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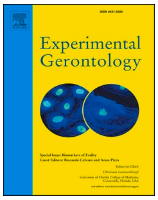

Improving serum redox balance, inflammatory status, physical function, and cognitive ability through dual-task resistance training and detraining in nursing home residents

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ABSTRACT

Objective: This study investigated the effects of dual-task resistance training (RT) and detraining on physical function, cognitive capacity, lipid profile, renal function, oxidative stress markers, and chronic inflammation of institutionalized older adults.

Methods: The study involved 11 older adults (83.09 ± 8.1 years) residing in a long-term care institution, spanning 42 weeks with assessments at weeks 1, 14–15, 28, and 42. The initial 12 weeks following the first assessment (weeks 2–13) served as a baseline, during which participants maintained their routine activities. A dual-task resistance training protocol was implemented from weeks 16 to 27, followed by a detraining period from weeks 29 to 41. Assessments included clinical characteristics, physical function, cognitive ability, blood samples for biochemical parameters, oxidative stress, and chronic inflammation.

Results: Dual-task RT significantly enhanced balance ($p = 0.027$) and 4 m walking speed ($p = 0.027$) post-training compared to the baseline. It also decreased the completion time for the sit-and-stand test both post-training ($p = 0.008$) and post-detraining ($p = 0.015$) relative to baseline. Cognitive ability showed significant improvements ($p < 0.05$). The CAT/TBARS ratio increased significantly post-training ($p < 0.001$) and remained elevated post-detraining. Nitric Oxide levels increased post-training ($p < 0.05$) and stayed higher post-detraining. The IL-10/TNF-α ratio significantly increased post-training ($p < 0.05$).

Conclusion: Dual-task RT performed over 12 weeks improved physical function, cognitive capacity, muscular strength, oxidative stress markers, and chronic inflammation in institutionalized older adults. Furthermore, these benefits were sustained even after a period of detraining.

1. Introduction

Aging is a continuous process characterized by degenerative changes that can diminish physical and cognitive functions, thereby impacting the quality of life of older adults (Freitas and Py, 2017). These changes can be increased by chronic inflammation and oxidative stress (Baechle

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et al., 2023; Hajam et al., 2022), significantly impairing the well-being of this population. Importantly, older adults value elements such as social relationships, functional autonomy, and staying active as essential components of their quality of life, and physical activity play a key role in these areas (Parra Rizo, 2017).

Physical exercise enhances the physiological and psychophysical health of older adults, underscoring the importance of personalized interventions to empower them to lead healthy and fulfilling lives (Parra-Rizo et al., 2024). Among the various forms of physical exercise, research highlights resistance training as a non-pharmacological strategy for preventing and treating physiological, physical and cognitive decline in older adults (Mollinedo et al., 2019; Coelho-Júnior and Uchida, 2021; Coelho-Júnior et al., 2024; Yoon et al., 2018). More recently, dual-task training has garnered attention from the scientific community for its potential benefits in this population.

Dual-task training involves the simultaneous integration of motor and cognitive tasks (Herold et al., 2018). Studies have demonstrated that this approach can provide greater cognitive benefits - such as enhanced executive function, faster processing speed, and improved visuospatial abilities - compared to protocols that independently target motor or cognitive tasks (Rezola-Pardo et al., 2019; Silsupadol et al., 2009; Horata et al., 2021). These benefits can significantly enhance performance in daily activities. Previous studies have demonstrated enhancements in physical and cognitive functions among institutionalized older adults after interventions (Mollinedo et al., 2019; Coelho-Júnior et al., 2024; Yoon et al., 2018; Castaño et al., 2022). Such outcomes may be attributed, at least partly, to improved antioxidant and anti-inflammatory defenses (Angulo et al., 2020; Petrella et al., 2021).

It is important to note that when it comes to aging, older adults still have different aspects that affect their daily lives. Studies show that loss of physical functionality and impaired cognitive ability are frequent in a large part of the older adult population and are the significant factors that can lead to their institutionalization, especially in cases where the family cannot meet the demands arising from this process (Lini et al., 2016; Machado, 2024).

However, evidence is scarce on the effects of dual-task resistance training (RT) in institutionalized older adults. In addition, the extent to which benefits acquired during the training are maintained after a detraining period is still being determined. To fill these gaps in knowledge, the present study was undertaken to investigate the effects of dual-task RT and detraining on physical function, cognitive capacity, lipid profile, renal function, serum oxidative stress markers, and chronic inflammatory status in institutionalized older adults. Notably, the comprehensive experimental design, which integrates dual-task RT with biochemical and biomolecular analyses, provides evidence to the literature on the sustained effects of Dual-task RT. Our findings may be valuable in clarifying the beneficial effects of an intervention model cognitively engaging that can induce protective responses in the vulnerable population, including functional outcomes, cognitive tasks, and biological health.

2. Materials & methods

2.1. Study design

This cross-over experimental study examined the effects of a dual-task RT program on the physical function and cognitive capacity of institutionalized older adults. Furthermore, the intervention's impact on the lipid profile, renal function, serum oxidative stress markers, and chronic inflammation were examined. The study protocol was approved by the Human Research Ethics Committee of Centro Universitário do Distrito Federal—UDF (Approval Number: 5.376.435) and adhered to the principles outlined in the Declaration of Helsinki (466/2012).

The study lasted 42 weeks, with assessments scheduled at weeks 1, 14–15, 28, and 42. After the initial evaluation, at week 1, participants remained without exercising or performing their customary activities for 12 weeks. This period served as a control period. Subsequently, a dual-task RT program was implemented from week 16 to week 27, and weeks 29 to 41 constituted the detraining period. The experimental design is depicted in Fig. 1.

2.2. Participants

Participants of the present study were recruited by direct contact in long-term care institutions (LTCI) in Brasilia, Brazil. Initial contact was established with the management of the long-term care institution. Following approval from the ethics committee, direct communication was initiated with the older adults and their families to determine their willingness to participate in the study. Volunteers were included if they (i) were 60+ years old, (ii) were able to understand and perform all tests and exercise protocols of the present study, and (iii) had medical authorization to engage in physical exercises. We excluded individuals with a heart pacemaker, whose pharmacological therapy was expected to change during the study timeline, who had uncorrected vision problems, who participated in a structured physical training program in the last six months, or who received hormone replacement therapy. All people involved (institution, families and volunteers) had consent.

2.3. Measurements

2.3.1. Clinical characteristics

Anthropometric and clinical characteristics were collected at baseline. Body mass and height were measured using an analog weight scale with a Filizola® (Brazil) stadiometer. BMI was calculated using the formula: BMI = body mass (kg) / height (m^2). Information about disease conditions, schooling, and institutionalization time was collected through self-reporting and the researchers' careful review of medical charts. Blood pressure was measured following the VII Joint National Committee of High Blood Pressure (JNC7) (Chobanian et al., 2003), using automated oscillometric equipment (BP 3BT0A, Microlife AG, Widnau, Switzerland) (Cuckson et al., 2002).

2.3.2. Physical function

2.3.2.1. Short physical performance battery (SPPB). The Short Physical Performance Battery (SPPB) involves three tests targeting lower-body function: a hierarchical assessment of standing balance, a 4-m walk speed test (4 M WS), and a five-repetition sit-to-stand (5STS) test. For the balance test, participants were instructed to maintain three different positions sequentially: feet side by side, semi-tandem (heel of one foot adjacent to the big toe of the other), and tandem (heel of one foot directly in front of and touching the other foot), each for 10 s. For the gait speed test, participants were requested to walk at their habitual pace over a 4-m course, with their performance timed. For the 5STS test, volunteers were asked to rise from a chair five times consecutively as quickly as possible, with arms crossed across their chest. Timing commenced when participants lifted their buttocks off the chair and were stopped upon returning to a seated position for the fifth time. Each SPPB component (balance, gait speed, and 5STS) was scored on a scale from 0 to 4, with 0 indicating the inability to perform the task and 4 representing the best performance. An overall score was calculated by summing the results of the individual SPPB subtests (range 0–12), with higher scores reflecting better lower-body physical performance (Guralnik et al., 1994; Pavasini et al., 2016).

