INTERNATIONAL JOURNAL OF EXERCISE SCIENCE

Original Research

Positive Changes in Functional Capacity, Muscle Strength and Body Composition after Short Time of Resistance Training Periodization in Older Women: A Quasi-experimental Study

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Abstract

International Journal of Exercise Science 18(7): 949-970, 2025. https://doi.org/10.70252/FIDZ3071 We investigated the effects of a new approach with mixed session periodization resistance training (MSP) on functional performance, muscular strength, and body composition in older women. Twenty-one participants were tested before and after the intervention (10 weeks) and were allocated for convenience into two groups according to their available time; our schedule made two classes available, one at 6 a.m. (MSP), and one at 7 a.m. (active group-control). Results were analyzed through a mixed-model analysis with repeated measures. There was a group vs. time interaction for timed up and go ($p < 0.001$, $\eta_p^2 = 0.478$; MSP: pre = 8.2 ± 1.3s, post = 7.1 ± 1.1 s; CON: pre = 7.8 ± 1.2s, post = 7.6 ± 1.1 s), stair ascent ($p = 0.001$, $\eta_p^2 = 0.478$; MSP: pre = 12.5 ± 2.1s, post = 10.8 ± 1.9s; CON: pre = 12.3 ± 2.0s, post = 12.1 ± 1.8s), and stair descent tests ($p < 0.001$, $\eta_p^2 = 0.579$; MSP: pre = 13.2 ± 2.3s, post = 11.4 ± 2.0s; CON: pre = 12.9 ± 2.2s, post = 12.7 ± 2.1s). There was also a group vs. time interaction for concentric knee extension ($p = 0.001$, $\eta_p^2 = 0.465$; MSP: pre = 120.5 ± 18.7 Nm, post = 135.6 ± 20.1 Nm; CON: pre = 118.3 ± 17.9 Nm, post = 119.8 ± 18.2 Nm), and for bench press ($p < 0.001$, $\eta_p^2 = 0.635$; MSP: pre = 25.3 ± 4.5 kg, post = 30.1 ± 5.0 kg; CON: pre = 24.8 ± 4.3 kg, post = 25.2 ± 4.4 kg), lat pulldown ($p = 0.005$, $\eta_p^2 = 0.345$; MSP: pre = 30.2 ± 5.1 kg, post = 35.0 ± 5.6 kg; CON: pre = 29.8 ± 5.0 kg, post = 30.1 ± 5.1 kg), deadlift ($p < 0.001$, $\eta_p^2 = 0.606$; MSP: pre = 45.6 ± 7.2 kg, post = 52.3 ± 7.8 kg; CON: pre = 44.9 ± 7.0 kg, post = 45.3 ± 7.1 kg), and squat ($p < 0.001$, $\eta_p^2 = 0.694$; MSP: pre = 40.5 ± 6.8 kg, post = 47.2 ± 7.5 kg; CON: pre = 39.8 ± 6.7 kg, post = 40.1 ± 6.8 kg). There were no significant changes in body fat percentage, absolute body fat, or lean mass. Our findings demonstrated that independently of sequence, the mixed session periodization model resulted in increased muscle strength and functional capacity in aging adults, but no significant changes in body composition were observed.

Keywords: Strength training, physical functional performance, mixed session periodization, elderly

Introduction

Aging is accompanied by reductions in functional capacity, which lead to impaired ability to perform daily living and work activities (e.g., walking, stair climbing, chair standing, and commuting).[1] Lower levels of functional capacity in older adults are related to reductions in independence,[2] frailty,[3] and increased risk of falling.[4] Moreover, impaired functional capacity has a significant personal impact since it affects the quality of life[5] and can increase hospitalization costs.[6] In addition, the personal implications reflect governmental costs with early retirement (pensions) and hospitalizations.[6]

Age-related declines in functional capacity are accompanied by a gradual deterioration in neuromuscular function, reductions in skeletal muscle mass, and increased fat accumulation.[7] Muscular strength is fundamental to movement generation, which is illustrated by the correlation between maximal dynamic strength and isokinetic peak torque with the timed up-and-go test.[8] Despite the relationship between muscle mass and strength,[9] there is no consensus about the association between muscle mass and functional capacity.[10] On the other hand, higher body fat levels seem to negatively affect the functional capacity of older adults,[11] which can be explained by the fact that fat mass is a non-contractile tissue that is carried during daily living activities and by the impairment that intramuscular fat content causes in contractile mechanics.[12] Fortunately, functional and neuromuscular performance and body composition can be improved by physical exercise.

Among the different types of physical exercise, resistance training (RT) is an effective exercise modality for improving functional capacity, muscular strength, and body composition in older adults.[13] It was recently suggested that mixing sets within the same training session, focusing on different training characteristics (e.g., muscle hypertrophy, strength, and power), could optimize the training adaptations and, consequently, improve functional capacity.[14] In this way, different load intensities and contraction speeds (fast or slow) result in greater motor unit recruitment and different fiber recruitment patterns.[16] These variations within the session can be based on the concept of allostasis, which suggests that organisms maintain physiological stability by anticipating "needs" before they arise, thus mobilizing a variety of neurological, biological, and immunological accommodations to combat emerging challenges.[17]

In older adults, an optimal periodization model has yet to be determined to facilitate concomitant improvements in body composition components (e.g., skeletal muscle mass and fat mass), gains in muscular strength, and functional task performance. In addition, few studies have compared the effects of progressive RT vs. different periodization models.[18] The periodization design was based on distributing the different neuromuscular stimuli (i.e., power, strength, hypertrophy, and localized muscular endurance) throughout the training period. To date, only one study proposed this distribution inside the same session (i.e., mixed session).[14] However, the combination proposed in the study mentioned above may potentiate the effects on muscle mass, strength, and functional task performance, if a simple change was made in the order of neuromuscular stimuli.

Therefore, the present study aims to investigate the effects of a new RT mixed session (MSP) approach on functional performance, muscular strength, and body composition in older adults. Our primary hypothesis was that MSP would improve functional capacities, muscular strength, and body composition measures more effectively than a control group. In addition to the primary objective, this study also aims to explore the association between functional capacity and strength variables at two distinct points of the intervention. These points are defined as the pre-intervention and post-intervention assessments, conducted prior to the commencement of training and following the completion of the 12-week program, respectively.

The selection of these two time points is based on the necessity to capture longitudinal changes in functional capacity and strength, allowing for a more robust analysis of the correlations between these variables over time. By comparing measures at these two points, we can identify not only the absolute improvements but also how changes in muscular strength may be associated with enhancements in functional capacity.

Methods

Participants

The participants were physically active older women from a community service program in Manaus city (Amazonas, Brazil), located in the Coroado district (east side of the city). Participants completed health history and physical activity questionnaires and met the following inclusion criteria: ≥ 60 years old, be physically independent, not have practiced resistance training in the 12 months before the study, free from lower limb orthopedic dysfunction (ex. osteoporosis), and not present unstable cardiovascular or diabetes disease (self-reported). Additionally, all individuals who met these criteria were included in the intervention sessions. However, completing the training sessions and physical fitness tests was a requirement for inclusion in the final analyses. This ensured that only those who fully participated in the intervention were analyzed.

Sixty-three older women volunteered to participate in the present study. After initial screening, forty-six were eligible to participate, and were allocated for convenience into two groups according to their available time; our schedule made two available classes, one at 6 a.m. (MSP), and one at 7 a.m. (control group [CON]); however, the participants were not informed about the group condition; they were invited to participate in one physical activity program and could only choose the class time. Half of the participants participated in the MSP, and the other half in the CON. During the intervention period, ten participants were excluded from the MSP group and fourteen from the CON group (all withdrawals were due to lack of time compatibility). Twenty-one participants completed all the procedures and were included in the data analyses (MSP, n = 13, 64.8 ± 4.6 years, 65.5 ± 8.6 kg, 1.53 ± 0.04 m; and CON, n = 8, 64.1 ± 5.4 years, 69.1 ± 5.5 kg, 1.55 ± 0.06 m). All participants signed the consent form. The study was approved by an institutional Research Ethics Committee (approval number: 1.753.546) and performed in accordance with the Helsinki declaration (2013: seventh revision, 64th meeting, Fortaleza, Brazil). This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science*.[19]

G*Power software, version 3.0.10 for Windows (University of Düsseldorf, Dusseldorf, Germany) was used to estimate the sample size. Considering a preliminary study for a two-sided contrast,[14] an effect size of 0.65, α value <.05, non-sphericity correction € = 1, the correlation between the repeated measures = 0.5, and a beta risk of 0.8 were accepted. Therefore, a minimum of 16 participants were required to make up the total sample size.

