



UNIVERSIDADE  
ESTADUAL DE LONDRINA

---

PAOLO MARCELLO DA CUNHA FABRO

**EFEITOS DE QUATRO ORDENS DE EXECUÇÃO DOS  
EXERCÍCIOS EM PROGRAMA DE TREINAMENTO  
RESISTIDO SOBRE A COMPOSIÇÃO CORPORAL, FORÇA  
MUSCULAR, CAPACIDADE FUNCIONAL, BIOMARCADORES  
SANGUÍNEOS E SAÚDE MENTAL EM MULHERES IDOSAS  
TREINADAS**

PAOLO MARCELLO DA CUNHA FABRO

**EFEITOS DE QUATRO ORDENS DE EXECUÇÃO DOS  
EXERCÍCIOS EM PROGRAMA DE TREINAMENTO  
RESISTIDO SOBRE A COMPOSIÇÃO CORPORAL, FORÇA  
MUSCULAR, CAPACIDADE FUNCIONAL, BIOMARCADORES  
SANGUÍNEOS E SAÚDE MENTAL EM MULHERES IDOSAS  
TREINADAS**

Tese de Doutorado apresentada ao Programa de Pós-Graduação Associado em Educação Física - UEM/UEL, como requisito para obtenção do título de Doutor em Educação Física.

Orientador: Prof. Dr. Edilson Serpeloni Cyrino

Londrina  
2021

Ficha de identificação da obra elaborada pelo autor, através do Programa de Geração Automática do Sistema de Bibliotecas da UEL

P212 Fabro, Paulo Marcello da Cunha.  
EFEITOS DE QUATRO ORDENS DE EXECUÇÃO DOS EXERCÍCIOS EM PROGRAMA DE TREINAMENTO RESISTIDO SOBRE A COMPOSIÇÃO CORPORAL, FORÇA MUSCULAR, CAPACIDADE FUNCIONAL, BIOMARCADORES SANGUÍNEOS E SAÚDE MENTAL EM MULHERES IDOSAS TREINADAS / Paulo Marcello da Cunha Fabro. - Londrina, 2021.  
105 f. : il.

Orientador: Edilson Serpeloni Cyrino.  
Tese (Doutorado em Educação Física) - Universidade Estadual de Londrina, Centro de Educação Física e Esportes, Programa de Pós-Graduação em Educação Física, 2021.  
Inclui bibliografia.

1. treinamento com pesos - Tese. 2. envelhecimento - Tese. 3. saúde - Tese. I. Serpeloni Cyrino, Edilson. II. Universidade Estadual de Londrina. Centro de Educação Física e Esportes. Programa de Pós-Graduação em Educação Física. III. Título.

CDU 796

PAOLO MARCELLO DA CUNHA FABRO

**EFEITOS DE QUATRO ORDENS DE EXECUÇÃO DOS  
EXERCÍCIOS EM PROGRAMA DE TREINAMENTO  
RESISTIDO SOBRE A COMPOSIÇÃO CORPORAL, FORÇA  
MUSCULAR, CAPACIDADE FUNCIONAL, BIOMARCADORES  
SANGUÍNEOS E SAÚDE MENTAL EM MULHERES IDOSAS  
TREINADAS**

Tese de Doutorado apresentada ao Programa de Pós-Graduação Associado em Educação Física - UEM/UEL, como requisito para obtenção do título de Doutor em Educação Física.

**BANCA EXAMINADORA**

---

Orientador: Prof. Edilson Serpeloni Cyrino  
Universidade Estadual de Londrina – UEL

---

Prof. Dr. Leandro Ricardo Altimari  
Universidade Estadual de Londrina – UEL

---

Prof. Dr. Denilson de Castro Teixeira  
Universidade Estadual de Londrina – UEL

---

Prof. Dr. Alex Silva Ribeiro  
Universidade Norte do Paraná – UNOPAR

---

Prof. Dr. Luís Alberto Gobbo  
Universidade Estadual Paulista – FCT

Londrina, 21 de dezembro de 2021.

## DEDICATÓRIA

Dedico este trabalho à minha mãe e ao meu pai, por todo apoio e suporte para que pudesse chegar até aqui.

## AGRADECIMENTOS

Agradeço à Deus por ter me proporcionado condições de chegar até o presente momento, me dando força, perseverança e foco para me manter no caminho certo. Agradeço também à minha família, especialmente a meus pais, por todo apoio dado durante todos esses anos. Também agradeço aos meus amigos pelo companheirismo, ensinamentos e risadas durante todo o percurso.

