Functional exercise circuit with dual task training on clinical outcomes related to sarcopenia in older adults: a nonrandomized controlled trial

Circuito de ejercicio funcional con tareas duales sobre variables clínicas relacionados con la sarcopenia

Authors

Walter Sepúlveda-Loyola[1,2,3]
Renata Pires Tricanico Maciel [2]
Denilson de Castro Teixeira [3]
Felipe Araya-Quintanilla [4]
Rubens Alexandre da Silva Junior[5,6]
Alejandro Álvarez-Bustos [7]
Suhaila Mahmoud Smaili [2]
Leocadio Rodríguez-Mañas [7,8]
Juan José Valenzuela- Fuenzalida [9]
Vanessa Suziane Probst [2]

[1] Faculty of Health and Social Sciences, Universidad de Las Américas. Satiago (Chile)
[2] Postgraduation Program in Rehabilitation Sciences UEL-UNOPAR, Health Sciences Center, State University of Londrina, Londrina-PR, Brazil (Brazil)
[3] Instituto de Salud Integral Intercultural, Facultad de Ciencias de la Salud, Universidad Nacional Toribio Rodríguez de Mendoza (Perú)
[4] Escuela de Kinesiología, Facultad de Odontología y Ciencias de la Rehabilitación, Universidad San Sebastián, Santiago (Chile)
[5] Faculty of Health Sciences, Universidades McGill and UQAC, (Canada)
[6] Centre Intégré de Santé et Services Sociaux du Saguenay-Lac-Saint-Jean, Specialized Geriatrics Services-Hôpital de La Baie, Saguenay, QC G7H 7K9 (Canada)
[7] Biomedical Research Center Network for Frailty and Healthy Ageing, Institute of Health Carlos III, Madrid (Spain).
[8] Servicio de Geriatría, Hospital Universitario de Getafe, Getafe, Madrid (Spain).
[9] Departamento de Morfología, Facultad de Medicina, Universidad Andrés Bello, Santiago 8370186, (Chile)

Corresponding author:
Walter Sepúlveda-Loyola
wsepulveda@udla.cl

How to cite in APA

Sepulveda-Loyola, W., Tricanico Maciel, R. P., de Castro Teixeira, D., Araya-Quintanilla, F., da Silva Junior, R. A., Álvarez-Bustos, A., Mahmoud Smaili, S., Rodríguez-Mañas, L., Valenzuela-Fuenzalida, J. J., & Suziane Probst, V. (2025). Functional exercise circuit with dual task training on clinical outcomes related to sarcopenia in older adults: a nonrandomized controlled trial. *Retos*, *63*, 459–471. https://doi.org/10.47197/retos.v63.110528

Abstract

Introduction: Most of exercise interventions to prevent sarcopenia have focused on individuals with sarcopenia or pre-sarcopenia. The effect of functional exercise with dual task on clinical variables of sarcopenia, have not been studied previously.
Objective: This study analyzed the effects of a functional exercise program with dual task compared to aerobic exercise on outcomes related to sarcopenia, in older adults without clinical suspicion of sarcopenia.
Methodology: This was a nonrandomized controlled trial (Registration: RBR-2HJJ7G/UTN:U1111-1254-3147). Forty-eight older adults were allocated into two interventions: 1) functional exercise circuit (FEC) with dual-task and 2) aerobic exercise. Both interventions were conducted for 12 weeks, 3 times a week, 50 minutes each session. Clinical suspicion of sarcopenia was determined by the algorithm of the European Working Group on Sarcopenia in Older People. Measurements of fat-free mass, fat mass, calf circumference, handgrip strength, 5-repetition sit-to stand, 4-meter gait speed, six-minute walking test and oxidative stress blood biomarkers were assessed before and after both interventions. Analyzes were performed using the SPSS version 22.0 and JAPS version 0.16.1.
Results: Fat-free mass ($p=0.049$) and calf circumference ($p<0.001$) increased, and fat mass ($p=0.017$) reduced after FEC (ES: 0.1-0.6). Both groups showed improvement in the 5-repetition sit-to stand, 4-meter gait speed, six-minute walking test ($p< 0.05$ for all). All antioxidant biomarkers increased after FEC (ES: 0.2-0.6; $p< 0.05$ for all).
Conclusion: Our study showed that FEC with dual task training improved muscle mass, muscle strength, physical performance, and antioxidant capacity, which are important outcomes related to sarcopenia.

Keywords

Aged; aging; oxidative stress; physical exercise; sarcopenia.

Resumen

Introducción: La mayoría de las intervenciones con ejercicio para prevenir la sarcopenia se han enfocado en individuos con sarcopenia o pre-sarcopenia. Los efectos del ejercicio funcional con tareas duales sobre variables clínicas asociadas a la sarcopenia no han sido estudiados.
Objetivo: Analizar los efectos de un programa de ejercicio funcional con tareas duales versus ejercicio aeróbico sobre variables relacionados con la sarcopenia en adultos mayores sin sospecha de esta condición.
Metodología: Un estudio clínico no aleatorizado (Registro: RBR-2HJJ7G/UTN:U1111-1254-3147) con 48 adultos mayores distribuidos en dos grupos: (1) circuito de ejercicio funcional (CEF) con tareas duales y (2) ejercicio aeróbico. Durante 12 semanas, tres veces por semana, con sesiones de 50 minutos. La sospecha clínica de sarcopenia se determinó mediante el algoritmo del Grupo Europeo de sarcopenia. Fue evaluado masa magra, grasa, circunferencia de pantorrilla, fuerza de prensión, prueba de sentarse y levantarse, velocidad de marcha, prueba de caminata de seis minutos y biomarcadores de estrés oxidativo. Los análisis se realizaron con SPSS versión 22.0 y JASP versión 0.16.1.
Resultados: El CEF mostró incrementos significativos en masa magra ($p = 0{,}049$) y circunferencia de la pantorrilla ($p < 0{,}001$), y una reducción en masa grasa ($p = 0{,}017$; TE: 0,1–0,6). Ambos grupos mejoraron en la prueba de cinco repeticiones, velocidad de marcha y caminata de seis minutos ($p < 0{,}05$). Los biomarcadores antioxidantes aumentaron tras el CEF (TE: 0,2–0,6; $p < 0{,}05$).
Conclusión: El CEF mejoró masa muscular, fuerza, rendimiento físico y capacidad antioxidante, importantes variables relacionadas con sarcopenia.

Palabras clave

Anciano; envejecimiento; estrés oxidativo; ejercicio físico; sarcopenia.