Protocol

Study design.

The study involved the following phases: a) familiarization with the free-weight exercises (bench press, anterior lat pull down, deadlift, and squat), isokinetic tests (concentric knee extension and flexion), and functional capacity tests; this phase was performed during three non-consecutive sessions (at least 48h of rest). All participants received instructions to ensure proper technique before the maximal tests. b) Baseline tests and retest assessments were performed to ensure data reproducibility. Tests were performed on two non-consecutive days with at least 48h of rest (i.e., days 1 and 3, isokinetic and functional tests; days 2 and 4, body composition and strength tests). c) Experimental group performed 12 weeks of RT (2 sessions per week); d) Post-testing was conducted using the same order as a baseline, 48h after the final training session. All baseline and post-tests were performed in the same order and applied by the same evaluators throughout the intervention (blinded evaluator). During the training program, all participants were advised to maintain their customary nutritional regimen. The control group was also evaluated at the same time points as the experimental group, with pre-testing conducted before and post-testing conducted after the 12-week period.

Resistance training and active control procedures.

Participants in the MSP group performed a general warm-up routine at the beginning of each training session. Subsequently, they performed the back squat and deadlift in all training sessions, alternating the order of these exercises. The RT protocol targeted different neuromuscular characteristics within the same session, with the following structure:

Set 1: 3-5 repetitions maximum (RM) with a cadence of 1 second for the concentric phase and 2 seconds for the eccentric phase. This set aimed to improve maximal strength.

Set 2: 4-6 repetitions performed as fast as possible during the concentric phase and 2 seconds for the eccentric phase. This set aimed to enhance power.

Set 3: 10-12 RM with a cadence of 2 seconds for both the concentric and eccentric phases. This set aimed to promote muscle hypertrophy.

The required RM's were defined according to the objectives of promoting strength, hypertrophy, and power, and were based on previous studies.[8,14] These recommendations are supported by established guidelines for resistance training in older adults, which emphasize varying intensities to target different muscular characteristics.[8,14]

The load for the first and third sets was increased by 2.5–5.0 kg in the next session when participants could perform more repetitions than prescribed. An inter-set rest of two minutes was adopted throughout the intervention. Immediately after completing all exercises, the Omni Scale was used to assess the rating of perceived exertion. Following the lower limb training, a complementary upper-body program was performed, consisting of two sets of 10-12 RM of the bench press and anterior lat pull-down, with a two-minute rest between sets. The load increase was as for the lower limb training. During all sessions, participants were directly supervised to ensure consistent and safe exercise performance. Volume-load was calculated using the equation: load lifted x sets x repetitions.

Functional capacity tests.

Timed up and go, stair ascent, and stair descent tests were adopted to assess lower limb functional capacity. Tests were recorded using a digital camera at a sampling frequency of 120 Hz (Camera Panasonic Lumix FZ200) and timed by an evaluator who was blinded to the subject's group assignment with specialized software (Kinovea, France), according to da Silva et al. [20] recommendations. Participants completed three attempts with a 30-second rest between them and a 2-minute rest between tests. The trials with the lowest completion time were used for further analysis. The TUG test measured the time taken to raise from a seated position, walk forward 2.44 m, and return to a seated position. The stair ascent and descent measured the time taken to go up and down a flight of eight steps, separately.

Isokinetic strength.

A Biodex System 3 Pro® isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA) was used to evaluate the muscle strength of the knee extensors and flexors. The principles of the isokinetic test were observed, and the equipment was calibrated according to the manufacturer's instructions. The measurements were bilaterally collected, always starting with the dominant limb, using concentric contractions at angular velocities of 60º/s and 120º/s (five repetitions), with a 60-second interval between each repetition and 120 seconds between velocities. The peak torque was used in each situation evaluated.

During the evaluations, the participants were seated, and straps were placed across the chest and waist to stabilize the body and the thigh and right leg, affixed by Velcro strips in a comfortable and stable way. The participant's trunk/thigh segment was positioned at 85º of flexion, and the dynamometer axis was aligned with the lateral epicondyle of the evaluated knee; to perform the evaluation, the evaluated knee was positioned at 70º (0º = full extension). The dynamometer arm was adjusted to ensure that the ankle pad remained above the medial and lateral malleolus.

Before the evaluation, a five-minute warm-up was performed using a walk and then a specific warm-up on the isokinetic dynamometer that consisted of 10 concentric actions for knee extensors and flexors. After a 2-minute break, the volunteers performed three submaximal voluntary contractions as familiarization before performing the test itself. All the care actions of the evaluation protocol suggested by the manufacturer, were observed, such as positioning, calibration, familiarization, and vigorous verbal encouragement. The preferred side of each participant was tested with the Waterloo Footedness Questionnaire.[21]

Ten-repetition maximum testing.

Three familiarization sessions were applied to control the best execution in all exercises to ensure test accuracy. The dynamic muscular resistance test in deadlift, back squat, bench press, and anterior lat pull-down was then performed using the same equipment used in the training sessions (Rotech®, RS, Goiás, Brazil). Ten-repetition maximum (10-RM) test was applied to determine muscular resistance changes.[22] The cadence for all exercises was 1 sec for the concentric and eccentric phases, with no pause between exercises. Standard exercise techniques were adopted for all exercises: (a) deadlift: the concentric phase started with the knee flexed (near 90^o) and ended with the knee completely extended; during exercise execution, the participants kept the trunk flat, the feet stayed parallel with hip distance apart; (b) back squat: the concentric phase started with the knee flexed (90^o, thigh parallel to floor) and ended with the knee completely extended; during exercise execution, the participants kept the trunk flat and the feet remained parallel with double hip distance apart; (c) bench press: the concentric phase started with the elbows flexed (90^o) and ended with the elbows completely extended; during exercise execution, the participants kept the trunk flat and the feet on the ground; (d) anterior lat pull-down: the concentric phase started with the elbows fully extended and ended with the elbows completely flexed (near 90^o); during exercise execution, the participants were seated with the trunk erect and the feet on the ground.

To minimize the error during the 10-RM testing, the following strategies were adopted:[23] (a) standardized instructions concerning the testing procedures and exercise technique were given to participants, and (b) verbal encouragement was provided during the testing procedures. The 10-RM was determined in fewer than five attempts with a rest interval of 5 minutes between attempts. The heaviest 10-RM resistance achieved was used in the statistical analysis. The 10-RM was assessed on two nonconsecutive days.

The 10-RM test was performed for a maximum of five attempts with a five-minute interval between them; in cases where a sixth attempt was required, a new test occurred after a 48-hour interval. A minimum interval of 15 minutes was observed between the exercises, and there was no speed control during the test. Before the strength test, all participants were submitted to a specific warm-up with regressions of 20, 15, 10, and 8 repetitions, with a load estimated to cause muscle discomfort. Afterward, the 1-RM value was estimated by the Brzycki [24] equation.

Body composition.

Whole body air displacement plethysmography was evaluated with the BOD POD (Body Composition System; Life Measurement Instruments, Concord, CA). Participants were dressed in appropriate clothing and a swim cap to minimize isothermal air trapped within the hair. The testing procedure involved two trials of approximately 45 seconds each, with the door opened between trials. If the trial results were not within 150 ml, a third trial was performed, and the two trials with the closest results were averaged. Body composition was calculated from body density using the Siri equation (Siri, 1961), which converts body density to percentage of body fat. Total body fat and lean mass were then derived from these percentages and the participant's total body weight.