2.3.2.2. Lower-limb muscle power. Lower-limb muscle power measures were estimated according to the formulas proposed by Alcazar et al. (Alcazar et al., 2018):

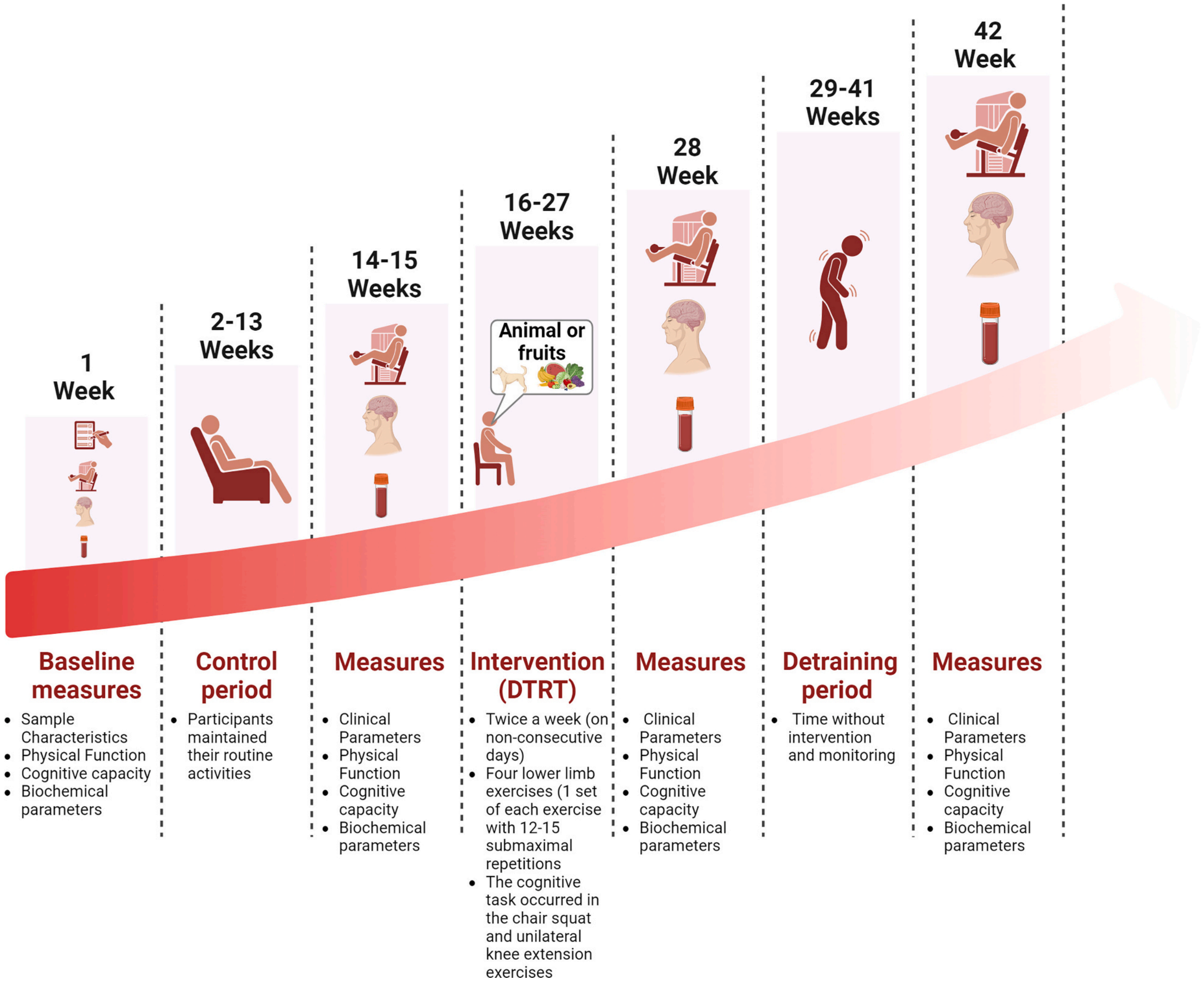

Fig. 1. Schematic representation of the steps involved in the study.

$$\text{Absolute muscle power (W)} = \frac{\text{Body weight (kg)} \times 0.9 \times g \times [\text{height (m)} \times 0.5 - \text{chair height (m)}]}{\left[\frac{\text{5STS test time (s)}}{\text{no.of STS repetitions}}\right] \times 0.5} \quad (1)$$

$$\text{Relative muscle power (W/kg)} = \frac{\text{Absolute muscle power (W)}}{\text{Body weight (kg)}} \quad (2)$$

$$\text{Allometric muscle power } (\text{W/m}^2) = \frac{\text{Absolute muscle power (W)}}{\text{Height } (\text{m}^2)} \quad (3)$$

2.3.3. *Cognitive capacity*

Cognitive capacity was assessed using the Mini-Mental State Examination (MMSE), Clock Drawing Test (CDT), and a verbal fluency test.

The MMSE assesses global cognitive function by evaluating seven abilities: orientation, registration and short-term memory, attention and concentration, language (naming, sentence writing, and comprehension), and visual-spatial skills. The score ranges from 0 to 30, with higher scores representing better cognitive capacity (Brucki et al., 2003).

The CDT involves drawing a giant clock, placing all the numbers inside the clock, and setting the pointers to 11:10 (eleven hours and ten minutes). It was analyzed using the method proposed by Shulman et al. (Shulman et al., 1993).

The verbal fluency test involved two semantic categories (i.e., animals and colors). Participants were asked to name aloud as many animals as possible within one minute for testing. Subsequently, the same was done for colors. One point was given for each item of different animals and colors (Troyer et al., 1997).

2.3.4. *Biochemical parameters*

Venous blood collection was conducted after an 8-h fasting. Triglycerides, high-density lipoprotein cholesterol (HDL-c), total cholesterol, creatinine, and blood glucose were determined using an automated chemistry analyzer (COBAS c111 system; Roche Diagnostics, Switzerland). Low-density lipoprotein (LDL-c) was determined using Friedewald's formula (Friedewald et al., 1972). Glomerular filtration rate (eGFR) was estimated using the equation: eGFR = ([140 - age] × weight in kg) / (serum creatinine × 72) for men, and eGFR = ([140 -

age] × weight in kg) / (serum creatinine × 72) × 0.85 for women (Delgado et al., 2022). Catalase concentration (CAT) was analyzed according to the manufacturer's instructions (Sigma-Aldrich, CA, USA). Thiobarbituric acid reactive substances (TBARS) were used to quantify lipid peroxidation (Sousa et al., 2019).

The redox balance was determined by calculating the pro- and antioxidant parameters ratio (CAT/TBARS). Finally, nitric oxide (NO) was analyzed using the Griess reaction technique. All assays were duplicated using a spectrophotometer at 540 nm (Cytomics FC500, Beckman Coulter, Brea, CA, USA). All redox state markers' intra- and inter-assay CVs were within 2 % to 10 %. Tumor necrosis factor alpha (TNF-α) and interleukin 10 (IL-10) were measured in triplicate by ELISA kits from R&D Systems (Minneapolis, MN, USA) according to the manufacturer's instructions. The pro- and anti-inflammatory markers (IL-10/TNF-α) ratio determined the inflammatory balance.

2.3.5. 10 repetitions maximum (10RM) test

The 10RM tests were performed before, monthly, at the end of the RT program and after the detraining period for the following exercises: (i) chair squat, (ii) unilateral knee extension, and (iii) unilateral hip flexion. No maximal strength test was conducted to determine the load of bilateral calf raise, so participants performed this exercise using the same load used for unilateral hip flexion exercise. Before testing, participants performed a brief specific warm-up using body weight. Then, the 10RM load was determined in up to 5 trials, with a 3-min interval between trials. The test was completed when participants could not perform at least 10 repetitions (Simão et al., 2012). All trials were performed with participants using the full range of motion possible. Subsequently, the 1RM was calculated based on the following formula (Brzycki, 1993):

$$1\text{RM} = 10\text{RM}/[1.0278\text{–}(0.0278 \times 10)].$$

2.4. Dual-task intervention

The dual-task RT program was conducted as previously described (Coelho-Júnior et al., 2024; Castaño et al., 2022), for 12 weeks, twice a week (on non-consecutive days), in the afternoon (starting at 2:00 p.m.). Each session was supervised by a team of at least four researchers or specialized health professionals. To ensure consistency and fidelity in the delivery of instructions to older adults, all team members underwent extensive training before the commencement of the interventions. This training focused on the proper execution of exercises, communication strategies, and adherence to the dual-task protocol. Training sessions were conducted with participants arranged in pairs or groups of three, held in the living room of each older adult's residence or the institution's garden. The scheduling was adapted to their availability, engagement in other activities, and physical limitations. A standard desk chair was used for the exercises, and no specific attire was required for the participants. Each weekly session followed a structured routine: direct contact with the patient, taking them to the table chair, warming them up, putting on the weights for the respective exercises and starting the training protocol.

The 15th week, the first week of intervention, was dedicated to participants' familiarization. In this period, participants performed four lower limb exercises: (i) chair squat (stand and sit), (ii) unilateral knee extension, (iii) unilateral hip flexion, and (iv) plantar flexion and dorsiflexion. Each exercise was performed once (one set) with 12–15 submaximal repetitions (avoiding fatigue) at 50 % 1RM (16th week). Subsequently, exercise volume increased progressively over six weeks, so two sets with 12–15 submaximal repetitions were performed in weeks 3 and 4, and three sets with 8–10 submaximal repetitions in the 5th week (20th week onwards). Exercise intensity was set at 60 % 1RM in weeks 2–4 (17th week to 19th week) and at 70 % 1RM in week 5 (20th week). Then, participants performed three sets of 8–10 repetitions at 75 % 1RM from week 6 to week 12 of the intervention period (21st week to 27th week). A detailed description of the resistance training routine is available in supplementary material 1.