Introduction

Sarcopenia is a disease characterized by the progressive loss of muscle mass, muscle strength, and
Sarcopenia is a disease characterized by the progressive loss of muscle mass, muscle strength, and
physical performance, affecting between 10% and 27% of older adults (Cruz-Jentoft et al., 2019). The presence of sarcopenia has been associated to age-related muscle decline (Can et al., 2017) and muscle function (Jones et al., 2022) due to oxidative stress and chronic inflammation (Meng & Yu, 2010). Sarcopenia impact on daily life, contributing to an increased risk of disability, falls, fractures, hospitalization and mortality in older adults and high healthcare costs for the public health system (Álvarez-Bustos et al., 2022; Miranda et al., 2021). Furthermore, sarcopenia significantly impairs the ability to perform dual tasks, which involve the simultaneous execution of physical and cognitive activities, such as walking while engaging in conversation or carrying an object while planning a task (Ghai et al., 2017; Wang et al., 2024; Zhou et al., 2023). These activities are crucial for daily living, and their deterioration severely compromises the independence and quality of life of older individuals (Pasten et al., 2024).

In terms of financial burden, sarcopenia was shown that a 10% reduction in the prevalence of sarcopenia would save $1.1 billion per year (Janssen et al., 2004), so its prevention remains imperative. Therefore, interventions aimed at preserving and enhancing muscle strength, functionality, body composition and reduce the oxidative stress are crucial for preventing sarcopenia and its associated adverse events (Beckwée et al., 2019; Moore et al., 2020a). Currently, exercise is the most extensively studied intervention for the prevention and treatment of sarcopenia, with positive effects on muscle mass, muscle strength and physical performance (Moore et al., 2020a). While most exercise interventions to prevent sarcopenia in community-dwelling older adults are multimodal exercise programs incorporating aerobic, resistance, flexibility and balance exercises (Aboarrage junior et al., 2024; Miyazaki et al., 2016), new intervention programs involving dual tasks have recently been studied in the context of programs for older adults (Merchant et al., 2021). These novel exercise programs aim to stimulate older adults to perform functional tasks resembling daily activities in which motor and cognitive tasks are performed simultaneously. These types of programs are commonly referred to as dual-task training (Ghai et al., 2017) and can be conducted within functional circuits in community-based programs (Chalapud Narváez & Molano Toba, 2023; Loyola et al., 2017).

Despite advancements in sarcopenia management, there is a clear gap in the literature regarding the impact of dual-task training on this condition. In addition, the effects of this intervention on muscle mass, an important component of sarcopenia, have not been studied previously (Varela-Vásquez et al., 2020) and there is a lack of studies simultaneously investigating the effects of dual-task training on physical domains and oxidative stress biomarkers related to sarcopenia (Yoon et al., 2020). Additionally, most exercise interventions to prevent sarcopenia have focused on individuals with sarcopenia or pre-sarcopenia (Miyazaki et al., 2016), leaving a gap on the effects of exercise programs in earlier stages or in individuals without sarcopenia. For this reason, the objective of this study was to analyze the effects of a functional exercise program with dual-task training on clinical measurements of sarcopenia (muscle mass, strength and physical performance) and oxidative stress biomarkers in community-dwelling older adults without clinical suspicion of sarcopenia, as determined by the algorithm of the European Working Group on Sarcopenia in Older People (EWGSOP) (Cruz-Jentoft et al., 2019).

Method

This was a nonrandomized controlled trial registered on the Brazilian Registry of Clinical Trials platform (RBR-2HJJ7G/UTN: U1111-1254-3147). The study was performed based on recommended guidelines for quasi-randomized trials (Haynes et al., 2021).

Participants

The study included a convenience or non-probabilistic sample of 58 older adults recruited via social media, social networks and community healthcare centers from Londrina, Brazil. Older adults interested in participating should write their name, age and phone number on a paper registration form.

Subsequently, the research team collected the information and made phone calls to inform the individuals about the project and asked if they performed any physical exercise during the last week and if they could carry out their daily activities independently. Those individuals who met the inclusion criteria via telephone call were scheduled for a face-to-face evaluation at the University's laboratories. The inclusion criteria were age ≥ 60 years, physical independence and no exercise practiced in the previous 3 months. Those older adults who presented a history of recent hip fracture or knee injury, any absolute contraindications to perform exercise or some apparent degree of cognitive impairment that would hinder exercise performance were excluded. Moreover, we also excluded subjects with clinical suspicion of sarcopenia by using the SARC-F questionnaire (cut-off value ≥ 4), as recommended by the EWGSOP2 algorithm (Cruz-Jentoft et al., 2019). The study was approved by the ethics committee from the State University of Londrina (Approval Number 2.788.802). Participation in the study was voluntary and all participants provided written informed consent. The study also followed the principles of the Declaration of Helsinki ("World Medical Association Declaration of Helsinki," 2013).

Procedure

Those older adults who met the inclusion criteria were allocated into two intervention groups: 1) functional exercise circuit (FEC) with dual-task and 2) aerobic exercise. Allocation of the older adults was matched for gender, age, body mass index (BMI) and presence of comorbidities (Charlson's comorbidity index); however, it was according to their proximity to the location where the program took place and the order of enrollment. Blinding of the physiotherapists involved in the treatment groups and the older adults was not possible, given the nature of the interventions. However, assessors involved in the assessment tests and the statistician were blinded to which group the subjects belonged. As primary outcomes we analyzed body composition, muscle strength and physical performance and as secondary outcomes we analyzed oxidative stress levels, all factors related to sarcopenia, were measured pre and post intervention (12 weeks).

Body composition

Body composition was measured by bioelectrical impedance (Biodynamics 310TM, Biodynamics Corp. USA) after 10 hours of fasting, during the morning, before the blood test and with an empty bladder. Patients were asked to go to the bathroom to urinate prior to the test. The fat and fat-free mass values were obtained directly from the device. Muscle mass was evaluated from the calf circumference; for this we used an inelastic measuring tape and measurement was performed at the maximum circumference in the plane perpendicular to the longitudinal line of the calf. Body composition and calf circumference were both assessed by the same person, blinded to the intervention group, before and after the intervention period.

Muscle strength

Muscle strength was assessed using the handgrip strength test, which measures the maximum isometric strength of the hand and forearm muscles. Muscle strength was measured for the right hand using a portable dynamometer (hydraulic dynamometer SH 5001, Saehan Medical, USA). The test was performed in a sitting position, with the arm parallel to the trunk, the elbow flexed at 90º and the forearm and hand in a neutral position. The test was repeated three times, and the highest value was considered for the analysis. To assess lower limb quadriceps strength and functionality, the five-repetition sit-to-stand test (5STS) was used (Cruz-Jentoft et al., 2019). This was performed with the individual sitting on a chair at 43 cm height and counting the time with a chronometer while the individual rose five times from the sitting position without using their arms.