Statistical Analysis

Shapiro-Wilks test checked normality. Levenes test was used to analyze the homogeneity of variances. Outliers were checked using the boxplot method, where data points lying beyond 1.5 times the interquartile range (IQR) from the first and third quartiles were considered outliers. If outliers were detected, they were examined to determine if they were due to data entry errors or other anomalies. Outliers that were not due to errors and were deemed to be valid data points were included in the analysis. In this study, 5 outliers were detected and 2 were removed from the analysis due to being identified as data entry errors or anomalies.

A mixed two-way analysis of variance (ANOVA) for repeated measures was used to verify the main effects of time, group, and interaction. In variables for which sphericity was violated, as indicated by Mauchly`s test, the analyses were adjusted using a Greenhouse-Geisser correction. When significant p-values were identified, a Bonferroni post-hoc test was performed to identify pairwise differences. The partial eta squared (η_p^2) for the ANOVAs was presented as a measure of effect size; less than 0.01 was considered as small, 0.02-0.1 as medium, and over 0.1 as a large effect size. Test-retest reliability with the intra-class correlation was used to reflect the variation in an instrument for the same subject, measured by one ratter across two or more trials, and classified according to what was described elsewhere.[25] Values <0.5 indicate poor reliability, 0.5-0.75 moderate reliability, >0.75-0.9 good reliability, and >0.90 excellent reliability. An alpha level of 5% was used in all statistical analyses. Descriptive data are shown as mean ± standard deviation (SD). All statistical procedures were completed using SPSS 24 for Windows (Statistical Package for the Social Science; IBM, Chicago, IL, USA).

Additionally, Repeated-measures Bland-Altman within subjects' correlation coefficients were computed with R programming language version 4.1.0 and package rmcorr. [26] This method was used to determine the association between functional capacity and strength variables across two moments in the intervention. Correlation magnitude was interpreted based on Cohen's[27] criteria: trivial r=<0.1; small: r=0.1-0.3; moderate: r=0.3-0.5; large: r=0.5-0.7; very large: r=0.7-0.9 and nearly perfect: = r>0.9. In addition, bootstrapping procedures (1000 resamples; 95% CI) were performed to obtain greater reliability of the results, to correct for deviations from the normality of the sample distribution and differences between group sizes, and to present a 95% confidence interval for the correlation indices.[28]

Results

The following table presents a comparative analysis between two groups, Control and Resistance, at different time points (pre and post) for a range of variables related to physical performance and body composition.

Functional capacity

Table 1. Testing Characteristics of MS (n=13) and CON (n=8) Groups

variable	group	min	max	median	iqr	mean	sd	95% CI
Stair ascent - pre	Control	3.08	4.54	3.76	0.69	3.77	0.52	0.44
	Resistance	3.11	4.35	3.54	0.32	3.61	0.33	0.20
Stair ascent – pós	Control	2.96	4.12	3.54	0.81	3.54	0.47	0.39
	Resistance	2.75	4.05	2.96	0.59	3.21	0.47	0.28
Tug - pre	Control	4.98	6.65	5.72	0.98	5.78	0.64	0.53
	Resistance	4.70	7.01	5.87	0.78	5.80	0.62	0.38
Tug - pós	Control	4.78	6.41	5.86	0.61	5.76	0.60	0.50
	Resistance	4.89	6.15	5.65	0.36	5.58	0.40	0.24
Stair descent - pre	Control	2.73	4.85	3.64	0.92	3.71	0.77	0.64
	Resistance	2.85	4.76	3.26	0.74	3.59	0.67	0.40
Stair descente - pós	Control	2.61	4.96	3.56	1.24	3.57	0.82	0.68
	Resistance	2.33	4.17	3.00	0.39	3.05	0.52	0.31
Qcon60 - pre	Control	66.60	103.50	86.45	10.45	85.40	10.88	9.10
	Resistance	56.00	107.10	93.00	14.50	89.86	14.78	8.93
Qcon60 - pós	Control	63.10	105.00	87.20	13.00	85.11	13.05	10.91
	Resistance	60.30	112.30	97.20	35.20	92.33	17.57	10.62
Hcon60 - pre	Control	30.20	45.00	39.85	4.40	39.74	4.82	4.03
	Resistance	26.70	53.60	42.30	13.90	41.05	9.13	5.52
Hcon60 - post	Control	28.70	49.50	41.15	6.90	40.16	6.36	5.32
	Resistance	36.20	65.10	43.00	10.10	45.91	8.81	5.33
Qcon 120 - pre	Control	54.10	77.70	67.40	9.50	67.40	8.17	6.83
	Resistance	41.50	89.00	76.70	12.80	71.78	13.61	8.23
Qcon 120 - post	Control	53.60	91.00	68.95	6.22	69.92	10.59	8.85
	Resistance	46.60	97.80	78.40	14.00	76.02	13.81	8.34
Hcon120 - pre	Control	23.50	45.40	35.95	7.20	35.33	6.72	5.62
	Resistance	29.20	54.10	37.40	9.20	39.00	7.83	4.73
Hcon120 - post	Control	18.20	43.70	33.55	11.40	32.92	8.80	7.35
	Resistance	31.30	59.70	40.70	11.50	41.37	8.16	4.93
Body fat kg - pre	Control	19.41	37.95	26.36	7.17	26.56	6.01	5.02
	Resistance	16.59	36.98	28.30	4.30	28.04	5.76	3.48
Body fat kg – post	Control	20.57	36.20	27.03	6.27	26.74	5.13	4.29
	Resistance	16.59	33.29	28.30	4.95	27.20	5.26	3.18
Lean mass kg - pre	Control	38.86	47.66	41.78	6.00	42.58	3.53	2.95
	Resistance	30.38	47.69	36.36	4.31	37.48	4.58	2.77
Lean mass kg – pos	Control	38.80	48.11	41.92	6.57	42.48	3.59	3.00
	Resistance	30.91	46.67	37.28	4.74	38.17	4.23	2.56
Bench press – pre	Control	14.00	20.00	18.00	4.00	17.75	2.25	1.88
	Resistance	16.00	26.00	20.00	2.00	19.39	2.63	1.59
Bench press – post	Control	14.00	22.00	17.00	4.00	17.75	2.71	2.27
	Resistance	20.00	30.00	22.00	2.00	23.08	2.53	1.53
Deadlift - pre	Control	18.00	28.00	24.00	4.00	23.75	3.10	2.60
	Resistance	16.00	32.00	30.00	6.00	28.00	4.69	2.83
Deadlift – post	Control	20.00	26.00	25.00	2.50	24.25	2.25	1.88
	Resistance	30.00	46.00	36.00	6.00	37.54	5.36	3.24

Lat pulldown - pré	Control	25.00	35.00	30.00	5.00	28.75	3.54	2.96
	Resistance	25.00	40.00	30.00	5.00	31.15	4.63	2.80
Lat pulldown - post	Control	25.00	35.00	30.00	2.50	30.00	3.78	3.16
	Resistance	30.00	45.00	35.00	5.00	36.54	3.75	2.27
Squat – pré	Control	12.00	26.00	13.00	7.50	16.25	5.80	4.85
	Resistance	12.00	36.00	18.00	12.00	20.77	7.98	4.82
Squat - post	Control	12.00	26.00	16.00	6.00	17.25	5.34	4.46
	Resistance	26.00	56.00	40.00	8.00	38.77	9.64	5.83

There was a group vs. time interaction for the timed up and go ($p<0.001$; $\eta_p^2 = 0.695$), stair ascent ($p=0.001$; $\eta_p^2 = 0.478$), and stair descent ($p<0.001$; $\eta_p^2 = 0.579$) tests. For the timed up and go, the control was faster than the trained group ($p = 0.047$) at baseline, but they did not differ after the intervention ($p = 0.102$) because only the trained group presented reductions in the timed up and go time ($p < 0.001$) (Figure 1A).