After a brief warm-up, participants performed the same exercises from the familiarization period using adjustable weight vests and ankle weights (DOMYOS®, Shanghai, China). Concentric and eccentric muscle contractions lasted approximately 2 s. A researcher monitored and ensured that the velocity of muscle contractions was adequate to the protocol. Participants rested for approximately 1 min between sets and exercises.

Cognitive tasks co-occurred with RT exercises. Participants were required to say words from a given category aloud during concentric muscle actions of the chair squat and unilateral knee extension exercises. Task difficulty was increased monthly by changing the categories of words from general to specific. In contrast, semantic categories (e.g., animals and colors) and phonological categories (e.g., words beginning with a particular letter) were changed in each exercise set. Participants were encouraged not to repeat words and think of new words.

During the first eight training sessions, researchers provided retrieval cues (i.e., keywords), such as a)"animal that provides eggs," b) "animal that provides milk," and c) "animal that serves for locomotion," to stimulate older adults. A detailed description of the cognitive training routine is available in the supplementary material 2. After the dual-task RT intervention, there was a period of detraining (weeks 29 to 41). During this period, the volunteers were instructed to avoid engaging in additional exercise beyond their usual daily activities.

2.5. Statistical analysis

Data normality was tested using the Shapiro-Wilk test. Data with a normal distribution were expressed as mean and standard deviation (±) or absolute numbers (percentages), while non-normal data were presented as median and 95 % confidence interval. A two-way ANOVA with repeated measures with Tukey's post hoc or Friedman's test with Durbin-Conover pairwise comparison was performed to investigate significant differences between the conditions (periods/conditions). The effect size analysis was calculated based on Cohen's d (pre- versus post-intervention) and classified according to the following scale: 0.20–0.49 = small; 0.50–0.79 = moderate; ≥0.80 = large (Simão et al., 2012). The significance level was set at 5 % ($p < 0.05$). All analyses were performed using the Statistical Package for the Social Sciences (SPSS) 23.0 software. Graphs were prepared using GraphPad Prism 6.0 software.

3. Results

Thirty-one older adults were recruited for the study. Ten candidate participants did not meet the inclusion criteria, so twenty-one older adults started the protocol. During the study, five participants died and five did not achieve the minimum adherence (at least 80 % participation in the training program). Then, data of 11 (6 women, 5 men)

Table 1
Main characteristics of study participants.

Clinical characteristics	Mean	Std deviation	Min - Max
Age (years)	83.09	8.10	67–93
Sex (women/men)	6/5	–	–
Body mass (kg)	61.50	11.68	42–87
Height (m)*	1.65	1.57–1.67	1.46–1.72
BMI (kg·m^{-2})	23.29	4.20	15.43–30.82
Education (years)*	11	4.82–11.17	0–15
Time of institutionalization (years)*	1	0.76–1.96	0.30–4.00
SBP (mm/Hg)	127.27	18.48	100–160
DBP (mm/Hg)*	80	58.16–69.11	60–90
HR (bpm)	63.64	9.26	50–77

* non-parametric data expressed as median and (95 %) confidence interval; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate.

Table 2
Main comorbidities of study participants.

Comorbidities	%
Hypertension	63.64
Osteoarthritis	18.18
Diabetes	9.09
Anxiety	18.18
Depression	18.18
Dementia	54.55

participants were analyzed. The main characteristics of study participants are shown in Table 1 and Table 2. The mean age was 83.0 ± 8.1 years and the average BMI was 23.2 ± 4.2 kg/m^2, indicative of normal weight.

3.1. *Effects of dual-task RT on physical function*

The effects of dual-task RT and detraining on physical function are shown in Table 3. According to the European consensus on sarcopenia (Cruz-Jentoft et al., 2019), scores lower than 8 on the SPPB indicate poor physical performance. After the dual-task RT, there was an increase in the number (%) of older adults who had a score >8. Dual-task RT significantly increased side-by-side ($p = 0.027$; $\Delta = -0.91$), 4 M WS ($p = 0.027$; $\Delta = -0.06$), 5STS ($p = 0.008$; $\Delta = 7.08$), 1RM chair squat ($p < 0.001$; $\Delta = -2.59$), 1RM knee extension ($p < 0.001$; $\Delta = -2.90$), and 1RM hip flexion ($p < 0.001$; $\Delta = -2.54$) performances, in comparison to baseline. Significant differences were also found between post-training 1RM muscle strength and the control period. After detraining, a significant reduction in side-by-side balance was observed ($p = 0.008$).

The results for lower limb muscle power were similar. An absolute and allostatic power improvement was found in the post-training period ($p = 0.024$; $p = 0.032$, respectively) and in the post-detraining period ($p = 0.034$; $p = 0.027$, respectively) compared to the baseline. The same was found for relative power. A significant increase was found in the post-training ($p = 0.001$) and post-detraining periods ($p = 0.001$) compared to thebaseline. In addition, a substantial improvement was found in the post-training ($p = 0.006$) and post-detraining ($p = 0.006$) period compared with the control period.

No significant results were found in the ANOVA for the other variables, but a comparison was made between baseline vs. post-training to analyze the effect size. The following results were found: SPPB total ($d = -0.25$; $\Delta = -0.84$) with a small effect size; SPPB semitandem ($d = -0.46$; $\Delta = -1.18$) with a small effect size and; SPPB tandem ($d = -0.39$; $\Delta = -0.45$) with a small effect size.

3.2. *Cognitive capacity*

The effects of dual-task RT and detraining on cognitive function are shown in Table 3. Dual-task RT significantly improved MMSE ($p = 0.044$) and CDT ($p = 0.049$) scores compared to baseline, with results being classified with moderate ($d = -0.57$; $\Delta = -3.00$) and small ($d = -0.43$; $\Delta = -0.73$) effect sizes, respectively. Improvements in verbal fluency were also found when post-training results were compared to baseline ($p = 0.004$) and control period ($p = 0.015$).

3.3. *Blood biochemistry*

Table 3 shows the effects of dual-task RT on clinical blood markers. No significant effects were observed.

Table 3
Effects of dual-task resistance training and comparison of variables at different time points.

	Baseline	Control	Post-Training	Post-Detraining
Physical Function				
SPPB <8 points	9 (81,82 %)	10 (90,91 %)	7 (63,64 %)	9 (81,82 %)
SPPB ≥8 points	2 (18,18 %)	1 (9,09 %)	4 (36,36 %)	2 (18,18 %)
SPPB Total	3.34 ± 3.10	3.90 ± 3.14	4.27 ± 3.58	3.80 ± 3.65
SPPB side-by-side (s)*	10.0 (2.9–8.7)	10.0 (3.7–9.3)	10.0 (4.0–9.4)^{a}	5.1 (2.1–8.0)^{c}
SPPB semitandem (s)	2.09 ± 1.75	2.54 ± 2.97	3.27 ± 3.10	1.50 ± 1.80
SPPB tandem (s)*	1.0 (0.2–1.1)	0.0 (0.2–1.9)	1.0 (0.3–2.0)	0.0 (0.0–0.7)
SPPB 4 m walking (m/s)	0.25 ± 0.08	0.26 ± 0.08	0.31 ± 0.10^{a}	0.22 ± 0.08
SPPB sit-to-stand (s)	25.16 ± 7.21	24.14 ± 8.37	18.08 ± 4.61^{a}	18.35 ± 3.67^{a}
$5STS_{abs}$ Power (W)	22.80 ± 7.30	24.30 ± 8.59	30.60 ± 7.18^{a}	29.90 ± 7.45^{a}
$5STS_{rel}$ Power (W/kg)*	0.32 (0.2–0.4)	0.38 (0.3–0.5)	0.44 (0.4–0.5)^{a,b}	0.46 (0.4–0.5)^{a,b}
$5STS_{allo}$ Power (W/m^2)	8.54 ± 2.37	9.11 ± 2.85	11.59 ± 2.73^{a}	11.20 ± 2.22^{a}
1RM chair squat (kg)	5.36 ± 4.27	5.31 ± 4.41	7.95 ± 4.60^{a,b}	7.45 ± 3.58
1RM uni knee extension (kg)	6.00 ± 3.31	6.68 ± 3.14	8.90 ± 3.04^{a,b}	8.19 ± 2.73^{a}
1RM uni hip flexion (kg)	6.09 ± 2.38	6.27 ± 2.37	8.63 ± 2.94^{a,b}	7.47 ± 2.21
Cognitive Capacity				
MMSE	15.90 ± 5.44	16.27 ± 5.56	18.90 ± 4.90^{a}	17.80 ± 5.38
CDT	1.63 ± 1.68	1.81 ± 1.53	2.36 ± 1.68^{a}	2.09 ± 1.37
Verbal fluency animals	5.27 ± 2.53	5.45 ± 3.88	8.72 ± 3.43^{a,b}	8.90 ± 4.22^{a,b}
Verbal fluency fruits	7.27 ± 2.28	7.00 ± 2.40	8.27 ± 2.28	8.63 ± 3.04^{b}
Blood biochemistry				
Creatinine (mg/dL) *	0.8 (0.7–1.1)	0.8 (0.7–1.1)	0.8 (0.2–1.0)	0.6 (0.2–1.1)
eGFR (ml/min/1.76m^2)	51.98 ± 16.03	50.48 ± 15.64	54.61 ± 14.44	57.56 ± 20.28
Total Cholesterol (mg/dL)	144.66 ± 48.99	146.21 ± 25.88	134.20 ± 22.84	151.33 ± 26.37
HDL-c (mg/dL)	33.23 ± 11.08	33.62 ± 7.80	33.18 ± 10.66	31.12 ± 6.65
Triglycerides (mg/dL)	85.30 ± 23.33	91.66 ± 15.41	88.82 ± 10.91	87.64 ± 23.45
LDL-c (mg/dL)	93.85 ± 37.69	98.34 ± 29.68	83.49 ± 19.86	99.15 ± 20.70
Blood glucose (mg/dL)	86.42 ± 11.37	93.96 ± 7.38	82.43 ± 9.30	85.09 ± 11.20