Physical performance

Physical performance was assessed using the four-meter gait speed test (4MGS) (Cruz-Jentoft et al., 2019). Subjects were instructed to walk at their usual pace for a distance of 4 meters. Two tests were performed, with the best result selected for the analysis.
The six-minute walk test (6MWT) was performed to measure the functional exercise capacity. Subjects were instructed to cover the greatest distance possible without running within 6 minutes along a 30-meter-long flat corridor. Two tests were performed, with the best result selected for the analysis.

Oxidative stress biomarkers

A qualified professional collected 10 ml of blood from each individual. Subjects needed to fast for 10 hours to perform the exam. For the oxidative stress analyses, the following markers were assessed: total plasma antioxidant potential (TRAP), total plasma sulfhydryl (SH), catalase (CAT), glutathione transferase (GT), nitric oxide (NO) and advanced protein oxidation products (AOPP), according to methodology published previously (Sepúlveda-Loyola et al., 2020).

Other measurements

Charlson's comorbidity index was assessed to quantify the overall burden of comorbidities, which is an index with 19 medical conditions along with the corresponding weights (Charlson et al., 1987). Comorbidities were weighted and scored using an algorithm proposed by Charlson et al. (Charlson et al., 1987). In addition, the Montreal Cognitive Assessment (MoCA) test was used to analyze memory and cognition in older adults (Nasreddine et al., 2005). The MoCA contains 30 questions to assess different types of cognitive or thinking abilities (orientation, short-term memory, executive function, language, abstraction and attention) (Nasreddine et al., 2005).

Interventions

Subjects were allocated into two intervention groups: 1) FEC with dual-task and 2) aerobic exercise. Both interventions were developed in two community centers.

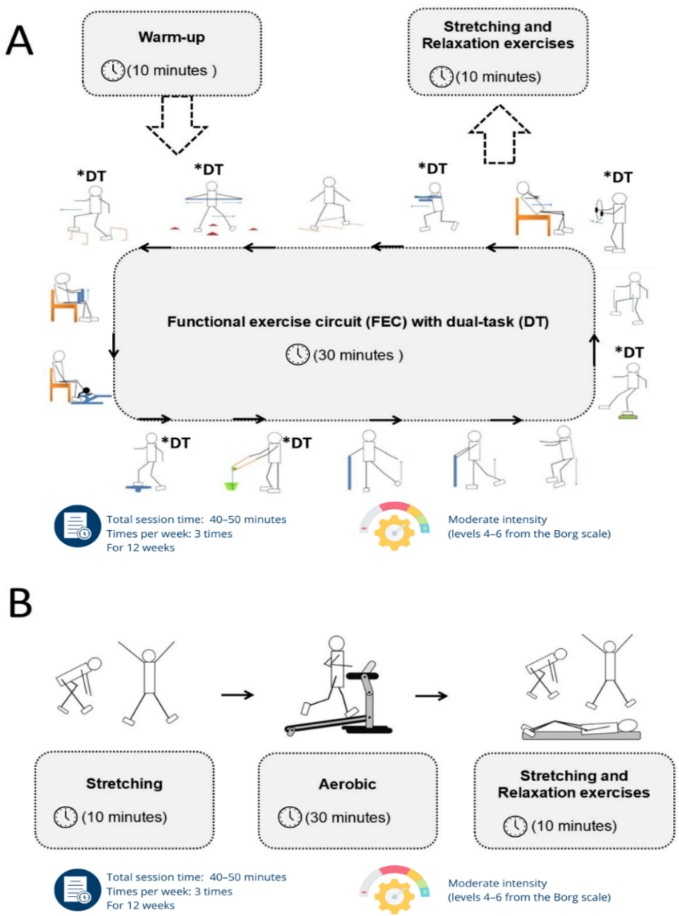
Functional exercise

FEC with dual-task activities is a protocol that was published before (Loyola et al., 2017), which included a battery of exercises of various modalities (aerobic, resistance, balance and coordination) applied as functional tasks and divided into 15 stations, as shown in Figure 1A. The older adults overcome obstacles, perform walking tasks with objects in both hands, maintain balance positions with different unstable platforms and perform tasks with both arms simultaneously. For aerobic exercise, static walking and exercise on a stationary bike were performed. For strength exercise, squats, a lower limb strength exercise on a chair and exercise with elastic bands and weights in upper limbs were performed (Loyola et al., 2017). The activities were carried out in two training groups, each with a maximum of 15 participants, distributed in a circuit. One minute was counted at each station before participants moved on to the next exercise. The session ended when all participants completed two laps of the circuit. Regarding the exercise prescription, each participant was evaluated for 1 minute at each station, where they were asked to perform the maximum number of repetitions (MNR) (e.g., maximum number of squats or number of laps walking with five obstacles) or to reach the maximum level of difficulty according to the characteristics of each task. The intensity was calculated according to the initial assessment, with the following exercise progression: first week, 50% of MNR; third week, 60% of MNR; fifth week, 70% of MNR; seventh week, 90% of MNR; ninth week, 110% of MNR; and eleventh week, 150% of MNR. At each station the name of the subject was written, along with the intensity for each week. Balance, coordination and accuracy stations were performed according to different levels of difficulty, adding to the exercise itself, with tasks involving both hands, such as holding objects and balls. The progression of these tasks was accomplished by reducing stability and increasing speed. Each session started with a 10-minute warm-up, alternating between running, walking, stretching and recreation, followed by the standardized functional exercise circuit. The sessions lasted 40–50 minutes on non-consecutive days three times a week for 12 weeks. Exercise sessions were always supervised by the same professionals, monitoring the MNR and the exercise intensity with levels 4–6 from the Borg scale. Any adverse event during the exercise session was reported to these professionals.

Aerobic Exercise

The aerobic exercise program included stretching, walking on an electric treadmill (EMBREEX 566 BX 3.0/566 BX 1.8/566 BXI, Embreex, Brazil) and relaxion exercises (Figure 1B). Subjects were divided into two subgroups for better monitoring. The first 10 minutes were used for stretching of the trunk and the upper and lower limbs. Including 3 repetitions of various stretches for 15 to 30 seconds according to the subject's tolerance. Then, subjects were placed on the treadmill and told to walk as fast as possible for 30 consecutive minutes, maintaining a self-selected speed corresponding to levels 4–6 from the Borg scale. The self-selected speed varied from 4.0 to 6.0 km/hour according to subject's tolerance. The configuration of the treadmills was without any inclination. For those who needed help, qualified professionals assisted in setting the equipment. The walking speed and the subjective perception of effort, using the Borg scale, were recorded after the first 10 minutes and at the end of the training session. Finally, stretching and relaxation exercises were performed for 10 minutes, totaling 50 minutes of each training session three times a week for 12 weeks (36 sessions). Exercise sessions were always supervised by the same professionals, monitoring exercise intensity between 4 and 6 using the Borg scale. Any adverse events occurring during the exercise sessions were promptly reported to the supervising professionals

Figure 1. Functional and aerobic exercise programs



A: Functional exercise program; B: Aerobic exercise program; DT: dual task
Nota: Sepúlveda-Loyola et al. (2024).