For both stair ascent and descent, the control and trained groups did not differ at baseline ($p = 0.420$ and $p=0.293$, respectively), but only the trained group presented reduced time following the intervention ($p < 0.001$), resulting in faster performance compared to control after the intervention ($p < 0.016$) (Figure 1C and B).

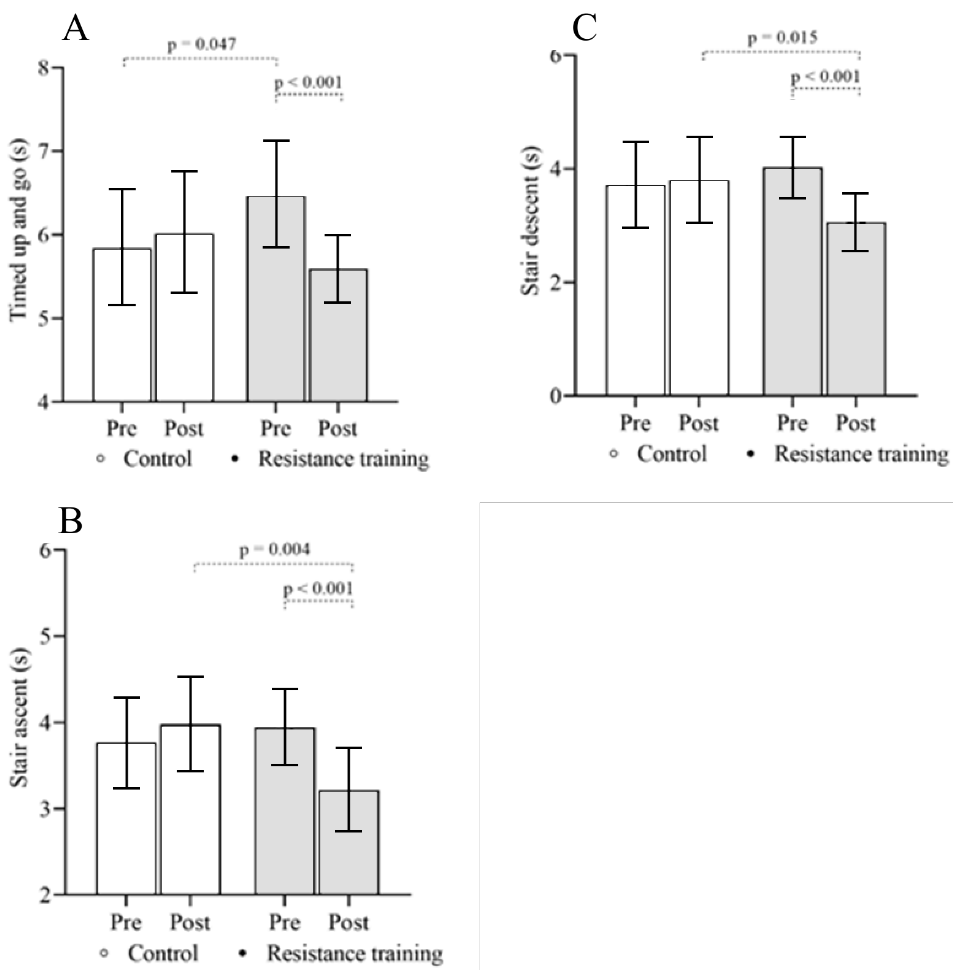

Figure 1. Time (pre vs. post) and group (control vs. resistance training – MSP) analysis of functional performance across the experimental period, panel A (timed up and go), B (stair ascent), and C (stair descent).

Isokinetic strength

There was a group vs. time interaction for Q_{CON} 60°/s ($p = 0.001$; $\eta_p^2 = 0.465$), H_{CON} 60°/s ($p = 0.01$; $\eta_p^2 = 0.300$), Q_{CON} 120°/s ($p = 0.038$; $\eta_p^2 = 0.178$), and H_{CON} 120°/s ($p = 0.001$; $\eta_p^2 = 0.420$). For Q_{CON} 60°/s and Q_{CON} 120°/s, only the trained group showed increased torque after the intervention compared to baseline ($p < 0.001$) (Figure 2A and C).

For H_{CON} 60°/s and H_{CON} 120°/s, only the trained group showed increased torque after the intervention compared to baseline ($p < 0.008$). The control group showed reduced H_{CON} 120°/s torque, resulting in lower torque compared to the trained group after the intervention (Figure 2D).

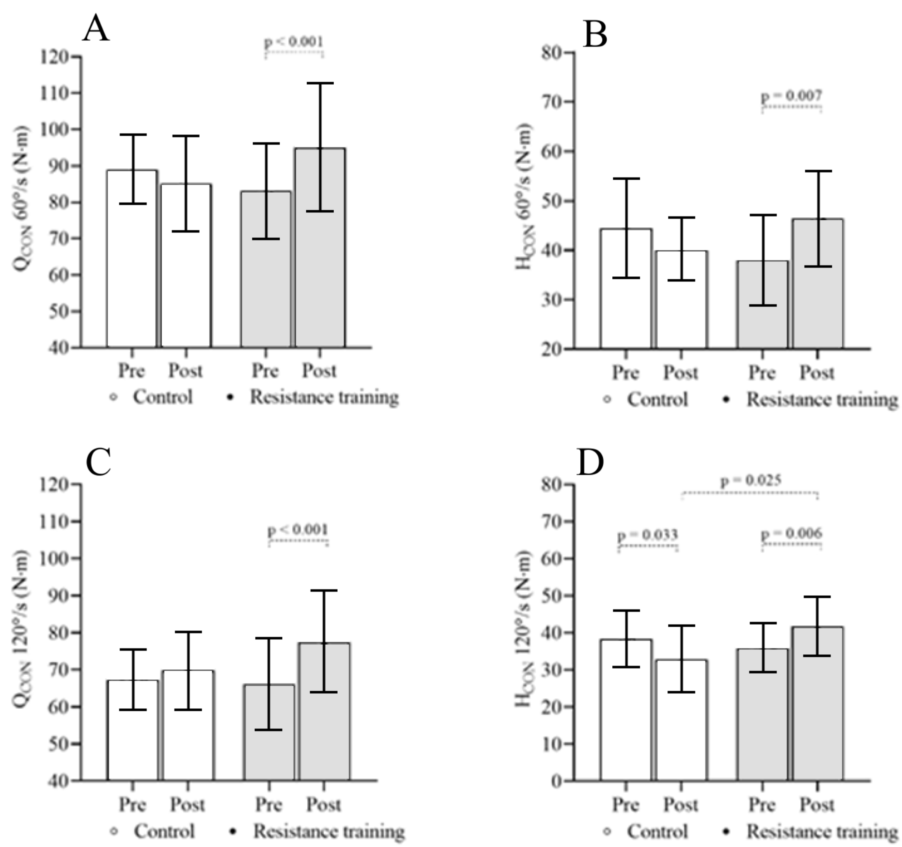

Figure 2. Time (pre vs. post) and group (control vs. resistance training – MSP) analysis of isokinetic strength across the experimental period, panel A (quadriceps concentric 60°/s (N·m)), C (quadriceps concentric 120°/s (N·m)), B (hamstring concentric 60°/s (N·m)), and D (hamstring concentric 120°/s (N·m)).

Muscular strength

There was a group vs. time interaction for bench press ($p < 0.001$ $\eta_p^2 = 0.635$), lat pulldown ($p = 0.005$ $\eta_p^2 = 0.345$), deadlift ($p < 0.001$ $\eta_p^2 = 0.606$), and squat ($p < 0.001$; $\eta_p^2 = 0.694$). For bench press, lat pulldown, deadlift, and squat, only the trained group presented an increased 10-RM ($p < 0.001$), resulting in larger values compared to the control group after the intervention ($p < 0.016$) (Figure 3A, C, B, and D).