Data expressed with mean ± standard deviation; * = non-parametric data (Friedman's test) expressed as median and (95 %) confidence interval (Friedman's test); $5STS_{abs}$ Power: absolute muscle power. $5STS_{rel}$ Power: relative muscle power. $5STS_{allo}$ Power: allostatic muscle power; ^{a} = significant difference compared to Baseline; ^{b} = significant difference compared to Control; ^{c} = significant difference compared to Post-Training; MMSE = mini mental state examination; CDT = clock drawing test; SPPB = Short Physical Performance Battery; 1RM = 1 Repetition Maximum; uni = unilateral; eGFR = estimated glomerular filtration rate; HDL-c = high density lipoprotein; LDL-c = low density lipoprotein.

3.4. *Serum redox markers*

The effects of dual-task RT on serum redox markers are shown in Fig. 2. No significant differences in CAT and TBARS levels were noted post-training. However, a substantial effect of dual-task RT was found for CAT/TBARS ($p < 0.001$). We also found significant improvements in NO bioavailability ($p = 0.025$).

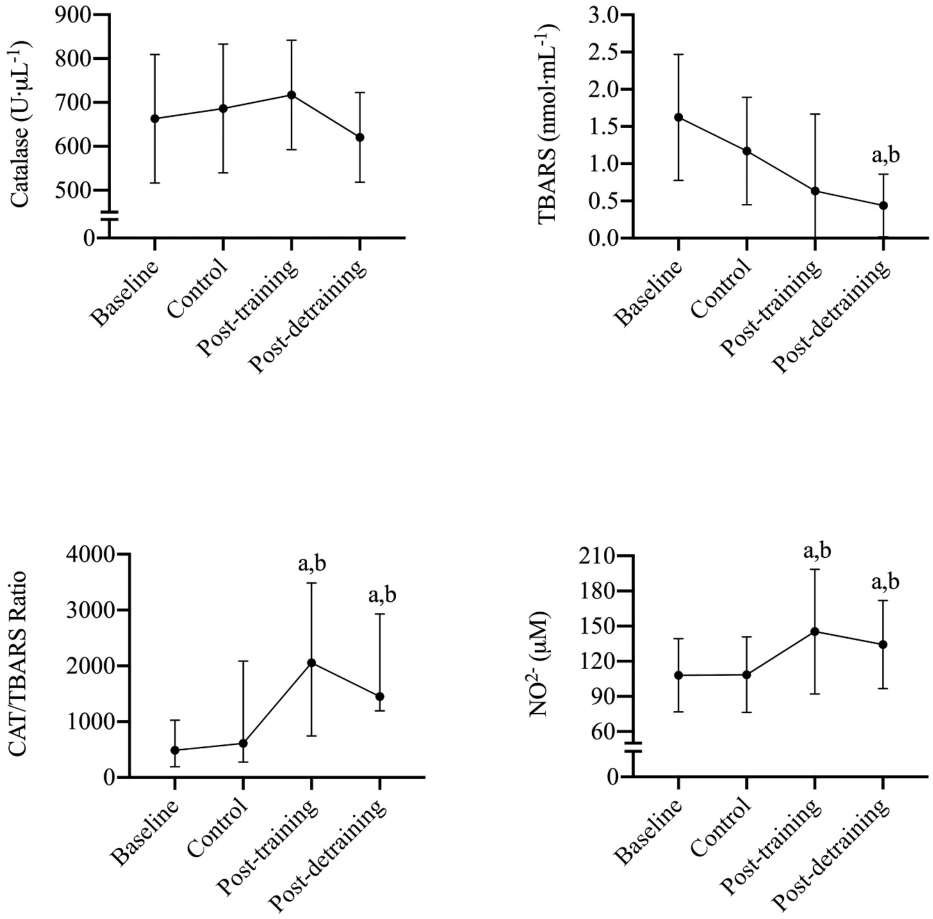

Fig. 2. Comparison between periods. ^{a} = significant difference compared to Baseline; ^{b} = significant difference compared to Control.

3.5. *Inflammatory markers*

Fig. 3 shows the effects of dual-task RT on inflammatory markers. Dual-task RT significantly increased IL-10 (p = 0.008) levels and reduced TNF-α concentrations (p = 0.006). Moreover, a significant increase in IL-10/TNF-α ratio was observed (p = 0.004).

4. Discussion

This study investigated the effects of dual-task RT and detraining on physical function, cognitive capacity, lipid profile, renal function, oxidative stress, and inflammatory markers in institutionalized older adults. In agreement with our hypotheses, we found that Physical function, muscle strength, and cognitive capacity improved significantly with dual-task RT. The intervention also decreased pro-oxidative substances, increased antioxidant enzymes, and enhanced inflammatory status by reducing pro-inflammatory TNF-α and increasing anti-inflammatory IL-10. Some of these effects were maintained during the detraining period. Fig. 4 summarizes the main findings of this study.

4.1. *Effects of dual-task resistance training on physical function*

Implementing physical exercise, particularly dual-task RT, has been shown to reduce age-related declines in physical and cognitive functions (Ali et al., 2022). This is mainly due to its impact on integrating sensory information from systems such as vision, the vestibular system, and proprioception (Wang et al., 2023a). Dual-task RT enhances postural balance by combining sensory input with neuromuscular responses and joint flexibility (Wang et al., 2023a; Cordes et al., 2019). The key to this process is proprioceptors in muscles and joints, which are part of the somatosensory system and relay postural information to the brain (Sousa et al., 2019), including trunk gravimeters (Osoba et al., 2019). The vestibular system also plays a crucial role in trunk movements and detecting head accelerations, benefiting from dual-task RT (Nascimento et al., 2023).

The improvements observed in balance tests, 4 m WS, and 5STS time likely stem from enhanced key components of postural control (Cordes et al., 2019; Coelho-Júnior et al., 2018; Castillo de Lima et al., 2023), which may help reduce fall risk (Coelho-Júnior et al., 2018). Similar to our findings, prior studies have reported significant gains in physical function following dual-task training (Wang et al., 2023a; Cordes et al., 2019; Coelho-Júnior et al., 2018; Castillo de Lima et al., 2023). However, ours is the first study to show positive results in physical function after 12 weeks of detraining.

Interestingly, dual-task RT improved muscle strength in institutionalized older adults. Aging leads to a gradual decline in muscle strength, which can hinder daily activities and contribute to sarcopenia (Lu et al., 2021), ultimately impacting the quality of life (Nascimento et al., 2023). Muscle weakness is also an essential aspect of physical frailty (Coelho-Junior et al., 2020). Previous studies in institutionalized older adults have reported strength gains through different training protocols (Naczk et al., 2020), such as strength-only training (Motalebi et al., 2018) elastic bands, and functional training (Vikberg et al., 2019).

In addition, the significant effect size indicates that this training modality may be practically relevant. While muscle strength decreased post-detraining, it remained higher than baseline levels.