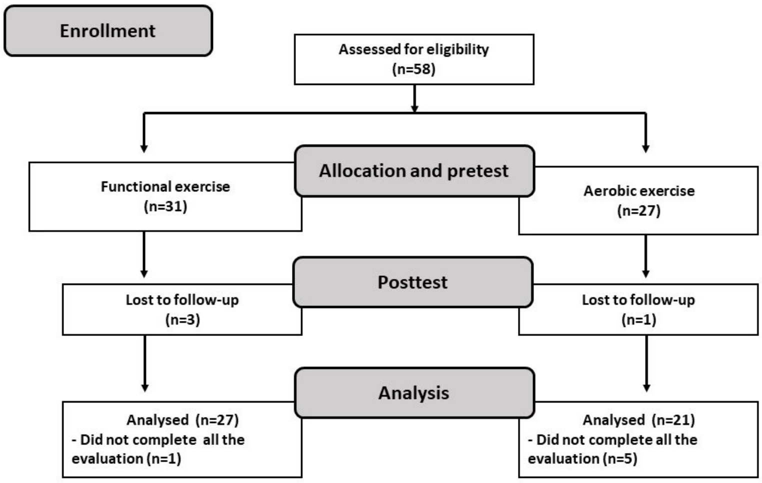
Data analysis

Analyses were performed using the following statistical software: Statistical Package for the Social Sciences (SPSS) Version 22.0 (IBM, Armonk, USA) and JAPS Version 0.16.1 (JASP Team, The Netherlands). The normality of the variables was verified by the Shapiro-Wilk test and described as the mean and standard deviation for normal variables or the median and interquartile range for non-normal variables. Intragroup comparisons (pre and post) were performed using the paired Student's t-test or Wilcoxon test according to the data distribution. Intergroup comparisons were assessed using the unpaired Student's t-test or the Mann-Whitney test, also according to the data distribution. Categorical data were compared using the χ^2 test. For comparisons between groups, we used analysis of covariance (ANCOVA) for differences in primary (body composition, muscle strength and physical performance) and secondary outcomes (oxidative stress) using continuous scales, with adjustment for baseline levels of outcomes, using group differences in the mean change from baseline to post-interventions as the dependent variable. This analysis was performed to avoid imbalances between groups, as participants with low scores at baseline tend to improve more than those with high scores, a phenomenon known as regression to the mean. Finally, we calculated Cohen's effect size (ES) for the effect of the FEC with dual-task intervention, considering the effect to be trivial (<0.2), small (0.2–0.5), medium (0.5–0.8) or large (>0.8) (Cohen, 1988). The level of statistical significance adopted was p ≤ 0.05.

Results

The study flow chart is illustrated in Figure 1. A total of 48 older adults were included in the study, 27 for the functional exercise and 21 for the aerobic exercise. No subject dropout was observed in any of the exercise programs. Table 1 describes the baseline characteristics of the included subjects. Since both groups were matched for gender, age, body mass index (BMI) and presence of comorbidities, there were no differences between groups at baseline (table 1). The cognitive status also did not differ between groups (p = 0.08).

Figure 2. Flow chart of data collection before and after the intervention



Nota: Sepúlveda-Loyola et al. (2024).

Table 1. Baseline characteristics

Variables	Functional exercise (n=27)	Aerobic exercise (n=21)	P value
Female, n (%)	21 (78%)	17 (81%)	0,602
Age (years)	69 ± 1	70 ± 1	0.6368
Height (m)	1.554 ± 0.015	1.545 ± 0.011	0.6563
Weight (kg)	70.16 ± 2.75	67.90 ± 2.24	0.5418
BMI (kg/m^2)	28.88 ± 0.88	28.49 ± 0.98	0.7634
Charlson's comorbidity index (points)	0 [0-1]	0 [0-1]	0.1672
MoCA, score	21.3 ± 4	19.4 ± 4	0.09

Data presented as mean ± standard deviation or median [interquartile range]; BMI: Body mass index, MoCA: Montreal Cognitive Assessment.
*Significant differences, p< .05.
Nota: Sepúlveda-Loyola et al. (2024).

Table 2 shows the comparisons between pre and post intervention and the effect on body composition, functional capacity and oxidative stress variables. The functional exercise group showed an increase in percentage fat-free mass (FFM%) (p = 0.049) and calf circumference (p < 0.001) but a reduction in percentage fat mass (FM%) (p = 0.017). No differences were observed in FM% or FFM% in the aerobic exercise group but there was a significant decrease in calf circumference (p = 0.011). Finally, comparison between groups was significative for FFM%, FM% and calf circumference (Cohen's d values from 0.4 to 0.6)

Regarding muscle strength, performance in the 5STS improved after training in both the functional exercise group (p = 0.002) and the aerobic exercise group (p < 0.001). There were no statistically significant differences for comparisons between groups.

Speed in the 4MGS test increased in the functional exercise group (p = 0.012) and in the aerobic exercise group (p = 0.02). The distance walked in the 6MWT increased after training in the functional exercise group (p = 0.003) and also in the aerobic exercise group (p = 0.004). However, there were no differences between groups for the 4MGS or the 6MWT (p = 0.10).

The NO level increased significantly in the functional exercise group (p = 0.035). Furthermore, all the antioxidant biomarkers increased after training in the functional exercise group: GT (p = 0.004), SH (p < 0.001), TRAP (p = 0.002) and CAT (p = 0.034). However, only SH (p = 0.020) and CAT (p < 0.001) increased in the aerobic exercise group. On comparison between groups, there was a statistically significant difference for SH (Cohen's d = 0.6, 95%CI = 3.4–9.6; p = 0.03).