Ao meu orientador Prof. Dr. Edilson Serpeloni Cyrino, agradeço por ter me dado a oportunidade e ter me acolhido como orientando desde o mestrado, pela confiança em meu trabalho e por acreditar que eu poderia colaborar de alguma forma com o grupo. Agradeço também pelas orientações e motivações. Espero poder colaborar ainda mais contigo e todo o grupo.

Ao meu grande amigo João Pedro Nunes, agradeço pela parceria na vida acadêmica e pessoal. Uma pessoa que sempre pude contar para qualquer coisa e nunca poupou tempo ou esforço para me ajudar. Sempre me motivou e ainda continua me motivando, nunca me deixando desanimar. Obrigado por ter dividido a coordenação do projeto de pesquisa desta tese.

A todos os meus colegas e amigos do Grupo de Estudo e Pesquisa em Metabolismo, Nutrição e Exercício (GPEMENE), com quem passei boa parte do meu tempo nesses últimos anos. Embora todos, de alguma fizeram parte da minha formação e me ajudaram direta e/ou indiretamente, quero ressaltar os nomes da Melissa, Letícia, Gabriel, Junior, André Werneck e nosso amigo Andrezão (*in memoriam*). Além deles, outras pessoas um pouco mais distantes também tiveram um papel importante nesse processo. Agradeço ao Prof. Dr. Daniel Machado, que me ajudou enormemente e me incentivou a estudar exercício físico e cognição, foco dos meus estudos nos últimos anos, e aos meus parceiros internacionais, Prof. Dr. Liye Zou e Prof. Dr. Brendon Stubbs, que me motivaram ainda mais a estudar questões sobre exercício físico e saúde mental.

Aos professores Dr. Leandro Ricardo Altimari, Dr. Denilson de Castro Teixeira, Dr. Alex Silva Ribeiro e Dr. Luís Alberto Gobbo pelas análises críticas cuidadosas e pelas valiosas sugestões para esta tese. Por fim, agradeço à CAPES pela bolsa de estudo outorgada e que se tornou fundamental para que eu pudesse conduzir minha formação acadêmica e contribuir com a comunidade científica.

Muito obrigado a todos!!

FABRO, Paolo Marcello da Cunha. **Efeitos de quatro ordens de execução dos exercícios em programa de treinamento resistido sobre a composição corporal, força muscular, capacidade funcional, biomarcadores sanguíneos e saúde mental em mulheres idosas treinadas.** 2021. 105 f. Tese (Doutorado em Educação Física) – Centro de Educação Física e Esporte. Universidade Estadual de Londrina, Londrina, 2021.

## RESUMO

**Introdução:** O treinamento resistido (TR) é uma estratégia eficaz para atenuar e/ou reverter diversos efeitos deletérios induzidos pelo processo de envelhecimento. Entretanto, muitas das respostas adaptativas proporcionadas pelo TR parecem ser dependentes da manipulação das variáveis que compõem os programas de treinamento. Uma das variáveis que merecem atenção é a ordem de execução dos exercícios, uma vez que pode influenciar tanto o volume quanto a intensidade do treinamento. **Objetivo:** Comparar o efeito de quatro ordens de execução dos exercícios em um programa de treinamento resistido sobre a composição corporal, força muscular, capacidade funcional, biomarcadores sanguíneos e saúde mental em mulheres idosas treinadas. **Métodos:** Setenta e duas mulheres idosas fisicamente independentes (> 60 anos) foram submetidas, inicialmente, a 12 semanas de TR (oito exercícios, 3x10-15 repetições, 3x/semana) para equiparação dos níveis de condicionamento físico. Posteriormente, a amostra foi dividida aleatoriamente em quatro grupos para executar o TR em diferentes ordens de execução dos exercícios, seguindo um delineamento cruzado, com 12 semanas de treinamento, 12 de destreinamento e, novamente 12 semanas de retreinamento. As ordens de execução testadas foram: multi- para mono-articulares, começando por membros superiores/tronco (n = 24), multi- para mono-articulares, começando por membros inferiores (n = 24), mono- para multi-articulares, começando por membros superiores/tronco (n = 24), e mono- para multi-articulares, começando por membros inferiores (n = 24). O cruzamento das ordens de execução ocorreu de acordo com o segmento analisado, ou seja, membros superiores/tronco ou membros inferiores. O programa de TR foi similar para todos os grupos, incluindo exercícios para todas regiões do corpo (oito exercícios, 3x8-12 repetições, 3x/semana). A massa isenta de gordura e osso (MIGO) e a gordura corporal foram determinadas por absorptometria radiológica de dupla-energia (DXA). Testes de uma repetição máxima (1RM) nos exercícios supino vertical, cadeira extensora e rosca *scott* foram utilizados para análise da força muscular. A aptidão funcional foi analisada pelo desempenho em quatro testes motores (caminhada de 6 min, caminhada de 4,6 m, agilidade de caminhada e sentar-e-levantar da cadeira por 30 s). Glicose, hemoglobina glicada, triglicerídeos, colesterol total, LDL-c, HDL-c, proteína C-reativa, BDNF, AOPP, TRAP e NOx foram os indicadores metabólicos analisados. Um conjunto de testes foi adotado para análise do comportamento cognitivo (MoCA, *Trail Making test*, *Semantic and Phonemic Fluency test*, *Stroop test*). Por fim, questionários de depressão (GDS-15) e ansiedade (BAI) foram aplicados para análise da saúde mental. **Resultados:** Efeito principal do tempo ( $P < 0,05$ ) revelou modificações acarretadas pelo TR sobre a composição corporal (aumento da MIGO e redução da gordura corporal), força muscular (aumento nos três exercícios analisados), aptidão funcional (melhoria de desempenho nos testes de caminhada de 6 min e sentar-e-levantar da cadeira por 30 s), biomarcadores sanguíneos (redução da glicose, hemoglobina glicada, LDL-c,