4.2. *Effects of dual-task resistance training on cognitive capacity*

In this study, dual-task RT improved cognitive capacity in

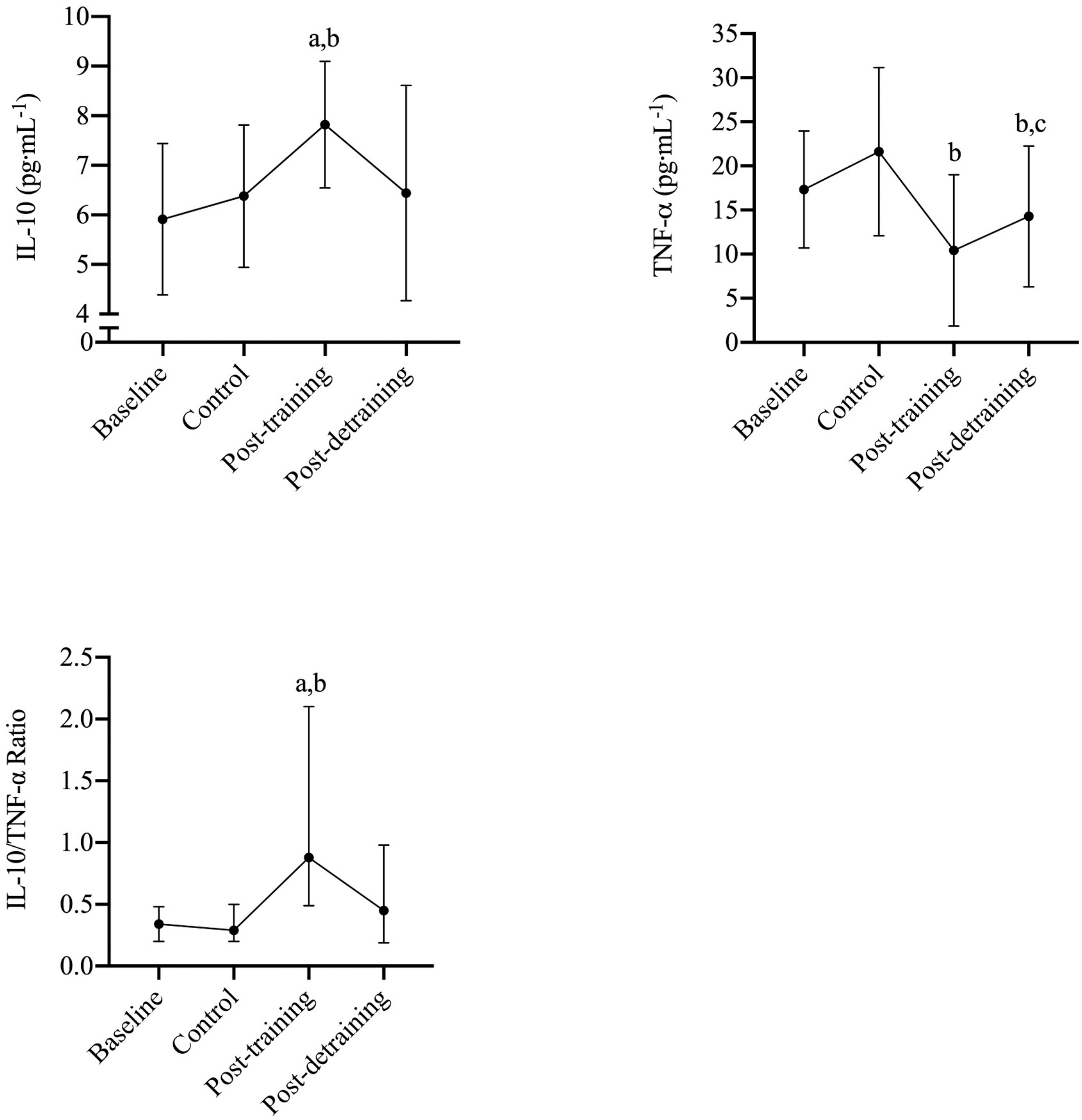

Fig. 3. Comparison between periods. ^{a} = significant difference compared to Pré-Control; ^{b} = considerable difference compared to post-Control; ^{c} = significant difference compared to post-Training.

institutionalized older adults, consistent with prior research that has shown cognitive benefits from dual-task training (Horata et al., 2021; Ali et al., 2022; Zak et al., 2021). However, most previous studies used varied interventions or placebo activities alongside dual-task exercises (Ali et al., 2022).

One possible explanation for these results is the role of physical exercise in promoting neuroplasticity (Trombini-Souza et al., 2023), specifically through increased release of brain-derived neurotrophic factor (BDNF) (Herold et al., 2018). BDNF supports synaptogenesis and neurogenesis, which may enhance memory, executive function, visual-spatial skills, and other cognitive abilities (Borror, 2017). Additionally, dual-tasking may simulate real-life activities that require multitasking (Horata et al., 2021; Trombini-Souza et al., 2023), which can improve cognitive and physical functions, potentially boosting overall functional abilities.

Given that older adults in long-term care often have more compromised cognitive capacities than those in the community (Lini et al., 2016). This finding is particularly significant. Notably, participants maintained better cognitive capacity after a 12-week detraining period than during the control period.

4.3. *Effects of dual-task resistance training on clinical parameters*

Clinical parameters did not change significantly at any period. However, the literature shows that conventional RT leads to an improvement in clinical parameters, such as lipid profile and blood glucose (Yun et al., 2023; De Sá et al., 2023; Park et al., 2020). Different meta-analyses indicate that this depends on the type of exercise, intensity, duration, frequency of training, and training environment (Yun et al., 2023; Zhuang et al., 2022).

Even so, “no change” can be considered positive. The study participants were older than the global life expectancy (World Health Organization, n.d.), and age-related changes are typically more severe at this stage (Freitas and Py, 2017). Therefore, maintaining clinical parameters at normal levels without deterioration can be viewed as a beneficial outcome. Although the effect size was small, these results may still have practical relevance for preserving clinical health in older adults.

4.4. *Effects of dual-task resistance training on oxidative stress*

In this study, Catalase (CAT) levels did not change significantly. At the same time, Thiobarbituric Acid Reactive Substances (TBARS) showed significant alterations during the detraining phase compared to

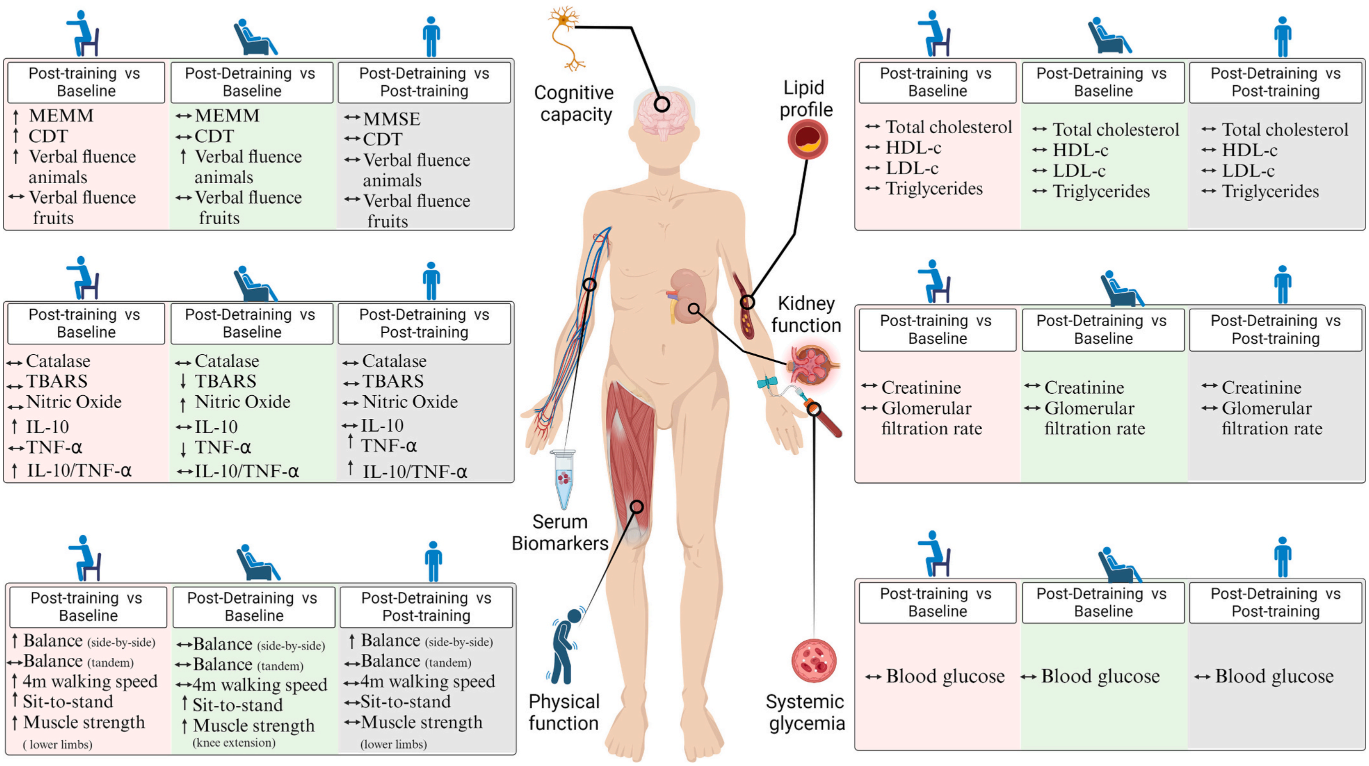

Fig. 4. Overview of the main effects of dual-task resistance training and detraining on physical function, cognitive capacity, lipid profile, renal function, and serum oxidative stress and inflammatory markers in institutionalized older adults.

both baseline and post-control periods, suggesting a delayed response to dual-task resistance training. Additionally, Nitric Oxide (NO) concentrations improved after training and during detraining, and the CAT/TBARS ratio increased significantly in both phases, indicating positive effects on redox balance. Oxidative stress is linked to various age-related conditions, such as cardiovascular and neurodegenerative diseases, as well as sarcopenia and frailty (Hajam et al., 2022; Chistiakov et al., 2014).

