HSRT in improving muscle power, a key factor of functional independence and fall prevention in older adults, as muscle power tends to decline earlier and more rapidly than muscle strength (El Hadouchi et al., 2022; Reid et al., 2014). These findings are consistent with those of Sañudo et al (Sañudo et al., 2022), who reported notable

increases in muscle power$_{\text{KE-right side}}$ by 24%, muscle power$_{\text{KE-left side}}$ by 62%, muscle power$_{\text{KF-right side}}$ by 42%, and muscle power$_{\text{KE-left side}}$ by 13%, following a six-week flywheel RT program.

These improvements in muscle strength and power may be attributed to the specific characteristics of the HSRT approach, aligning with recommendation from a recent meta-analysis study that favors high-velocity over high-load protocols (El Hadouchi et al., 2022). Thus, HSRT programs may lower the activation threshold for fast-twitch motor units while increasing their firing rates (Van Cutsem et al., 1998), potentially promoting adaptations in type II muscle fibers (Häkkinen et al., 2001). The training protocol appears effective in mitigating age-related fast-twitch fiber atrophy, promoting a shift from Type IIx to Type IIa fibers and enhancing muscle hypertrophy, power, and functional outcomes in older adults (Lavin et al., 2019). The emphasis on explosive actions and real-time feedback may also enhance motor units recruitment and firing rates (Maffiuletti et al., 2016). Lastly, since type II fibers, responsible for muscle power, degenerate faster than muscle strength (Aagaard et al., 2010), it is plausible that IG participants experienced changes in muscle fiber type composition (Harridge et al., 1996).

Regarding the peak torque$_{\text{KF/KE ratio}}$, used to evaluate knee joint muscle balance, previous study reported increases of 14% on DS and 12% on NDS after eight months of HSRT (Monteiro et al., 2020). However, this study found no significant changes for either group post-intervention. Despite the variability, Figure 1 indicates a *small* ES favoring the IG. Ratios below 0.5 may compromise joint integrity, exposing the knee to excessive concentric movements (da Rosa Orssatto et al., 2018).

Regarding total work, both groups showed significant increases in total work$_{\text{KE-DS}}$, with greater improvements in the IG (34%) *vs.* CG (9%). Moreover, only the IG exhibited significant increases for total work$_{\text{KE-NDS}}$ (38%), total work$_{\text{KF-DS}}$ (39%), and total work$_{\text{KF-NDS}}$ (44%). Figure 1 demonstrates *moderate*-to-*large* positive ESs favoring the IG post-intervention. These findings may suggest not only improved muscular effort but also increased energy expenditure (Kowal et al., 2024), potentially enhancing functional performance and resilience in daily activities.

Finally, regarding work fatigue measures, which are seldom reported in the literature (Kowal et al., 2024), the HSRT program did not improve muscle fatigability in the older adults (Table 1). These findings are consistent with previous studies showing greater fatigability in older adults, particularly during high-velocity contractions in the KE muscles (Callahan & Kent-Braun, 2011; Dalton et al., 2012). Some mechanisms may explain these results. First, the observed improvements in strength and power may reflect adaptations involving a greater contribution of type II fibers, which are known to fatigue more rapidly during repeated contractions (Carr et al., 2015). In addition, age-related reductions in contractile speed and impairments in action potential transmission along the motor axon and across the neuromuscular junction may further exacerbate neuromuscular fatigue (Hepple & Rice, 2016; Yoon et al., 2013). Future studies should include work fatigue as an outcome to enhance the interpretability of the results.

Improvements in pain are plausibly linked to physiological adaptations induced by HSRT, such as increased muscle strength and enhanced neuromuscular function, which can contribute to better physical function ultimately a decrease in pain (Latham & Ju, 2010). In contrast, improvements in mental health may be partially attributable to psychosocial factors inherent to supervised group-based exercise, including opportunities for social interaction (Franco et al., 2015), perceived support from instructors, and increased feelings of competence and autonomy. Importantly, participants spontaneously organized additional activities during the intervention (e.g., charity walks), which may have further mitigated social isolation and inactivity (Mays et al., 2021). Together, these physiological and psychosocial pathways may help explain the multidimensional benefits observed in the present study. Additionally, other studies have further shown that RT programs can effectively improve psychosocial health outcomes, such as perceived stress (Putiri et al., 2012), depression (Sparrow et al., 2011), and anxiety (Ferreira et al., 2018).

Despite the positive findings, some limitations should be acknowledged. First, the study employed a non-randomized design, and neither the assessor, intervention technicians, nor participants were blinded. The non-randomized allocation based on availability may have introduced selection bias, potentially leading to an overestimation of the intervention effects. Second, the absence of a traditional RT comparison group limits the ability to directly determine whether HSRT provides superior benefits compared with more traditional RT approaches. Future studies including multiple training arms would help clarify the relative effectiveness of these modalities. Third, the unequal sex distribution between groups, particularly the higher proportion of female participants in the IG, may limit the generalizability of the findings and is consistent with prior studies, which reflect the greater participation and adherence typically observed among older women in community-based exercise programs (Carvalho et al., 2010; Sañudo et al., 2022; Vieira et al., 2022).

This imbalance could potentially bias the magnitude of the observed intervention effects, especially given the non-randomized allocation procedure. To mitigate this limitation, sex was included as a fixed factor in all ANCOVA models, allowing the analyses to statistically adjust for sex-related variability. Even so, the findings should be interpreted with caution, as statistical adjustment cannot fully compensate for baseline differences in group composition. To enhance transparency and address the potential influence of sex imbalance on the intervention effect, we reported all ANCOVA sex and Group × Sex interaction effects in Supplementary Table D. These results show that sex-specific responses were generally limited, although one outcome (total work$_{\text{KE-NDS}}$) demonstrated a significant interaction, indicating that sex differences may have influenced this specific parameter.

While including such a group would have enhanced interpretability, this feasibility study was intentionally designed to assess the preliminary efficacy of a velocity-based HSRT protocol using general velocity zones. Future studies should adopt randomized controlled designs and include traditional RT to better elucidate the relative benefits of different RT modalities in older adults.

Conclusion

This feasibility study demonstrates that a HSRT program structured around general velocity zones can effectively improve muscle strength and power in older adults. The use of real-time MCV monitoring appears to enhance both training stimulus and participant engagement, supporting its feasibility in this population. Given the progressive decline in neuromuscular function with aging, these findings provide preliminary evidence supporting the integration of velocity-based training approaches into exercise programs for older adults in clinical and community settings.

In addition to neuromuscular benefits, the intervention was associated with improvements in several health-related quality of life domains, suggesting that HSRT may positively influence both physical and psychosocial health. Collectively, these results indicate that HSRT may contribute to the preservation of functional independence and overall well-being in aging populations.

Practical applications

- HSRT using general velocity zones can be safely implemented in older adults to enhance muscle strength and power.
- Real-time velocity feedback may increase motivation, engagement, and adherence to exercise programs in clinical and community-based settings.
- Velocity-based monitoring offers clinicians a practical tool to individualize exercise intensity without relying on maximal strength testing.
- Incorporating HSRT into exercise prescriptions may support functional independence and improve quality of life in older adults.
- This approach may be particularly useful in preventive and rehabilitative programs targeting age-related declines in neuromuscular function.

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Disclosure statement

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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