Table 2. Changes in body composition, muscle strength, physical function and oxidative stress biomarkers

Variables Group	Functional exercise			Aerobic exercise			Difference between group		
	Baseline	Post-intervention	p	Baseline	Post-intervention	P alue	Mean change	ES (CI 95 %)	P value
Body Composition									
FFM (kg)	41.07±6.94	41.66±7.33	0.273	40.41±4.27	40.06±3.71	0.384	1.54	0.2(-3.5 to 6.3)	0.10
FFM (%)	59.21±6.36	60.64±6.77	0.049*	60.24±7.08	60.18±6.01	0.933	0.42	0.1(-5.5 to 7.3)	0.10
FM (kg)	29.10±9.41	27.85±9.57	0.017*	27.20±8.44	29.18±11.55	0.385	-1.3	0.6 (-8.3 to 0.9)	0.03**
FM (%)	40.79±6.36	39.36±6.77	0.049*	39.35±7.16	42.54±14.47	0.353	-3.2	0.4 (0.3 to 7.0)	0.04**
Calf circ. right (cm)	35.5 [34.0-36.5]	36.5 [35.0-39.0] ‡	< 0.001*	36.45±2.59	34.93±3.07	0.011*	1.5	0.5 (0.07 to 3.1)	0.04**
Muscle strength									
HGS right (kg)	28 [24-36]	30 [24-35]	0.680	28±6	28±6	0.872	2	0.09(-0.03 to 0.02)	0.79
5STS (s)	11.82 [9.98-13.70]	9.80 [8.29-10.76]	0.002*	13.14±2.90	10.32±2.75	< 0.001*	-0.52	0.2 (1.2 to 2.4)	0.10
Physical performance									
4MGST (s)	3.71±0.56	3.45±0.52	0.012*	4.11±0.98	3.55±0.54	0.020*	-0.1	0.1(-0.7 to 0.5)	0.10
6MWT predict (%)	109.5±18.25	123.9±14.99	0.003*	111.9±17.79	122.7±17.56	0.004*	1.2	0.1(-0.7 to 0.2)	0.10
Oxidative markers									
NO (pmol/mg)	4.93 [3.78-6.87] †	9.01 [6.93-12.22]	0.035*	7.66 [6.77-13.01]	8.80 [7.29-10.36]	0.899	0.21	0.07 (-3.0 to 4.0)	0.10
AOPP (uM/l)	97.56 [63.9-125.3]	104.5 [85.1-126.2]	0.387	89.46±22.59	94.53±30.35	0.477	10	0.05(-2.9 to .04)	0.10
Antioxidant markers									
GT (U/mgHb)	6.20 [5.89-6.77]†	7.22 [6.51-7.52]	0.004*	7.10±1.07	7.19±0.93	0.780	0.03	0.005 (-1.9 to 1.9)	0.10
TRAP (uM trolox)	856.6±181.9	949.0±168.2	0.002*	933.4±145.3	971.7±156.2	0.350	-22.7	0.2 (-2.1 to 3.4)	0.69
SH (mM/mg)	230.1±37.9†	307.7±74.6‡	< 0.001*	195.5 [181.9-221.2]	235.4 [200.9-278.6]	0.020*	72.3	0.6 (3.4 to 9.6)	0.03**
CAT (U/mgHb)	63.11±23.40†	72.89±16.75‡	0.034*	81.73±20.30	107.10±18.73	< 0.001*	-34.21	0.02 (-5.8 to -5.0)	0.22

Data presented as mean ± standard deviation or median [interquartile range]; 4MGST: 4 meter gait speed test; 6MWT: 6-minute walk test; Effect size: effect size; 5STS: 5-repetitions si-to-stand; HGS: handgrip strength; FFM: fat-free mass, FM: fat mass; NO: nitric oxide; AOPP: advanced oxidation protein products; GT: glutathione transferase; TRAP: total plasma antioxidant potential; SH: sulfhydryl grouping; CAT: catalase.
† Difference between groups at baseline (functional exercise compared to aerobic exercise) (p value ≤ 0.05).
‡ Difference between groups after exercise programs (functional exercise compared to aerobic exercise) (p value ≤ 0.05).
* Intragoup comparison (baseline versus post intervention) p ≤ 0.05.
** Difference between groups adjusted for baseline scores analyzed with ANCOVA (p < .05).
Nota: Sepúlveda-Loyola et al. (2024).

Discussion

In this study, we analyze a novel intervention comprising functional exercises combined with dual-task activities, delivered through a community-based circuit training program. Our findings demonstrated significant improvements in all clinical measurements of sarcopenia, including muscle mass, muscle strength, and physical performance, as well as enhanced antioxidant capacity in older adults compared to an aerobic exercise program.

A recent study reported that older adults with sarcopenia exhibit dual-task interference when performing simultaneous cognitive and motor tasks, which increases their risk of falls (Wang et al., 2024). Exercise has been extensively studied as an intervention for the prevention and treatment of sarcopenia (Cadore & Rodrı, 2013), with substantial evidence supporting its beneficial effects on muscle strength, muscle mass, and physical performance (Moore et al., 2020). Although several exercise programs have been proposed to prevent sarcopenia (Martin et al., 2012; Takagi et al., 2013; Unger et al., 1999; Willie-Tyndale et al., 2016), most interventions have not incorporated dual-task functional exercises. Additionally, the evidence regarding dual-task training has concentrated on outcomes such as balance and cognition (Norouzi et al., 2019; Varela-Vásquez et al., 2020) than on sarcopenia-specific clinical variables, such as body composition, strength, physical performance, and oxidative stress biomarkers.

Our functional exercise circuit with dual-task training demonstrated a positive effect on body composition by increasing muscle mass and reducing fat mass, which has not been previously studied in this exercise modality (Varela-Vásquez et al., 2020). Furthermore, we observed an increase in calf circumference, a clinically significant measurement associated with reduced sarcopenia risk, frailty, hospitalization, and mortality (Kim et al., 2018). These changes can be attributed to the prescription of functional tasks at moderate to high intensity, based on the MNR test. The intensity of the tasks was comparable to other exercise modalities, such as aerobic and resistance training, which are known to produce favorable changes in body composition (Willis et al., 2012a). Additionally, the protocol incorporated a battery of functional exercises of various modalities, including aerobic and resistance exercises. It is well established that aerobic and strength exercises performed at moderate to high intensity have significant effects on body composition by increasing muscle mass and reducing body fat percentage (Said et al., 2017; Willis et al., 2012b). These effects provide important benefits in the prevention and treatment of other metabolic comorbidities.

Although the primary aim of functional exercise and dual-task training is not body composition improvement, previous studies have demonstrated its effects on metabolic parameters, such as lipid profiles, in older adults (Maciel et al., 2020). This may explain the observed reduction in fat mass in our study. Importantly, our findings also revealed an increase in antioxidant capacity, a physiological response that aligns with previous studies investigating dual-task interventions (Maciel et al., 2020; Yoon et al., 2020). This indicates that, regardless of the type of motor task performed by the older adult, if it is prescribed at adequate intensity, it can produce physiological effects.