Previous research has shown the benefits of resistance training on oxidative stress (Gomes et al., 2017), likely due to reactive oxygen species generated during muscle contractions, which upregulates genes associated with antioxidant defense and mitochondrial biogenesis (Sousa et al., 2019). Catalase responds to increased reactive oxygen species by decomposing hydrogen peroxide and oxidizing hydrogenated compounds (Hajam et al., 2022). For NO, the primary mechanism involves modulating shear stress, enhancing vasodilation throughout the body (Sousa et al., 2019). The observed improvements in oxidative balance post-detraining highlight the importance of physical exercise. The enormous effect size also suggests significant practical applicability for these adaptations.

4.5. *Effects of dual-task resistance training on chronic inflammation*

A hallmark of aging is chronic low-grade inflammation (Baechle et al., 2023; Franceschi et al., 2018), which can be worsened by reactive oxygen species (Baechle et al., 2023). Elevated pro-inflammatory cytokines like IL-6, IL1-β, TNF-α, and CRP are linked to reduced muscle quality, mobility and an increased risk of early death in older adults (Baechle et al., 2023; Franceschi et al., 2018). In this study, dual-task RT led to a significant decrease in TNF-α, an increase in the anti-inflammatory marker IL-10, and an improved IL-10/TNF-α ratio among institutionalized older adults.

While this is one of the first studies to explore dual-task resistance training's effects on chronic inflammation in institutionalized older adults, evidence shows that long-term exercise can reduce inflammation. (Scheffer and Latini, 2020). Similar results were found in community-dwelling older adults, indicating improvements in inflammatory status following training (Gadelha et al., 2021). These findings are essential for understanding the protective effects of exercise in healthy aging.

Acute exercise may induce temporary inflammation due to cellular stress, but chronic training improves immunocompetence (Wang et al., 2023b). Increased anti-inflammatory cytokines activate the immune response (Scheffer and Latini, 2020; Siti et al., 2015), helping to reduce inflammatory biomarkers over time. IL-10 plays a role by modifying gene expression in bone marrow-derived macrophages, dampening pro-inflammatory responses (Fulop et al., 2023). Notably, the study found these benefits persisted even after the training period.

4.6. *Limitations and strengths*

Some limitations of this study should be considered. 1) The small sample size, which is primarily due to the inherent challenges of accessing this specific population; 2) The lack of analysis of neurotrophins (BDNF), which could explain the improvement in cognition or even neuronal images to look at plasticity and 3) The study evaluates an exclusively long-term care institution population, which may cause different results for older adults in the community.

Despite these limitations, the study also has key strengths. First, the sample's average age is above the global life expectancy (World Health Organization, n.d.) focusing on a potentially more vulnerable population. Second, this study is one of the first to investigate the effects of dual-task RT in institutionalized older adults and to analyze parameters of oxidative stress and chronic inflammation in this population. Third, it emphasizes the value of dual-tasking in physical exercise, even at advanced ages, which aligns with existing literature (Marzuca-Nassr et al., 2023). Lastly, the study design allowed the same participants to be analyzed during control, post-training, and post-detraining periods, strengthening internal validity.

Our findings suggest that cognitive tasks should be integral to exercise guidelines for mitigating aging's adverse effects. The persistence of benefits after detraining indicates practical significance for adherence, responsiveness, and minimizing dropout rates in training regimens. These results underscore the importance of initiating dual-task resistance training as early as possible to support cognitive health, muscle function, and overall quality of life. Further studies need to be conducted to establish a standardized dual-task training protocol, and to understand the outcomes of this protocol in comparison with others.

5. Conclusion

Dual-task resistance training over 12 weeks improved physical function, cognitive capacity, muscular strength, oxidative stress markers, and chronic inflammation in institutionalized older adults. These enhancements are crucial for facilitating the performance of daily tasks among the older population. Furthermore, these beneficial effects are maintained after a detraining period, highlighting the effectiveness of this exercise modality type. However, dual-task resistance training does not cause significant changes in clinical parameters (lipid profile, blood glucose, and renal function). Dual-task resistance training may be incorporated into exercise recommendations in this population.

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CRediT authorship contribution statement

Erivaldo Machado Araújo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hélio José Coelho-Júnior:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Caio Victor Sousa:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Thiago dos Santos Rosa:** Visualization, Supervision, Software, Resources, Project administration. **Ivo Vieira Sousa Neto:** Writing – review & editing, Writing – original draft, Supervision, Software, Investigation, Data curation, Conceptualization. **Emanuele Marzetti:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Octávio Luiz Franco:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Conceptualization. **Samuel da Silva Aguiar:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest to disclose.

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References

Alcazar, J., Losa-Reyna, J., Rodriguez-Lopez, C., Alfaro-Acha, A., Rodriguez-Mañas, L., Ara, I., García-García, F.J., Alegre, L.M., 2018. The sit-to-stand muscle power test: An easy, inexpensive and portable procedure to assess muscle power in older people. Exp. Gerontol. 112, 38–43. https://doi.org/10.1016/J.EXGER.2018.08.006.

Ali, N., Tian, H., Thabane, L., Ma, J., Wu, H., Zhong, Q., Gao, Y., Sun, C., Zhu, Y., Wang, T., 2022. The effects of dual-task training on cognitive and physical functions in older adults with cognitive impairment; A systematic review and meta-analysis. Journal of Prevention of Alzheimer's Disease 9, 359–370. https://doi.org/10.14283/JPAD.2022.16/FIGURES/10.

Angulo, J., El Assar, M., Álvarez-Bustos, A., Rodríguez-Mañas, L., 2020. Physical activity and exercise: strategies to manage frailty. Redox Biol. 35, 101513. https://doi.org/10.1016/j.redox.2020.101513.

Baechle, J.J., Chen, N., Makhijani, P., Winer, S., Furman, D., Winer, D.A., 2023. Chronic inflammation and the hallmarks of aging. Mol. Metab. 74, 101755. https://doi.org/10.1016/J.MOLMET.2023.101755.

Borror, A., 2017. Brain-derived neurotrophic factor mediates cognitive improvements following acute exercise. Med. Hypotheses 106, 1–5. https://doi.org/10.1016/J.MEHY.2017.06.024.

Brucki, S.M.D., Nitrini, R., Caramelli, P., Bertolucci, P.H.F., Okamoto, I.H., 2003. Sugestões para o uso do mini-exame do estado mental no Brasil. Arq. Neuropsiquiatr. 61, 777–781. https://doi.org/10.1590/S0004-282X2003000500014.

Brzycki, M., 1993. Strength testing—predicting a one-rep max from reps-to-fatigue. The Journal of Physical Education, Recreation & Dance 64, 88–90. https://doi.org/10.1080/07303084.1993.10606684.

Castaño, L.A.A., Castillo de Lima, V., Barbieri, J.F., de Lucena, E.G.P., Gáspari, A.F., Arai, H., Teixeira, C.V.L., Coelho-Júnior, H.J., Uchida, M.C., 2022. Resistance training combined with cognitive training increases brain derived neurotrophic factor and improves cognitive function in healthy older adults. Front. Psychol. 13, 870561. https://doi.org/10.3389/FPSYG.2022.870561/BIBTEX.

Castillo de Lima, V., Castaño, L.A.A., Sampaio, R.A.C., Sampaio, P.Y.S., Teixeira, C.V.L., Uchida, M.C., 2023. Effect of agility ladder training with a cognitive task (dual task) on physical and cognitive functions: a randomized study. Front. Public Health 11. https://doi.org/10.3389/FPUBH.2023.1159343.

Chistiakov, D.A., Sobenin, I.A., Revin, V.V., Orekhov, A.N., Bobryshev, Y.V., 2014. Mitochondrial aging and age-related dysfunction of mitochondria. Biomed. Res. Int. 2014. https://doi.org/10.1155/2014/238463.