Body composition

There was no group vs. time interaction and no time effect for body fat percentage ($p=0.225$; $\eta_p^2 = 0.077$), total body fat ($p=0.289$; $\eta_p^2 = 0.059$), and lean mass ($p=0.258$; $\eta_p^2 = 0.067$) (Figure 4A, C, and B).

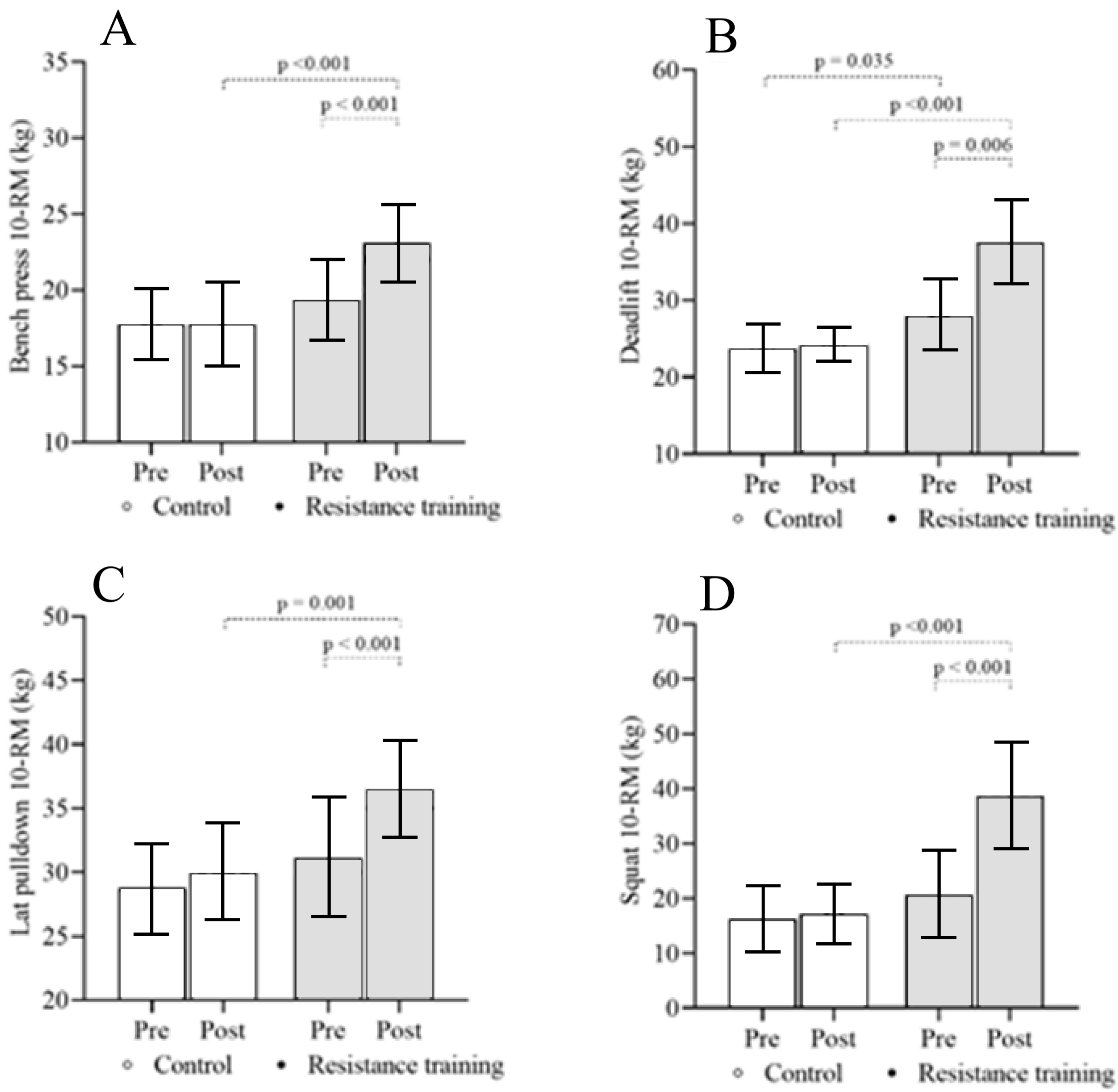

Figure 3. Time (pre vs. post) and group (control vs. resistance training – MSP) analysis of muscular strength across the experimental period, panels A (bench press), C (lat-pull down), B (deadlift), and D (squat).

Intraclass Correlation Coefficients

The intraclass correlation coefficients for overall participants were: stair ascent (PRE=0.92, and POST=0.85), stair descent (PRE=0.93, and POST=0.95), and TUG (PRE=0.89, and POST=0.95), bench press (PRE=0.69, and POST=0.94), lat pulldown (PRE=0.64, and POST=0.83), deadlift (PRE=0.95, and POST=0.95), and back squat (PRE=0.90, and POST=0.95).

Repeated-measures correlation coefficients

The potential association between functional capacity and strength variables across two moments of the intervention was applied with repeated-measures correlation coefficients. There were significant large repeated measures correlations between functional capacity (stair descent) and concentric strength measurements in the isokinetic tests for Quadriceps 120º/s (r(12)= -0.622, CI95%= -0.922, -0.176; p= 0.017). Furthermore, there were significant large repeated measures correlations between functional capacity (stair ascent) and strength measures in 10 RM Squat (r(12)= -0.647, CI95%= -0.945, -0.279; p= 0.012). All details can be accessed in the supplementary analysis.