In our study, we have also observed that the functional exercise group exhibited an increase in all antioxidant biomarkers. Biomarkers such as sulfhydryl groups and catalase increased significantly in both exercise protocols. Sulfhydryl groups, the most abundant plasma antioxidant, and catalase, a primary defense against hydrogen peroxide, play protective roles in muscle mass and function, as demonstrated in recent research (Xu et al., 2021). Additionally, biomarkers like total radical-trapping antioxidant parameter and glutathione transferase increased exclusively in the functional exercise group. These biomarkers have been associated with improvements in muscle mass, strength and physical performance in studies involving older adults (Sepúlveda-Loyola et al., 2020), which may be related to the observed increase in fat-free mass and calf circumference in our study.

Another relevant observation was the improvement in nitric oxide (NO) levels in the functional exercise group. NO has been associated with angiogenesis, improved blood flow to muscle tissue, and enhanced cardiovascular capacity, potentially explaining the observed improvements in the 6-minute walk test (Manuneedhi Cholan et al., 2017). Therefore, this increase of NO levels observed in the functional exercise group, may have a positive effect on cardiovascular health (Manuneedhi Cholan et al., 2017). These physiological responses underscore the versatility of dual-task interventions in addressing both physical and biochemical domains in older adults. On the other hand, it is important to highlight that very few studies have investigated the influence of functional exercise with dual-task training on both physical domains and biological biomarkers simultaneously (Yoon et al., 2020). The positive results found in the present study open a new field of knowledge about the benefits generated by this type of exercise modality in different physical and biological variables in older adults.

While most evidence supports the positive effects of dual-task training on physical and cognitive health, some inconsistencies and controversial results have been published (Halvarsson et al., 2014a; Konak et al., 2016; Silsupadol et al., 2009; Varela-Vásquez et al., 2020). For example, Morita et al. (Morita et al., 2018) did not observe benefits in physical function after a 2-year intervention. This could be attributed to confounding factors, such as underlying diseases or the aging process, which may not have been adequately controlled. In contrast, randomized controlled trials (Halvarsson et al., 2014b; Silsupadol et al., 2009) have reported important improvements in gait speed, physical function and balance in older adults after dual-task training. Consistent with these findings, our study also found benefits in physical function after functional exercise with dual task. Similar findings were observed in the randomized controlled trial conducted by Konak et al. (Konak et al., 2016). Therefore, based on our results and the existing research (Halvarsson et al., 2014a; Konak et al., 2016; Silsupadol et al., 2009; Varela-Vásquez et al., 2020), it is evident that while both dual-task and single-task training are recommended for enhancing physical function, dual-task training represents a more complex modality that closely aligns with the daily activities performed by individuals, as many activities require the simultaneous execution of multiple tasks (Muir-Hunter & Wittwer, 2016; Woollacott & Shumway-Cook, 2002). Moreover, impaired performance in gait and balance during dual-task testing has been linked to an increased risk of future falls (Muir-Hunter & Wittwer, 2016). Hence, the older adults are trained with dual-task exercises, the better their performance will be in daily activities, ultimately reducing the risk of falls and disability (Muir-Hunter & Wittwer, 2016).

As a clinical implication, the exercise protocol proposed in this study offers a cost-effective, scalable intervention for non-sarcopenic older adults. By incorporating dual-task activities and functional exercises in group sessions, this approach not only enhances physical and cognitive function but also fosters social interaction, a recognized protective factor for healthy aging (Hashidate et al., 2021). Therefore, this intervention, which is equally effective as previous ones, provides patients and clinicians a cost-effective approach that supports 15 older adults in group sessions, incorporating dual-task activities and promoting social interaction.

Finally, this study has several limitations that should be considered. First, the lack of randomization that might introduce important risk of bias. Second, while significant differences were observed between groups, the effect sizes ranged from small to medium (Cohen, 1988). Therefore, the results must be interpreted with caution to avoid over estimation of the intervention group. Despite these limitations, the study's strengths include high adherence to the protocols, the use of standardized assessment tools, and the geographical allocation of participants to enhance accessibility and engagement. Future randomized controlled trials should investigate the effects of functional exercise with dual-task training specifically in individuals with sarcopenia, examining the biological markers considered in this study as well as those explored in previous research.

Conclusions

In conclusion, functional exercises with dual-task training produced significant benefits across all clinical and biological variables associated with sarcopenia in older adults. This includes improvements in muscle mass, muscle strength, physical performance and antioxidant capacity. Future randomized controlled trials should focus on the effects of this intervention in individuals with sarcopenia, incorporating the biochemical and functional biomarkers assessed here to further substantiate its benefits.

Acknowledgements

We would like to thank the community groups of older adults, the members of the Church Nossa Senhora do Rocio, and the professionals from the University Hospital from Londrina, PR, Brazil for all the support in this project.

Financing

This study was financed in part by the Programa de Apoio à Extensão Universitária do Ministério da Educação (PROEXT) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES). WSL and RPT received scholarships from CAPES, Brazil. VSP is supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil.

References

Aboarrage junior, A. M., Rodrigues Scartoni, F., Fernandes Machado, A., Sales Bocalini, D., & Giovanetti Yazigi, F. (2024). Effect of the Aquatic Program on Strength and Indicators of Sarcopenia in