colesterol total, proteína C-reativa, BDNF, AOPP e NOx) e saúde mental (melhoria do desempenho nos testes MoCA, *semantic and phonemic fluency tests* e BAI), sem diferenças entre os grupos ( $P > 0,05$ ). Nenhuma mudança que pudesse ser atribuída ao TR ou, ainda, as diferentes ordens de execução dos exercícios foram encontradas para as demais variáveis analisadas ( $P > 0,05$ ). **Conclusão:** Os resultados do presente estudo indicam que a ordem de execução dos exercícios não parece influenciar o comportamento da composição corporal, força muscular, capacidade funcional, de biomarcadores sanguíneos e saúde mental em mulheres idosas previamente treinadas.

**Palavras-chave:** envelhecimento; treinamento com pesos; massa muscular; desempenho motor; saúde da mulher.

FABRO, Paolo Marcello da Cunha. **Effects of four exercise order in a resistance-training program on body composition, muscular strength, functional capacity, blood biomarkers and mental health in trained older woman.** 2021. 105 p. Dissertation (Doctoral in Physical Education) – Center for Physical Education and Sport. State University of Londrina, Londrina, 2021.

## ABSTRACT

**Introduction:** Resistance training (RT) is an effective strategy to attenuate and/or reverse several harmful effects induced by the aging process. However, many of the adaptive responses provided by RT seem to depend on manipulating the variables that make up the training programs. One of the variables that deserve attention is the sequencing of exercises since it can influence both the training volume and intensity. **Objective:** To compare the effect of four exercise orders in an RT program on body composition, muscular strength, functional fitness, blood biomarkers, and mental health in trained older women. **Methods:** Seventy-two physically independent older women (> 60 years old) were initially submitted to 12 weeks of RT (eight exercises, 3x10-15 repetitions, 3x/week) to equalize their fitness levels. Afterward, the sample was randomly divided into four groups to perform TR in different exercise orders, following a crossover design, with 12 weeks of training, 12 weeks of detraining, and 12 weeks of retraining. The exercise orders tested were: multiple- to single-joint starting from upper limb/trunk (n = 24), multiple- to single-joint starting from lower limb (n = 24), single- to multiple-joint starting from upper limb/trunk (n = 24), and single- to multiple-joint starting from lower limb (n = 24). According to the segment analyzed, the crossover of the sequencing of exercises occurred, i.e., upper limbs/trunk or lower limbs. The TR program was similar for all groups, including all body regions exercises (eight exercises, 3x8-12 repetitions, 3x/week). Dual-energy X-ray absorptiometry (DXA) determined lean soft mass (LSM) and body fat. One-repetition maximum (1RM) tests in the chest press, leg extension, and preacher curl exercises were used for muscular strength analysis. Functional fitness was analyzed by performance in four motor tests (6 min walk, gait speed, timed-up-and-go, and chair stand for 30 s). The metabolic indicators analyzed were glucose, glycated hemoglobin, triglycerides, total cholesterol, LDL-c, HDL-c, C-reactive protein, BDNF, AOPP, TRAP, and NOx. A set of tests was adopted for cognitive behavior analysis (MoCA, Trail Making tests, semantic and phonemic fluency tests, Stroop test). Finally, depression (GDS-15) and anxiety (BAI) questionnaires were applied for mental health analysis. **Results:** A main effect of time ( $P < 0.05$ ) revealed modifications entailed by RT on body composition (increased MIGO and reduced body fat), muscle strength (increased in all three exercises analyzed), functional fitness (improved performance in the 6 min walk and chair stand for 30 s), blood biomarkers (reduced glucose, glycated hemoglobin, LDL-c, total cholesterol, C-reactive protein, BDNF, AOPP, and NOx), and mental health (improved performance on MoCA, semantic and phonemic fluency tests, and BAI), with no differences between groups ( $P > 0.05$ ). No changes that could be attributed to the RT or the different orders of execution of the exercises were found for the other variables analyzed ( $P > 0.05$ ). **Conclusion:** The results of the present study suggest that the exercise execution order does not seem to influence the behavior of body composition, muscular strength, functional fitness, blood biomarkers, and mental health in previously trained older women.