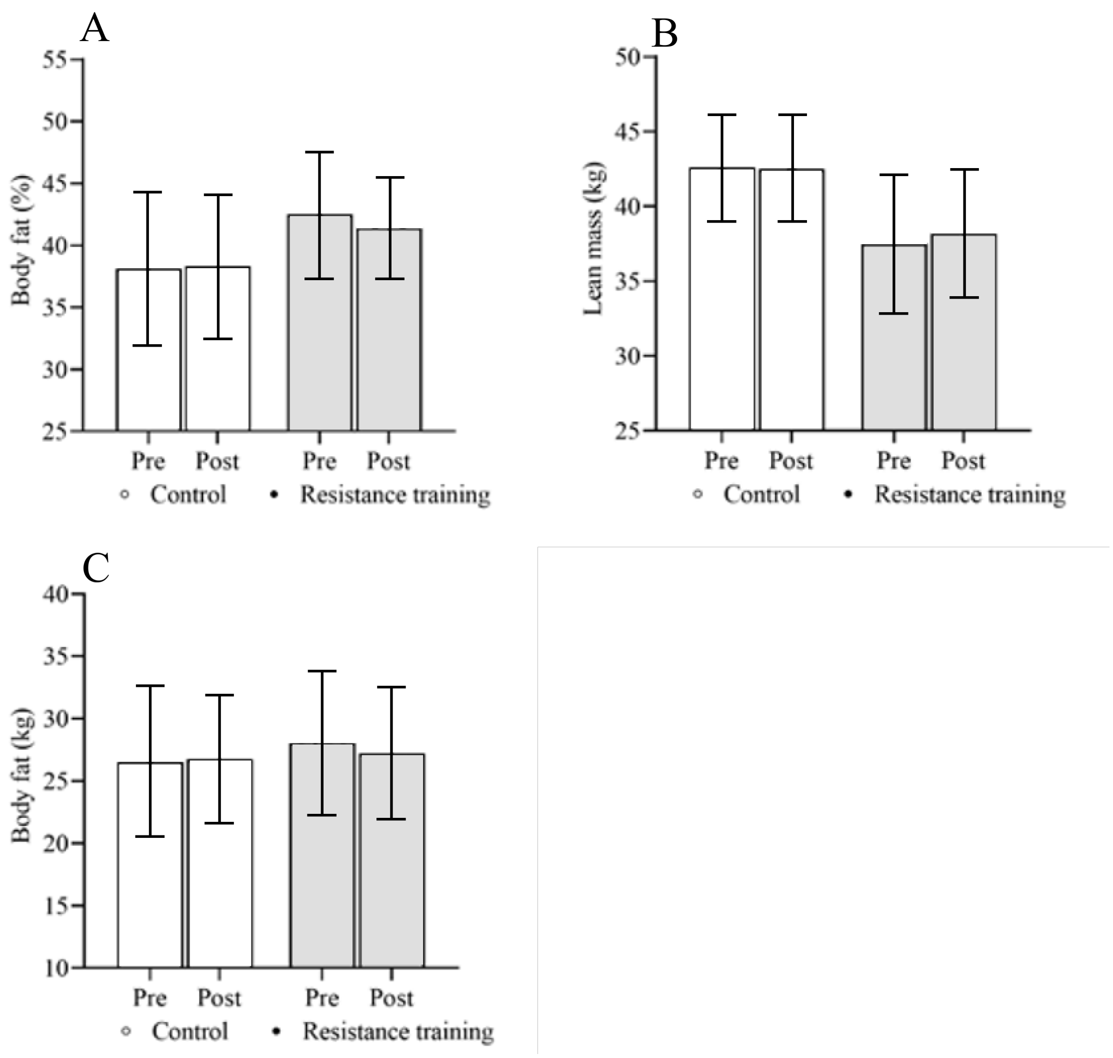

Figure 4. Time (pre vs. post) and group (control vs. resistance training – MSP) analysis of functional performance across the experimental period, panel A (body fat%), C (body fat-kg), and E (lean mass-kg).

Discussion

Our main hypothesis that MSP would promote superior improvements in functional capacity, muscular strength, and body composition measures when compared with a CON group was confirmed. Our findings showed that 12 weeks of MSP, twice a week, promoted improvement in functional capacity (TUG, stair ascent and descent), muscular strength (isokinetic strength and 10RM). However, contrary to our hypothesis, there were no significant effects on body composition variables. Thus, demonstrating that MSP is a valuable strategy to promotes positive changes in morpho-functional health-related parameters in the older adult population.

The improvement in functional capacity induced by RT has already been widely observed in some studies,[29] and is supported by a recent meta-analysis.[30] Muscular power and explosive strength are strongly associated with functional performance in older adults, and it has been suggested that fast-intended-velocity resistance training may elicit greater improvements in functional capacity. To comply with this statement, our RT model started with a focus on maximum strength, followed by power and finishing with a moderate load, in contrast to the similar design initially proposed by Bezerra et al.[14] The authors found a small effect size for TUG (0.50), stair ascent (0.53), and descent (0.58) tests, while our findings presented an intermediate effect size (based on partial eta squared ($\eta p2$)). It is worth mentioning that all functional capacities reduced the time in the final test by more than 12%. Although quite similar, our design differentiates because the power set comes after the strength maximum set, and theoretically, different physiological aspects such as the phosphorylation of myosin light chains, greater ATP activity and contractile ability, and the utilization of higher-order motor recruitment, and type II muscle fibers, could support this improvement in performance.[31] Furthermore, the abovementioned benefits related to the targeting of the force and velocity components of the power equation in the same session are believed to be the main mechanisms of adaptation.[32]

Recently, some studies have demonstrated the efficiency of performing contractions as fast as possible to increase muscle power in the adult population,[8] given its importance in the development of power and in attenuating the risk of disability, falls, and injuries in older adults.[33] In this case, we expected that training with MSP, which presents characteristics of power training (fast concentric contraction), would increase the functional capacity of older adults. The results supported this assumption because, even though the experimental group presented a lower capacity in the TUG at baseline compared to the control group, after the 12 weeks of intervention, the experimental group showed a significant improvement in relation to baseline and a greater percentage of improvement compared to the control group (Δ% changes). This increase may directly impact the daily performance of this population by increasing physical activity and promoting a more active social life.[34]

The improvements identified in our study, more specifically in muscle strength, have been widely reported in several studies,[29] many of which sought to investigate the influence of various training strategies on this improvement.[14] In our study, training with MSP promoted improvements in the experimental group compared to baseline (increased perceptual delta) for all strength tests and improvements in the 10-repetition strength test compared to the control group. It is worth to remember that MSP organize different stimulus within de session, what it requires different motor units and, with this, variation in the recruitment of these during the training process It worth to remember that MSP, organize different stimulus within de session, what it requires different motor units and, with this, variation in the recruitment.[8,14] Besides, we evidenced strong intra-individual relationship (baseline vs. post intervention) between increase in strength performance test with time reduction during functional tests (ascendent and descendent stairs test) for mixed session periodization group, although we must recognize that similar comparisons have not yet been shown in strength training field, we know that this analysis may more robustly indicate individual performance (see more details in appendices file).

Some studies have compared different types of periodization in older adults, and reported no differences between the periodization models in muscular adaptations.[8,35] The results of these studies unfortunately could not compare with our, because they compared different periodization model. On the other hand, we performed the variation in the same session, thus corroborating our hypothesis that variation within the session can promote important adaptations for older individuals. The variation in the different possibilities of stimuli during the resistance training also proved to be effective in the study of Bezerra,[14] which observed that after 9 weeks of training, the group based on MSP presented a greater adaptations in the muscular strength tests than the group with traditional periodization.

Another important aspect of our study was the rate of force development analysis, which reflects how fast an individual produces force in a short interval (~ 250 m/s) [36]. Low levels of maximal and rapid force negatively influence the ability to perform daily living activities in older individuals (i.e., difficulty rising from a chair and walking, and going upstairs). Despite the growth in the amount of evidence showing expressive results in maximal force independent of the periodization model in aging adults,[14] these increments are surrounded by great heterogeneity among participants. Recently Moura et al[37] observed improvement in maximum voluntary isometric contraction independently of periodization model [MSP (16% range – 6% to 36%); and traditional (5%, range – 5% to 18%)]. However, MSP (hypertrophy-maximum strength-power) presented more responders with a significant time effect for rate of torque development for the intervals 0-50 (n = 5, 49%), 0-100 (n = 6, 39%), and 0-200 (n = 5, 37%) in comparison to traditional periodization. Although our isokinetic test was for concentric (60^{o} and 120^{o}/s) knee extension and flexion, it was possible to observe greater individual responders for MSP (maximum strength-power-hypertrophy) than in control active group (above 12% for all measures). The comparison between our results and the previous study mentioned is difficult because the heterogeneity of gain in the neuromuscular system, indicating that the responsiveness to resistance training models could have been influenced by different factors such as, age, sex, race, genotype, exercise mode/dose, environment, and training background;[37] it is important to mention that dynamic contractions influence the ability to develop a high rate of torque development, and this condition appears to be more relevant to functional tasks.[36]

Notably, improvement in muscular strength after resistance training is more consistent than changes in lean mass among studies in the aging population.[38] In our study, a not significant body recomposition occurred after the new MSP design when compared to the active control group after 12 weeks, the experimental group presented a mean reduction of 5% in fat mass (ES=0.27, small) and improvement of the same value in lean mass (ES=0.25, small), (assessed by air displacement plethysmography), Figure 4. These results agree with the results of the study conducted by Bezerra et al,[14] and Lixandrão et al[39] - in the first study, MSP (hypertrophy-maximum strength-power) led to greater lower-limb fat-free mass vs. the control group (ES = 2.81, large), conversely, similar to the traditional periodization (ES=1.80, moderate) (assessed by DXA). In agreement, the second study examined the time course of muscle hypertrophy after progressive linear RT (after 10 weeks) and found significant increases in vastus lateralis cross-sectional area of ~7 to 8% (ES = 0.37) (assessed by ultrasonography).

Apparently, range of variation in effect size between the studies mentioned above could have occurred by different reasons; the methods to assess body composition, and the diet monitoring during the experimental protocol. Furthermore, there is no consistency in studies about body recomposition, as a body of evidence reports no increase in muscle mass or fat-free mass in aging participants [14]. In addition, in our current data set, responsivity about body recomposition was favorable for MSP. At the same time, 53% of participants presented body recomposition through increased lean mass and decreased %fat mass based on the mean of the group. In contrast, no active control participants presented body recomposition, figure 4F and B. Surpassing the findings of Moura et al[37] for the MSP group, where responders showed a decrease (3.8%) in thigh fat percentage, and an increase (4%) in thigh lean mass. Indeed, aging is associated with blunted muscle protein synthesis responses (protein/exercise stimuli response), while physical inactivity (hypokinesia) induces a premature muscle full, promoting muscle atrophy.