Elderly. Retos, *56*, 31–39. https://doi.org/10.47197/retos.v56.103882
Álvarez-Bustos, A., Rodríguez-Sánchez, B., Carnicero-Carreño, J. A., Sepúlveda-Loyola, W., Garcia-Garcia, F. J., & Rodríguez-Mañas, L. (2022). Healthcare cost expenditures associated to frailty and sarcopenia. BMC Geriatrics, 22(1). https://doi.org/10.1186/s12877-022-03439-z
Beckwée, D., Delaere, A., Aelbrecht, S., Baert, V., Beaudart, C., Bruyere, O., de Saint-Hubert, M., & Bautmans, I. (2019). Exercise Interventions for the Prevention and Treatment of Sarcopenia. A Systematic Umbrella Review. The Journal of Nutrition, Health & Aging, 23(6), 494–502. https://doi.org/10.1007/s12603-019-1196-8
Cadore, E. L., & Rodrı, L. (2013). Effects of Different Exercise Interventions on Risk of Falls , Gait Ability , and Balance in Physically Frail Older Adults : A Systematic Review. 16(2). https://doi.org/10.1089/rej.2012.1397
Can, B., Kara, O., Kizilarslanoglu, M. C., Arik, G., Aycicek, G. S., Sumer, F., Civelek, R., Demirtas, C., & Ulger, Z. (2017). Serum markers of inflammation and oxidative stress in sarcopenia. Aging Clinical and Experimental Research, 29(4), 745–752. https://doi.org/10.1007/s40520-016-0626-2
Chalapud Narváez, L. M., & Molano Toba, N. J. (2023). Programa de ejercicios propioceptivos para la prevención de caídas en el adulto mayor (Proprioceptive exercise program for the prevention of falls in the elderly). Retos, *48*, 413–419. https://doi.org/10.47197/retos.v48.96315
Charlson, M. E., Pompei, P., Ales, K. L., & MacKenzie, C. R. (1987). A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. Journal of Chronic Diseases, 40(5), 373–383. https://doi.org/10.1016/0021-9681(87)90171-8
Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd Edition) 2nd Edition.
Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., Bautmans, I., Baeyens, J. P., Cesari, M., … Schols, J. (2019). Sarcopenia: Revised European consensus on definition and diagnosis. Age and Ageing, 48(1), 16–31. https://doi.org/10.1093/ageing/afy169
Ghai, S., Ghai, I., & Effenberg, A. O. (2017). Effects of dual tasks and dual-task training on postural stability: a systematic review and meta-analysis. Clinical Interventions in Aging, Volume 12, 557–577. https://doi.org/10.2147/CIA.S125201
Halvarsson, A., Franzén, E., & Ståhle, A. (2014a). Balance training with multi-task exercises improves fall-related self-efficacy, gait, balance performance and physical function in older adults with osteoporosis: a randomized controlled trial. Clinical Rehabilitation, 29(4), 365–375. https://doi.org/10.1177/0269215514544983
Halvarsson, A., Franzén, E., & Ståhle, A. (2014b). Balance training with multi-task exercises improves fall-related self-efficacy, gait, balance performance and physical function in older adults with osteoporosis: a randomized controlled trial. Clinical Rehabilitation, 29(4), 365–375. https://doi.org/10.1177/0269215514544983
Hashidate, H., Shimada, H., Fujisawa, Y., & Yatsunami, M. (2021). An Overview of Social Participation in Older Adults: Concepts and Assessments. Physical Therapy Research, 24(2), R0013. https://doi.org/10.1298/ptr.R0013
Haynes, A. B., Haukoos, J. S., & Dimick, J. B. (2021). TREND Reporting Guidelines for Nonrandomized/Quasi-Experimental Study Designs. JAMA Surgery, 156(9), 879. https://doi.org/10.1001/jamasurg.2021.0552
Janssen, I., Shepard, D. S., Katzmarzyk, P. T., & Roubenoff, R. (2004). The Healthcare Costs of Sarcopenia in the United States. Journal of the American Geriatrics Society, 52(1), 80–85. https://doi.org/10.1111/j.1532-5415.2004.52014.x
Jones, R. L., Paul, L., Steultjens, M. P. M., & Smith, S. L. (2022). Biomarkers associated with lower limb muscle function in individuals with sarcopenia: a systematic review. Journal of Cachexia, Sarcopenia and Muscle. https://doi.org/10.1002/jcsm.13064
Kim, S., Kim, M., Lee, Y., Kim, B. S., Yoon, T. Y., & Won, C. W. (2018). Calf circumference as a simple screening marker for diagnosing sarcopenia in older Korean adults: The Korean Frailty and Aging Cohort Study (KFACS). Journal of Korean Medical Science, 33(20), 1–10. https://doi.org/10.3346/jkms.2018.33.e151
Konak, H. E., Kibar, S., & Ergin, E. S. (2016). The effect of single-task and dual-task balance exercise programs on balance performance in adults with osteoporosis: a randomized controlled preliminary trial. Osteoporosis International, 27(11), 3271–3278.

https://doi.org/10.1007/s00198-016-3644-1
Loyola, W. S., Camillo, C. A., Torres, C. V., & Probst, V. S. (2017). Effects of an exercise model based on functional circuits in an older population with different levels of social participation. Geriatrics & Gerontology International. https://doi.org/10.1111/ggi.13167
Maciel, R. P. T., Sepúlveda-Loyola, W., Moreto, V., Cobbo, P., Gomes, B. P., Honorato, A. da S., Teixeira, D. C., & Probst, V. S. (2020). Functional exercise circuit reduce the metabolic risk factor in older people in three months of training. Brazilian Journal of Development, 6(5), 29923–29932. https://doi.org/10.34117/bjdv6n5-447
Manuneedhi Cholan, P., Cartland, S. P., & Kavurma, M. M. (2017). NADPH Oxidases, Angiogenesis, and Peripheral Artery Disease. Antioxidants (Basel, Switzerland), 6(3). https://doi.org/10.3390/antiox6030056
Martin, B. W., Marques, M., Gouveia, M., Leal, I., Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., Alkandari, J. R., Andersen, L. B., Bauman, A. E., Brownson, R. C., Bull, F. C., Craig, C. L., Ekelund, U., Goenka, S., Guthold, R., ... Luiz, C. (2012). Atividade física, saúde e qualidade de vida. The Lancet, 380(9838), 247–257. https://doi.org/10.1016/S0140-6736(12)61031-9
Meng, S. J., & Yu, L. J. (2010). Oxidative stress, molecular inflammation and sarcopenia. International Journal of Molecular Sciences, 11(4), 1509–1526. https://doi.org/10.3390/ijms11041509
Merchant, R. A., Chan, Y. H., Hui, R. J. Y., Lim, J. Y., Kwek, S. C., Seetharaman, S. K., Au, L. S. Y., & Morley, J. E. (2021). Possible Sarcopenia and Impact of Dual-Task Exercise on Gait Speed, Handgrip Strength, Falls, and Perceived Health. Frontiers in Medicine, 8(April). https://doi.org/10.3389/fmed.2021.660463
Miranda, K. A., Gouveia, É. R., Gouveia, B., Marques, A., Campos, P., Tinôco, A., Jurema, J., Kliegel, M., & Ihle, A. (2021). Sarcopenia and Physical Activity Predict Falls in Older Adults from Amazonas, Brazil (La sarcopenia y la actividad física predicen caídas en adultos mayores de Amazonas, Brasil). Retos, *43*, 215–222. https://doi.org/10.47197/retos.v43i0.88526
Miyazaki, R., Takeshima, T., & Kotani, K. (2016). Exercise Intervention for Anti-Sarcopenia in Community-Dwelling Older People. Journal of Clinical Medicine Research, 8(12), 848–853. https://doi.org/10.14740/jocmr2767w
Moore, S. A., Hrisos, N., Errington, L., Rochester, L., Rodgers, H., Witham, M., & Sayer, A. A. (2020a). Exercise as a treatment for sarcopenia: an umbrella review of systematic review evidence. Physiotherapy, Jun, 189–201. https://doi.org/10.1016/j.physio.2019.08.005
Moore, S. A., Hrisos, N., Errington, L., Rochester, L., Rodgers, H., Witham, M., & Sayer, A. A. (2020b). Exercise as a treatment for sarcopenia: an umbrella review of systematic review evidence. Physiotherapy, Jun, 189–201. https://doi.org/10.1016/j.physio.2019.08.005
Morita, E., Yokoyama, H., Imai, D., Takeda, R., Ota, A., Kawai, E., Suzuki, Y., & Okazaki, K. (2018). Effects of 2-Year Cognitive–Motor Dual-Task Training on Cognitive Function and Motor Ability in Healthy Elderly People: A Pilot Study. Brain Sciences, 8(5). https://doi.org/10.3390/brainsci8050086
Muir-Hunter, S. W., & Wittwer, J. E. (2016). Dual-task testing to predict falls in community-dwelling older adults: a systematic review. Physiotherapy, 102(1), 29–40. https://doi.org/10.1016/j.physio.2015.04.011
Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. Journal of the American Geriatrics Society, 53(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x
Norouzi, E., Vaezmosavi, M., Gerber, M., Pühse, U., & Brand, S. (2019). Dual-task training on cognition and resistance training improved both balance and working memory in older people. The Physician and Sportsmedicine, 47(4), 471–478. https://doi.org/10.1080/00913847.2019.1623996
Pasten, J. G., Aguayo, J. C., Aburto, J., Araya-Quintanilla, F., Álvarez-Bustos, A., Valenzuela-Fuenzalida, J. J., Camp, P. G., & Sepúlveda-Loyola, W. (2024). Dual-Task Performance in Individuals with Chronic Obstructive Pulmonary Disease: A Systematic Review with Meta-Analysis. In Pulmonary Medicine (Vol. 2024). Hindawi Limited. https://doi.org/10.1155/2024/1230287
Said, M., Lamya, N., Olfa, N., & Hamda, M. (2017). Effects of high-impact aerobics vs. low-impact aerobics and strength training in overweight and obese women. Journal of Sports Medicine and Physical Fitness, 57(3), 278–288. https://doi.org/10.23736/S0022-4707.16.05857-X