**Keywords:** aging; strength training; muscle mass; motor performance; women's health.

## LISTA DE TABELAS

### ARTIGO 1

<b>Table 1.</b> General characteristics of the four training groups at baseline of the study.....	49
<b>Table 2.</b> Raw pre-and post-training values and adjusted mean changes for the measures of muscular strength and muscle mass according to the different exercise order conditions.....	50
<b>Table 3.</b> Raw pre-and post-training values and adjusted mean changes for the measures of functional fitness according to the different exercise order conditions.....	51
<b>Table 4.</b> E Effect size values for the measures of muscular strength, muscle mass, and functional fitness according to the different exercise order conditions.....	52

### ARTIGO 2

<b>Table 1.</b> Results of the body fat at pre- and post-training according to groups.....	77
<b>Table 2.</b> Results of the glycemic and lipid profiles at pre- and post-training according to groups... ..	78
<b>Table 3.</b> Results of the C-reactive protein, BDNF, and oxidative biomarkers at pre- and post-training according to groups.....	79
<b>Table 4.</b> Results of the cognitive functions, depression, and anxiety at pre-and post-training according to groups .....	80

## LISTA DE FIGURAS

### ARTIGO 1

<b>Figure 1.</b> Experimental design of the study .....	47
<b>Figure 2.</b> Volume-load values at weeks 1, 4, 8, and 12 of the training program .....	48
<b>Supplementary material 1.</b> Energy and macronutrients intake of older women during the study period according to groups.....	53
<b>Supplementary material 2.</b> Results of the muscle mass and muscular strength at pre-and post-training for the Upper vs. Lower additional analyzes.....	54
<b>Supplementary material 3.</b> Results of the detraining period for 1RM.....	55
<b>Supplementary material 4.</b> Results of the detraining period for LST.....	56
<b>Supplementary material 5.</b> Results of the detraining period for functional fitness.....	57

### ARTIGO 2

<b>Figure 1.</b> Results of the 6MWT at pre-and post-training according to the groups.....	76
<b>Supplementary material 1.</b> Results of the detraining period for body fat.....	81
<b>Supplementary material 2.</b> Results of the detraining period for glycemic and lipid profiles .....	82
<b>Supplementary material 3.</b> Results of the detraining period for C-reactive protein, BDNF, and oxidative biomarkers .....	.83
<b>Supplementary material 4.</b> Results of the detraining period for cognitive test, depressive and anxiety symptoms .....	84

## SUMÁRIO

<b>1</b>	<b>INTRODUÇÃO</b> .....	<b>12</b>
<b>2</b>	<b>OBJETIVOS</b> .....	<b>20</b>
2.1	OBJETIVO GERAL.....	20
2.2	OBJETIVOS ESPECÍFICOS .....	20
<b>3</b>	<b>HIPÓTESES</b> .....	<b>21</b>
<b>4</b>	<b>MÉTODOS</b> .....	<b>22</b>
4.1	DELINEAMENTO EXPERIMENTAL.....	22
4.2	PARTICIPANTES .....	23
4.3	ANTROPOMETRIA .....	24
4.5	FORÇA MUSCULAR.....	25
4.6	BIOQUÍMICA SANGUÍNEA .....	26
4.7	AVALIAÇÕES COGNITIVAS .....	27
4.7.1	<i>Montreal Cognitive Assessment</i> .....	27
4.7.2	<i>Trail Making Test</i> .....	27
4.7.3	<i>Stroop Test</i> .....	28
4.7.4	Fluência Verbal Semântica E Fonológica .....	29
4.8	APTIDÃO FUNCIONAL .....	29
4.9	SINTOMAS DE DEPRESSÃO E ANSIEDADE .....	30
4.11	PROGRAMA DE TREINAMENTO RESISTIDO.....	30
4.12	TRATAMENTO ESTATÍSTICO .....	32
<b>5</b>	<b>RESULTADOS</b> .....	<b>33</b>
5.1	ARTIGO ORIGINAL 1 .....	34
5.2	ARTIGO ORIGINAL 2 .....	60
<b>6</b>	<b>CONSIDERAÇÕES FINAIS</b> .....	<b>87</b>
	<b>REFERÊNCIAS</b> .....	<b>90</b>