Chobanian, A.V., Bakris, G.L., Black, H.R., Cushman, W.C., Green, L.A., Izzo, J.L., Jones, D.W., Materson, B.J., Oparil, S., Wright, J.T., et al., 2003. Seventh report of the joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. Hypertension 42, 1206–1252. https://doi.org/10.1161/01.HYP.0000107251.49515.C2.

Coelho-Júnior, H.J., Uchida, M.C., 2021. Effects of low-speed and high-speed resistance training programs on frailty status, physical performance, cognitive function, and blood pressure in prefrail and frail older adults. Front. Med. (Lausanne) 8, 1–19. https://doi.org/10.3389/fmed.2021.702436.

Coelho-Júnior, H.J., Gonçalvez, I.D.O., Sanches, I.C., Gonçalves, L., Caperuto, E.C., Uchida, M.C., Rodrigues, B., 2018. Multicomponent exercise improves physical functioning but not cognition and hemodynamic parameters in elderly osteoarthritis patients regardless of hypertension. Biomed. Res. Int. 2018. https://doi.org/10.1155/2018/3714739.

Coelho-Junior, H.J., Marzetti, E., Picca, A., Calvani, R., Cesari, M., Uchida, M.C., 2020. Prevalence of prefrailty and frailty in South America: A systematic review of observational studies. J. Frailty Aging 9, 197–213. https://doi.org/10.14283/jfa.2020.22.

Coelho-Júnior, H.J., Araújo, E.M., Uchida, M.C., Marzetti, E., Aguiar, S. da S., 2024. Effects of resistance training associated with a verbal fluency task on physical performance and cognitive function in frail nursing home residents. Arch. Gerontol. Geriatr., 105353 https://doi.org/10.1016/J.ARCHGER.2024.105353.

Cordes, T., Bischoff, L.L., Schoene, D., Schott, N., Voelcker-Rehage, C., Meixner, C., Appelles, L.M., Bebenek, M., Berwinkel, A., Hildebrand, C., et al., 2019. A multicomponent exercise intervention to improve physical functioning, cognition and psychosocial well-being in elderly nursing home residents: a study protocol of a randomized controlled trial in the PROCARE (prevention and occupational health in long-term care) project. BMC Geriatr. 19. https://doi.org/10.1186/S12877-019-1386-6.

Cruz-Jentoft, A.J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A.A., et al., 2019. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 48, 16. https://doi.org/10.1093/AGEING/AFY169.

Cuckson, A.C., Reinders, A., Shabeeh, H., Shennan, A.H., 2002. Validation of the microlife BP 3BTO-A oscillometric blood pressure monitoring device according to a modified British hypertension society protocol. Blood Press. Monit. 7, 319–324. https://doi.org/10.1097/00126097-200212000-00005.

De Sá, C.A., Saretto, C.B., Cardoso, A.M., Remor, A., Breda, C.O., da Silva, Corralo V., 2023. Effects of a physical exercise or motor activity protocol on cognitive function, lipid profile, and BDNF levels in older adults with mild cognitive impairment. Mol. Cell. Biochem. https://doi.org/10.1007/S11010-023-04733-Z.

Delgado, C., Baweja, M., Crews, D.C., Eneanya, N.D., Gadegbeku, C.A., Inker, L.A., Mendu, M.L., Miller, W.G., Moxey-Mims, M.M., Roberts, G.V., et al., 2022. A unifying approach for GFR estimation: recommendations of the NKF-ASN task force on reassessing the inclusion of race in diagnosing kidney disease. Am. J. Kidney Dis. 79, 268–288.e1. https://doi.org/10.1053/J.AJKD.2021.08.003.

Franceschi, C., Garagnani, P., Parini, P., Giuliani, C., Santoro, A., 2018. Inflammaging: a new immune–metabolic viewpoint for age-related diseases. Nature Reviews Endocrinology 14, 576–590. https://doi.org/10.1038/s41574-018-0059-4, 2018 14:10.

Freitas, E.V., Py, L., 2017. Tratado de Geriatria e Gerontologia. In: Grupo Editorial Nacional (GEN), 4a Edição.

Friedewald, W.T., Levy, R.I., Fredrickson, D.S., 1972. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin. Chem. 18, 499–502. https://doi.org/10.1093/CLINCHEM/18.6.499.

Fulop, T., Larbi, A., Pawelec, G., Khalil, A., Cohen, A.A., Hirokawa, K., Witkowski, J.M., Franceschi, C., 2023. Immunology of aging: the birth of inflammaging. Clin Rev Allergy Immunol 64, 109–122. https://doi.org/10.1007/S12016-021-08899-6.

Gadelha, A.B., Cesari, M., Corrêa, H.L., Neves, R.V.P., Sousa, C.V., Deus, L.A., Souza, M. K., Reis, A.L., Moraes, M.R., Prestes, J., et al., 2021. Effects of pre-dialysis resistance training on sarcopenia, inflammatory profile, and anemia biomarkers in older community-dwelling patients with chronic kidney disease: a randomized controlled trial. Int. Urol. Nephrol. 53, 2137–2147. https://doi.org/10.1007/S11255-021-02799-6.

Gomes, M.J., Martinez, P.F., Pagan, L.U., Damatto, R.L., Cezar, M.D.M., Lima, A.R.R., Okoshi, K., Okoshi, M.P., 2017. Skeletal muscle aging: influence of oxidative stress and physical exercise. Oncotarget 8, 20428. https://doi.org/10.18632/ONCOTARGET.14670.

Guralnik, J.M., Simonsick, E.M., Ferrucci, L., Glynn, R.J., Berkman, L.F., Blazer, D.G., Scherr, P.A., Wallace, R.B., 1994. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J. Gerontol. 49, M85–M94. https://doi.org/10.1093/GERONJ/49.2.M85.

Hajam, Y.A., Rani, R., Ganie, S.Y., Sheikh, T.A., Javaid, D., Qadri, S.S., Pramodh, S., Alsulimani, A., Alkhanani, M.F., Harakeh, S., et al., 2022. Oxidative stress in human pathology and aging: molecular mechanisms and perspectives. Cells 11. https://doi.org/10.3390/CELLS11030552.

Herold, F., Hamacher, D., Schega, L., Müller, N.G., 2018. Thinking while moving or moving while thinking - concepts of motor-cognitive training for cognitive performance enhancement. Front. Aging Neurosci. 10, 228. https://doi.org/10.3389/FNAGI.2018.00228/BIBTEX.

Horata, E.T., Cetin, S.Y., Erel, S., 2021. Effects of individual progressive single- and dual-task training on gait and cognition among older healthy adults: a randomized-controlled comparison study. Eur. Geriatr. Med. 12, 363–370. https://doi.org/10.1007/S41999-020-00429-5.

Lini, E.V., Portella, M.R., Doring, M., 2016. Factors associated with the institutionalization of the elderly: a case-control study. Revista Brasileira de Geriatria e Gerontologia 19, 1004–1014. https://doi.org/10.1590/1981-22562016019.160043.

Lu, L., Mao, L., Feng, Y., Ainsworth, B.E., Liu, Y., Chen, N., 2021. Effects of different exercise training modes on muscle strength and physical performance in older people with sarcopenia: a systematic review and meta-analysis. BMC Geriatr. 21. https://doi.org/10.1186/S12877-021-02642-8.

Machado, Araújo E., 2024. O treinamento de força associado à tarefa cognitiva melhora o balanço oxidativo, perfil inflamatório, capacidade cognitiva e função física de idosos institucionalizados [Dissertação].. UFMT, Cuiabá, pp. 1–102.

Marzuca-Nassr, G.N., Alegría-Molina, A., SanMartín-Calísto, Y., Artigas-Arias, M., Huard, N., Sapunar, J., Salazar, L.A., Verdijk, L.B., van Loon, L.J.C., 2023. Muscle mass and strength gains following resistance exercise training in older adults 65-75 years and older adults above 85 years. Int. J. Sport Nutr. Exerc. Metab. 34, 11–19. https://doi.org/10.1123/IJSNEM.2023-0087.

Mollinedo, C.I., López, A., Cancela Carral, J.M., 2019. The effects of different types of physical exercise on physical and cognitive function in frail institutionalized older adults with mild to moderate cognitive impairment. A randomized controlled trial. Arch. Gerontol. Geriatr. 83, 223–230. https://doi.org/10.1016/j.archger.2019.05.003.

Motalebi, S.A., Cheong, L.S., Iranagh, J.A., Mohammadi, F., 2018. Effect of low-cost resistance training on lower-limb strength and balance in institutionalized seniors. Exp. Aging Res. 44, 48–61. https://doi.org/10.1080/0361073X.2017.1398810.

Naczk, M., Marszalek, S., Naczk, A., 2020. Inertial training improves strength, balance, and gait speed in elderly nursing home residents. Clin. Interv. Aging 15, 177. https://doi.org/10.2147/CIA.S234299.