Sepúlveda-Loyola, W., de Castro, L. A., Matsumoto, A. K., Camillo, C. A., Barbosa, D. S., Galvan, C. C. R., & Probst, V. S. (2020). NOVEL antioxidant and oxidant biomarkers related to sarcopenia in COPD. Heart and Lung, 000, 1–8. https://doi.org/10.1016/j.hrtlng.2020.06.001

Silsupadol, P., Shumway-cook, A., & Woollacott, M. (2009). Effects of Single-Task versus dual-task training on Balance in Oder Adults. Arch Phys Med Rehabil, 90(3), 381–387. https://doi.org/10.1016/j.apmr.2008.09.559.Effects

Takagi, D., Kondo, K., & Kawachi, I. (2013). Social participation and mental health: moderating effects of gender, social role and rurality. BMC Public Health, 13(1), 701. https://doi.org/10.1186/1471-2458-13-701

Unger, J. B., McAvay, G., Bruce, M. L., Berkman, L., & Seeman, T. (1999). Variation in the impact of social network characteristics on physical functioning in elderly persons: MacArthur Studies of Successful Aging. The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 54(5), S245-51

Varela-Vásquez, L. A., Minobes-Molina, E., & Jerez-Roig, J. (2020). Dual-task exercises in older adults: A structured review of current literature. Journal of Frailty, Sarcopenia and Falls, 05(02), 31–37. https://doi.org/10.22540/jfsf-05-031

Wang, C., Jin, B., & Lu, A. (2024). Effects of Cognitive–Motor and Motor–Motor Dual Tasks on Gait Performance in Older Adults with Sarcopenia. Healthcare, 12(12), 1206. https://doi.org/10.3390/healthcare12121206

Willie-Tyndale, D., Holder-Nevins, D., Mitchell-Fearon, K., James, K., Laws, H., Waldron, N. K., & Eldemire-Shearer, D. (2016). Participation in Social Activities and the Association with Socio-Demographic and Health-Related Factors among Community-Dwelling Older Adults in Jamaica. Journal of Cross-Cultural Gerontology, 31(4), 427–447. https://doi.org/10.1007/s10823-016-9297-x

Willis, L. H., Slentz, C. A., Bateman, L. A., Shields, A. T., Piner, L. W., Bales, C. W., Houmard, J. A., & Kraus, W. E. (2012a). Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults. Journal of Applied Physiology, 113(12), 1831–1837. https://doi.org/10.1152/japplphysiol.01370.2011

Willis, L. H., Slentz, C. A., Bateman, L. A., Shields, A. T., Piner, L. W., Bales, C. W., Houmard, J. A., & Kraus, W. E. (2012b). Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults. Journal of Applied Physiology, 113(12), 1831–1837. https://doi.org/10.1152/japplphysiol.01370.2011

Woollacott, M., & Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review of an emerging area of research. Gait & Posture, 16(1), 1–14. https://doi.org/10.1016/s0966-6362(01)00156-4

World Medical Association Declaration of Helsinki. (2013). JAMA, 310(20), 2191. https://doi.org/10.1001/jama.2013.281053

Xu, H., Ranjit, R., Richardson, A., & Van Remmen, H. (2021). Muscle mitochondrial catalase expression prevents neuromuscular junction disruption, atrophy, and weakness in a mouse model of accelerated sarcopenia. Journal of Cachexia, Sarcopenia and Muscle, 12(6), 1582–1596. https://doi.org/10.1002/jcsm.12768

Yoon, J., Isoda, H., & Okura, T. (2020). Evaluation of beneficial effect of a dual-task exercise based on Japanese transitional games in older adults: a pilot study. Aging, 12(19), 18957–18969. https://doi.org/10.18632/aging.103908

Zhou, Z., Huang, Y., Wang, J., Su, H., Tang, H., & Wang, Y. (2023). A novel digital biomarker of sarcopenia in frail elderly: New combination of gait parameters under dual-task walking. Frontiers in Aging Neuroscience, 15. https://doi.org/10.3389/fnagi.2023.1087318

Authors' and translators' details:

Walter Sepúlveda-Loyola	wsepulveda@udla.cl	Author/Translator
Renata Pires Tricanico Maciel	renataptrica@hotmail.com	Author
Denilson de Castro Teixeira	denict@uel.br	Author
Felipe Araya-Quintanilla	fandres.kine@gmail.com	Author
Rubens Alexandre da Silva Junior	rubens.dasilva@uqac.ca	Author
Alejandro Álvarez-Bustos	a.alvarezbu@gmail.com	Author
Suhaila Mahmoud Smaili	suhailaneuro@gmail.com	Author
Leocadio Rodríguez-Mañas	leocadio.rodriguez@salud.madrid.org	Author
Juan José Valenzuela- Fuenzalida	juan.kine.2015@gmail.com	Author
Vanessa Suziane Probst	vanessaprobst@gmail.com	Author/Translator