<b>APÊNDICES</b> .....	101
Apêndice A: Termo de consentimento .....	101
Apêndice B: Recordatório Alimentar .....	102
<b>ANEXOS</b> .....	103
Anexo A: Comitê de ética.....	103
Anexo B: <i>Montreal Cognitive Assessment (MoCA)</i> .....	104
Anexo C: <i>Trail Making Test A e B</i> .....	105
Anexo D: Escala de Depressão Geriátrica - GDS .....	106
Anexo E: Inventário de Ansiedade de Beck - BAI .....	107

## 1 INTRODUÇÃO

O processo de envelhecimento acarreta inúmeras modificações morfológicas, funcionais-motoras, fisiológicas, metabólicas, cognitivas e comportamentais, muitas das quais com impacto negativo sobre a saúde e qualidade de vida. Nesse sentido, a preservação da força muscular ou a atenuação do declínio com o avançar da idade tem sido um dos grandes desafios da comunidade científica e dos profissionais das áreas de saúde, uma vez que a redução da força muscular limita a execução de atividades da vida diária, reduz a autonomia funcional, aumenta o comportamento sedentário e o risco de quedas, lesões e fraturas (BARBAT-ARTIGAS et al., 2013; GERMAIN et al., 2016).

Paralelamente ao declínio da força muscular, o envelhecimento está associado a importantes modificações na composição corporal, com ênfase na redução da massa muscular e ao aumento da gordura corporal - sobretudo a visceral e a intramuscular - que pode desencadear importantes doenças como a sarcopenia e a obesidade, de forma isolada ou combinada, fenômeno denominado obesidade sarcopênica (STENHOLM et al., 2008). Tais modificações estão relacionadas ao desenvolvimento de diversas doenças crônicas não-transmissíveis, com destaque para as cardiometabólicas e mentais (STUNKARD; FAITH; ALLISON, 2003; TUCSEK et al., 2014; CHANG et al., 2017; ROSSI et al., 2018).

O aumento dos depósitos de gordura corporal *per si* em idosos está associado a uma piora no quadro metabólico, caracterizado por resistência à insulina, intolerância a glicose, dislipidemia, inflamação de baixo grau e estresse oxidativo (BASTARD et al., 2006; ANDERSON-HANLEY et al., 2018; SINGH-MANOUX et al., 2018). Além disso, tanto o sobrepeso quanto a obesidade apresentam-se como fatores de risco para o declínio de diversas funções cognitivas, com reflexo direto na saúde mental (SILVA et al., 2012; SINGH-MANOUX et al., 2018), de modo que alterações periféricas associadas ao envelhecimento podem afetar o sistema nervoso central e, em especial, o funcionamento do cérebro (TROLLOR et al., 2012; MILLER; SPENCER, 2014). Assim, a população idosa torna-se mais vulnerável ao desenvolvimento de doenças neurodegenerativas e demências, como a Doença de Alzheimer (BEYDOUN et al., 2014), e a sintomas de ansiedade e depressão (FRITH; LOPRINZI, 2018; VAN DAM et al., 2018). Todo esse cenário nocivo afeta negativamente a qualidade de vida e aumenta o risco de mortalidade precoce (RUIZ et al., 2008; KANG; LIM; PARK, 2018).