Nascimento, M. de M., Maduro, P.A., PMB, Rios, Nascimento, L. dos S., Silva, C.N., Kliegel, M., Ihle, A., 2023. The Effects of 12-Week Dual-Task Physical–Cognitive Training on Gait, Balance, Lower Extremity Muscle Strength, and Cognition in Older Adult Women: A Randomized Study. Int. J. Environ. Res. Public Health 20. https://doi.org/10.3390/IJERPH20085498.

Osoba, M.Y., Rao, A.K., Agrawal, S.K., Lalwani, A.K., 2019. Balance and gait in the elderly: A contemporary review. Laryngoscope Investig Otolaryngol 4, 143. https://doi.org/10.1002/LIO2.252.

Park, W., Jung, W.S., Hong, K., Kim, Y.Y., Kim, S.W., Park, H.Y., 2020. Effects of moderate combined resistance- and aerobic-exercise for 12 weeks on body composition, cardiometabolic risk factors, blood pressure, arterial stiffness, and physical functions, among obese older men: A pilot study. Int. J. Environ. Res. Public Health 17, 1–12. https://doi.org/10.3390/IJERPH17197233.

Parra Rizo, M.A., 2017. Componentes de influencia más valorados en la calidad de vida por las personas mayores de 60 años físicamente activas. In: EJIHPE: European Journal of Investigation in Health, Psychology and Education, 7, pp. 135–144. ISSN 2174-8144, ISSN-e 2254-9625, Vol 7, No 3, 2017, págs 135-144. https://dialnet.unirioja.es/servlet/articulo?codigo=6477858&info=resumen&idioma=SPA. (Accessed 12 November 2024).

Parra-Rizo, M.A., Cigarroa, I., Olivera-Sánchez, S., Guillem-Saiz, J., Agustí-López, A.I., González-Moreno, J., Cantero-García, M., Cordero-Galíndez, C.F., Yáñez-Yáñez, R. A., 2024. Perfil sociodemográfico de los adultos mayores físicamente activos según el tipo de actividades de-portivas practicado: gimnasia, actividades acuáticas, yoga, pilates y danza (sociodemographic profile of physically active older adults according to the type of physical activities practiced: gymnastic exercises, aquatic activities, yoga, pilates and dance). Retos 56, 280–288. https://doi.org/10.47197/RETOS.V56.102223.

Pavasini, R., Guralnik, J., Brown, J.C., di Bari, M., Cesari, M., Landi, F., Vaes, B., Legrand, D., Verghese, J., Wang, C., et al., 2016. Short physical performance battery and all-cause mortality: systematic review and meta-analysis. BMC Med. 14, 1–9. https://doi.org/10.1186/S12916-016-0763-7/TABLES/2.

Petrella, M., Aprahamian, I., Mamoni, R.L., de Vasconcellos Romanini, C.F., Lima, N.A., de Cássio, Robello E., da Costa, D.L., An, V.N., Aguirre, B.N., Galdeano, J.R., et al., 2021. The effect of a multicomponent exercise protocol (VIVIFRAIL©) on inflammatory profile and physical performance of older adults with different frailty status: study protocol for a randomized controlled trial. BMC Geriatr. 21, 1–11. https://doi.org/10.1186/s12877-021-02030-2.

Rezola-Pardo, C., Arrieta, H., Gil, S.M., Yanguas, J.J., Iturburu, M., Irazusta, J., Sanz, B., Rodriguez-Larrad, A., 2019. A randomized controlled trial protocol to test the efficacy of a dual-task multicomponent exercise program in the attenuation of frailty in long-term nursing home residents: aging-ONDUAL-TASK study. BMC Geriatr. 19, 1–9. https://doi.org/10.1186/s12877-018-1020-z.

Scheffer, D. da L., Latini, A., 2020. Exercise-induced immune system response: anti-inflammatory status on peripheral and central organs. Biochim. Biophys. Acta Mol. basis Dis. https://doi.org/10.1016/J.BBADIS.2020.165823, 1866:

Shulman, K.I., Pushkar Gold, D., Cohen, C.A., Zucchero, C.A., 1993. Clock-drawing and dementia in the community: A longitudinal study. Int. J. Geriatr. Psychiatry 8, 487–496. https://doi.org/10.1002/GPS.930080606.

Silsupadol, P., Shumway-Cook, A., Lugade, V., van Donkelaar, P., Chou, L.S., Mayr, U., Woollacott, M.H., 2009. Effects of single-task versus dual-task training on balance performance in older adults: a double-blind, randomized controlled trial. Arch. Phys. Med. Rehabil. 90, 381–387. https://doi.org/10.1016/J.APMR.2008.09.559.

Simão, R., Spineti, J., De Salles, B.F., Matta, T., Fernandes, L., Fleck, S.J., Rhea, M.R., Strom-Olsen, H.E., 2012. Comparison between nonlinear and linear periodized resistance training: hypertrophic and strength effects. J. Strength Cond. Res. 26, 1389–1395. https://doi.org/10.1519/JSC.0B013E318231A659.

Siti, H.N., Kamisah, Y., Kamsiah, J., 2015. The role of oxidative stress, antioxidants and vascular inflammation in cardiovascular disease (a review). Vascul. Pharmacol. 71, 40–56. https://doi.org/10.1016/j.vph.2015.03.005.

Sousa, C.V., Aguiar, S.S., Santos, P.A., Barbosa, L.P., Knechtle, B., Nikolaidis, P.T., Deus, L.A., Sales, M.M., Rosa, E.C.C.C., Rosa, T.S., et al., 2019. Telomere length and redox balance in master endurance runners: the role of nitric oxide. Exp. Gerontol. 117, 113–118. https://doi.org/10.1016/J.EXGER.2018.11.018.

Trombini-Souza, F., de Moura, V.T.G., da Silva, L.W.N., dos Santos Leal, I.D.S., Nascimento, C.A., Silva, P.S.T., Perracini, M.R., Sacco, I.C.N., de Araújo, R.C., de Maio, Nascimento M., 2023. Effects of two different dual-task training protocols on gait, balance, and cognitive function in community-dwelling older adults: a 24-week randomized controlled trial. PeerJ 11. https://doi.org/10.7717/PEERJ.15030/SUPP-2.

Troyer, A.K., Moscovitch, M., Winocur, G., 1997. Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. Neuropsychology 11, 138–146. https://doi.org/10.1037//0894-4105.11.1.138.

Vikberg, S., Sörlén, N., Brandén, L., Johansson, J., Nordström, A., Hult, A., Nordström, P., 2019. Effects of resistance training on functional strength and muscle mass in 70-year-old individuals with pre-sarcopenia: A randomized controlled trial. J. Am. Med. Dir. Assoc. 20, 28–34. https://doi.org/10.1016/J.JAMDA.2018.09.011.

Wang, C., Wang, B., Liang, J., Niu, Z., Lu, A., 2023a. Effects of multi-task mode on cognition and lower limb function in frail older adults: A systematic search and review. Healthcare (Switzerland) 11. https://doi.org/10.3390/HEALTHCARE11233012/S1.

Wang, Y.H., Tan, J., Zhou, H.H., Cao, M., Zou, Y., 2023b. Long-term exercise training and inflammatory biomarkers in healthy subjects: a meta-analysis of randomized controlled trials. Front. Psychol. 14. https://doi.org/10.3389/FPSYG.2023.1253329.

World Health Organization. Healthy life expectancy at birth (years). https://data.who.int/indicators/i/C64284D [Accessed January 14, 2024].

Yoon, D.H., Lee, J.Y., Song, W., 2018. Effects of resistance exercise training on cognitive function and physical performance in cognitive frailty: A randomized controlled trial. J. Nutr. Health Aging 22, 944–951. https://doi.org/10.1007/S12603-018-1090-9.

Yun, H., Su, W., Zhao, H., Li, H., Wang, Z., Cui, X., Xi, C., Gao, R., Sun, Y., Liu, C., 2023. Effects of different exercise modalities on lipid profile in the elderly population: A meta-analysis. Medicine 102, E33854. https://doi.org/10.1097/MD.0000000000033854.

Zak, M., Krupnik, S., Brola, W., Rebak, D., Sikorski, T., Dutheil, F., Andrychowski, J., Courteix, D., 2021. Functional capacity and dual-task cost in the institutionalized older adults, both affected and unaffected by mild cognitive impairment. Eur. Rev. Aging Phys. Act. 18. https://doi.org/10.1186/S11556-021-00270-0.

Zhuang, M., Jin, M., Lu, T., Lu, L., Ainsworth, B.E., Liu, Y., Chen, N., 2022. Effects of three modes of physical activity on physical fitness and hematological parameters in older people with sarcopenic obesity: A systematic review and meta-analysis. Front. Physiol. 13. https://doi.org/10.3389/FPHYS.2022.917525/FULL.