It is important to acknowledge some limitations in this study design, the dropouts (n = 10) reduced the sample size and statistical power, and although according to the sample size calculation this did not influence the statistical analysis, the results moved closer to a type II error. Furthermore, our body composition method is not a gold-standard model to evaluate muscle mass changes. Notwithstanding, the calculation of ESs provided additional information for between-group comparisons. In addition, the current study used valid methods to evaluate functional capacities and muscle strength, and the test-retest measurements showed high reproducibility pre and post intervention, resulting in reliable data. The lack of a standardized resistance training control group makes it difficult to determine whether the observed improvements were specifically due to the type of periodized resistance training program used (MSP) or simply the result of engaging in resistance training in general. Future studies should include a control group that follows a standardized resistance training protocol to better isolate the effects of the MSP model.

Given this limitation, the conclusions drawn from this study should be interpreted with caution. While the MSP model appears to offer benefits in terms of functional capacity and muscular strength, it is not possible to definitively attribute these improvements to the periodization strategy itself without further comparative studies.

We demonstrated that regardless independently of sequence (hypertrophy-maximum strength-power) or (maximum strength-power-hypertrophy) as used in the current study, the mixed session periodization model resulted in increased muscle strength and functional capacity in aging adults. Considering the great power necessities of healthy older people, the new frontier could be contrast training, defined as training that involves the use of contrasting heavy and light loads, where all high-load strength exercises are performed at the beginning of the session and all lighter load power exercises at the end.

Acknowledgements

The authors thank the Foundation for Research Support of the State of Amazonas (FAPEAM) for MSc scholarship conceded to Luhan Ammy Andrade Picanço, Coordination for the Improvement of Higher Education Personnel (CAPES) for support to Programa de Pós-Graduação em Ciências da Saúde (Grant 001). Dr. Joao O.L. dos Santos would thank the Brazilian National Board for Scientific and Technological Development (CNPq) to conceded scientific scholarship for Ericles de Paiva Vieira.

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Supplementary Analysis

Statistical analysis

Repeated-measures Bland-Altman within subjects correlation coefficients were computed with R programming language, version 4.1.0 and the rmcorr package [40]. This method was used to determine the association between functional capacity and strength variables across two moments of the intervention. Correlation magnitude was interpreted based on Cohen's criteria: trivial r=<0.1; small: r=0.1-0.3; moderate: r=0.3-0.5; large: r=0.5-0.7; very large: r=0.7-0.9; and nearly perfect: = r>0.9. In addition, bootstrapping procedures (1000 resamples; 95% CI) were performed to obtain greater reliability of the results, to correct for deviations from normality of the sample distribution and differences between group sizes, and to present a 95% confidence interval for the correlation indices.

Results

Isokinetic tests

The repeated measures correlation between functional capacity (TUG) and concentric strength measurements in the isokinetic tests for quadriceps at 60º/s (r(12)=0.354, CI95% = -0.305, 0.800, p=0. 214), quadriceps at 120º/s (r(12)= -0.193, CI95% = -0.769,0.573, p=0.507), hamstrings at 60º/s (r(12)=0.134, CI95%= -0.406, 0.623, p=0.645), and hamstrings at 120º/s (r(12)=0.070, CI95%= -0.498, 0.766, p=0.812) were not significant.

Fig1 - Repeated measures correlations plot for association between functional capacity (TUG) and strength measures in isokinetic tests across two moments of the intervention. A – Results for quadriceps concentric 60º; B – Results for quadriceps concentric 120º; C - Results for hamstrings concentric 60º; D – Results for hamstrings concentric 120º. Separate parallel lines are fitted to the data from each participant across pre and post intervention and are represented by different colors.

For repeated measures correlation between functional capacity (stair ascent) and concentric strength measures in isokinetic tests for quadriceps at 60º/s (r(12)= -0.354, CI95% = -0.305, 0.800; p= 0. 214), quadriceps at 120º/s (r(12)= -0.375, CI95% = -0.815, 0.438; p= 0.185), hamstrings at 60º/s (r(12)= -0.115, CI95% = -0.618, 0.431; p= 0.694), and hamstrings at 120º/s (r(12)= 0.009, CI95% = -0.586, 0.687; p= 0.975).

Fig 2 - Repeated measures correlations plot for association between functional capacity (stair ascent) and strength measures in isokinetic tests across two moments of the intervention. A – Results for quadriceps concentric 60º; B – Results for quadriceps concentric 120º; C - Results for hamstrings concentric 60º; D – Results for hamstrings concentric 120º. Separate parallel lines are fitted to the data from each participant across pre and post intervention and are represented by different colors.

There were significant large repeated measures correlations between functional capacity (stair descent) and concentric strength measurements in isokinetic tests for quadriceps 120º/s (r(12)= -0.622, CI95%= -0.922, -0.176; p= 0.017). For quadriceps 60º/s (r(12)= -0.360, CI95% = -0.814, -0.024; p= 0.204), hamstrings 60º/s (r(12)= -0.115, CI95%= -0.618, 0.431; p= 0.694), and hamstrings 120º(r(12)= -0.029,CI95%= -0.827, 0.369; p= 0.920), the differences were not significant.

Fig 3 - Repeated measures correlations plot for association between functional capacity (stair descent) and strength measures in isokinetic tests across two moments of the intervention. A – Results for quadriceps concentric 60º; B – Results for quadriceps concentric 120º; C - Results for hamstrings concentric 60º; D – Results for hamstrings concentric 120º. Separate parallel lines are fitted to the data from each participant across pre and post intervention and are represented by different colors.

10 RM

The repeated measures correlation between functional capacity (TUG) and strength measurements in 10 RM for deadlift (r(12)= -0.196, CI95%= -0.810, 0.360; p= 0.5) and squat (r(12)= -0.359, CI95%= -0.793, 0.208, p= 0.206) were not significant.

Fig 4 - Repeated measures correlations plot for association between functional capacity (TUG) and strength measures 10-RM across two moments of the intervention. A – Results for 10-RM for deadlift; B – Results for 10-RM for squat. Separate parallel lines are fitted to the data from each participant across pre and post intervention and are represented by different colors.

There were significant large repeated measures correlations between functional capacity (stair ascent) and strength measures in 10 RM squat (r(12)= -0.647, CI95%= -0.945, -0.279; p= 0.012). The results were not significant for deadlift (r(12)= -0.412, CI95%= -0.905, 0.027; p= 0.142).

Fig 5 - Repeated measures correlations plot for association between functional capacity (TUG) and strength measures 10-RM across two moments of the intervention. A – Results for 10-RM for deadlift; B – Results for 10-RM for squat. Separate parallel lines are fitted to the data from each participant across pre and post intervention and are represented by different colors.

There were significant moderate repeated measures correlations between functional capacity (stair descent) and strength measurements in 10 RM for deadlift (r(12)= -0.529,CI95% = -0.876, -0.271; p= 0.052) and squat (r(12)= -0.574,CI95% = -0.912, -0.316; p = 0.032).

Fig 6 - Repeated measures correlations plot for association between functional capacity (TUG) and strength measures 10-RM across two moments of the intervention. A – Results for 10-RM for deadlift; B – Results for 10-RM for squat. Separate parallel lines are fitted to the data from each participant across pre and post intervention and are represented by different colors.

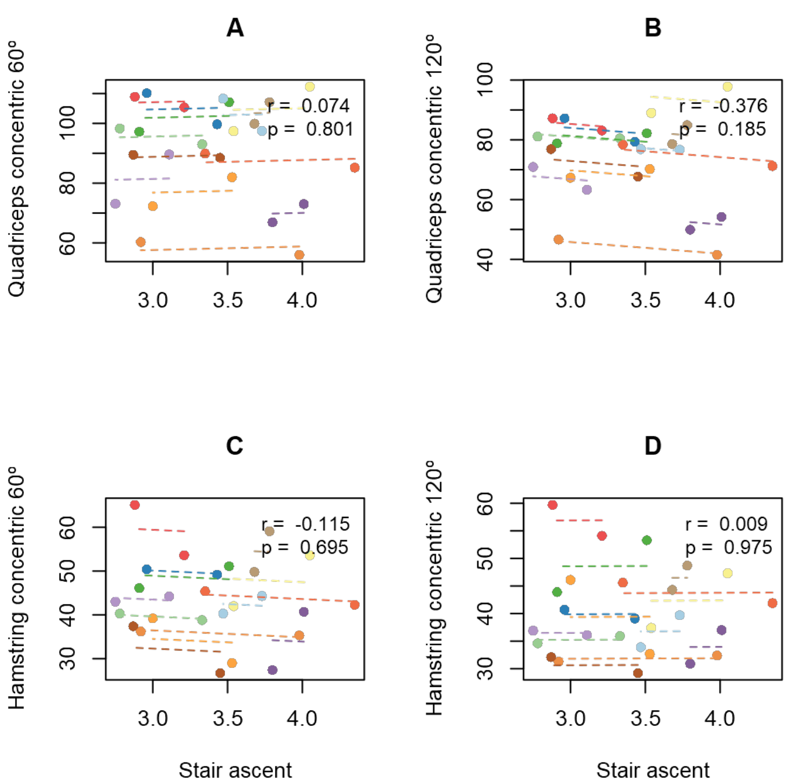
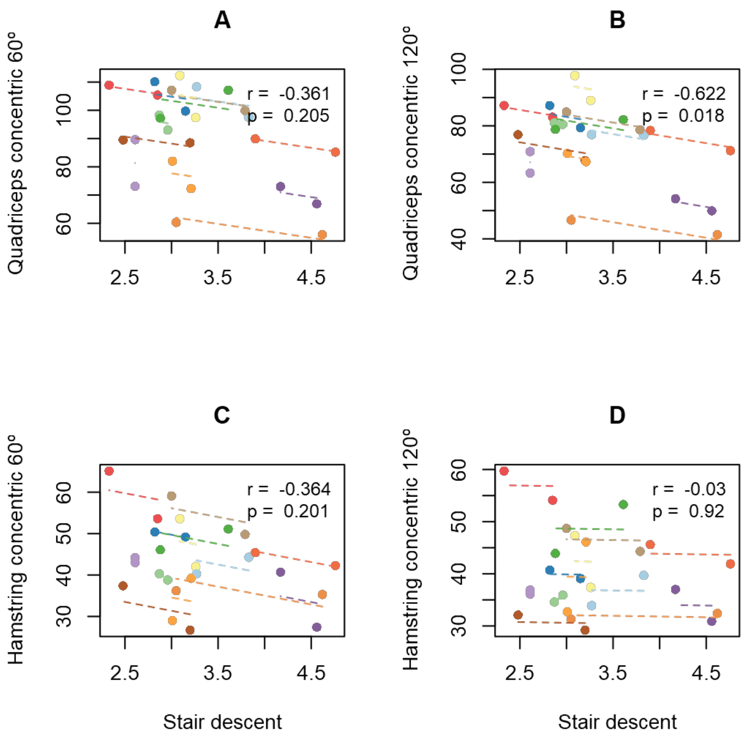


fig2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Quadriceps concentric 60°
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p = 0.205
B
Quadriceps concentric 120°
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p = 0.018
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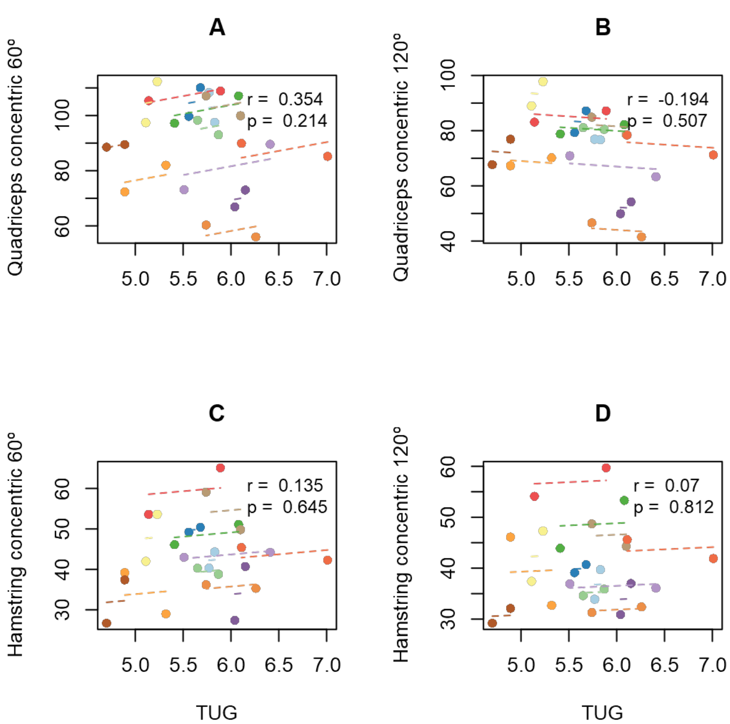
Stair descent
Stair descent

fig3


A
Quadriceps concentric 60°
r = 0.354
p = 0.214
B
Quadriceps concentric 120°
r = -0.194
p = 0.507
C
Hamstring concentric 60°
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p = 0.645
D
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TUG
TUG

fig4

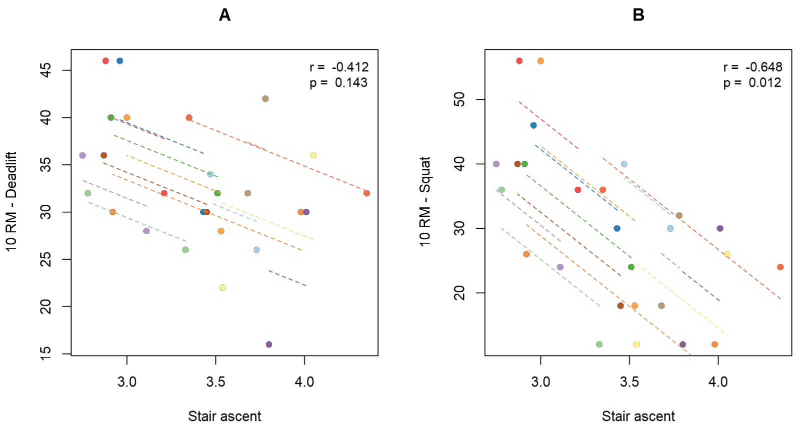

fig5

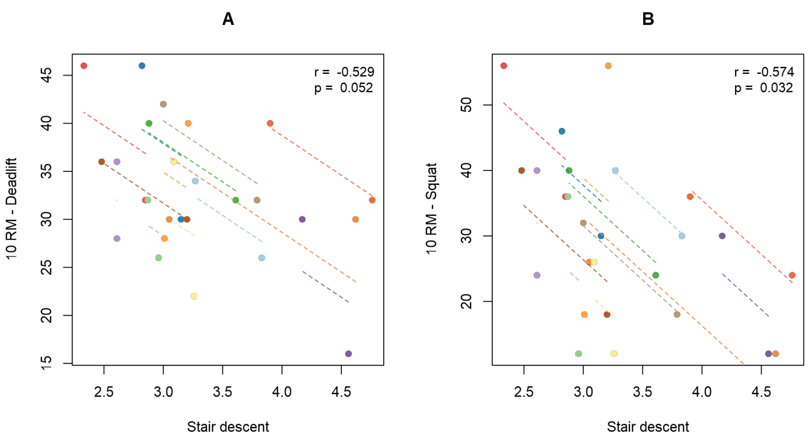

fig6