Diante disso, estratégias farmacológicas e não-farmacológicas têm sido desenvolvidas e utilizadas para a atenuação ou reversão, pelo menos em parte, dos

efeitos deletérios à saúde associados ao envelhecimento. Desse modo, a prática regular de exercícios físicos tem se destacado como uma das principais estratégias não-farmacológicas com eficácia comprovada e de baixo risco para a população idosa, especialmente o treinamento resistido (TR), devido as suas características bastante peculiares, ou seja, é um tipo de exercício que pode ser prescrito individualmente, com base nas limitações e necessidades do praticantes; permite a execução dos movimentos de forma lenta, sem movimentos bruscos; sua execução pode ocorrer de forma confortável, sentado, em pé, deitado ou inclinado, sem exigência de grandes deslocamentos; possibilita a progressão da sobrecargas, de acordo com os avanços graduais na força muscular (WILLIAMS; STEWART, 2009; WESTCOTT, 2012; FRAGALA et al., 2019).

Os principais efeitos da prática do TR na população idosa são suportados por inúmeras investigações produzidas, sobretudo, nas últimas duas décadas, com destaque para o aumento da força muscular (CUNHA et al., 2018), melhoria da aptidão funcional (SANTOS et al., 2017), ganho da massa muscular (RIBEIRO et al., 2017), redução da gordura corporal (CAVALCANTE et al., 2018; CUNHA et al., 2021a), aumento do conteúdo e da densidade mineral óssea (KELLEY; KELLEY, 2001), melhoria do perfil lipídico (TOMELERI et al., 2016; CUNHA et al., 2019) e diminuição dos fatores de risco de síndrome metabólica (TOMELERI et al., 2018), redução da pressão arterial (GERAGE et al., 2013; TOMELERI et al., 2020), diminuição da resistência à insulina (MAVROS et al., 2014), melhoria da saúde mental (MAVROS et al., 2017; CUNHA et al., 2021b), entre outros.

Entretanto, as respostas adaptativas ao TR podem ser determinadas, em grande parte, pela manipulação adequada das variáveis de treino, visto que diferenças tanto na intensidade quanto no volume podem afetar a sobrecarga e, conseqüentemente, os benefícios. Portanto, dependendo do número de exercícios, séries e repetições; da velocidade de execução; dos intervalos de recuperação entre as séries e os exercícios; da frequência semanal; do sistema de treinamento; da ordem de execução dos exercícios; as respostas adaptativas podem se manifestar em maior ou menor magnitude (STEIB; SCHOENE; PFEIFER, 2010; BORDE; HORTOBÁGYI; GRANACHER, 2015; CSAPO; ALEGRE, 2016). Embora diversos estudos publicados recentemente tenham buscado analisar o possível impacto da manipulação de cada uma dessas variáveis em idosos, a dose-resposta mais adequada ainda não está bem estabelecida pela literatura

(STEIB; SCHOENE; PFEIFER, 2010; BORDE; HORTOBÁGYI; GRANACHER, 2015; CSAPO; ALEGRE, 2016).

Considerando o conjunto de variáveis relatadas anteriormente, a ordem de execução dos exercícios (OE), provavelmente, seja uma das que merecem ser analisadas de maneira mais consistente, visto que a sua manipulação que pode influenciar tanto o volume quanto a intensidade do TR (ACSM, 2009a; SIMÃO et al., 2012a; NUNES et al., 2021a). A OE pode afetar o número de repetições executadas (SFORZO; TOUEY, 1996; SIMÃO et al., 2007) e a carga a ser utilizada (FARINATTI; DA SILVA; MONTEIRO, 2013; MIRANDA et al., 2013; ROMANO et al., 2013), resultando em diferenças na percepção de esforço (SIMÃO et al., 2012b; FARINATTI; DA SILVA; MONTEIRO, 2013) e no volume-carga total (cargas x repetições) de treino por sessão (SFORZO; TOUEY, 1996; SIMÃO et al., 2007; TOMELERI et al., 2020b). Tais fatores podem resultar em diferentes adaptações crônicas induzidas pela prática do TR.

O Colégio Americano de Medicina do Esporte propôs a mais de uma década atrás, em seu posicionamento sobre modelos de progressão para o TR em adultos saudáveis, que o treinamento deveria ser estruturado para iniciar pelos exercícios multi-articulares seguidos pelos mono-articulares, partindo dos grandes grupamentos musculares para os menores (ACSM, 2009a). Essa proposição foi pautada no fato de que, ao se adotar essa OE, o volume-total de treino tenderia a ser maior do que quando se utilizasse ordem inversa, ou seja, dos exercícios mono- para os multi-articulares (ACSM, 2009a). Mais recentemente essa orientação tem sido questionada, de modo que alguns pesquisadores têm defendido que a tomada de decisão com relação a OE deve ser pautada nas necessidades ou objetivos individuais, devendo se dar prioridade no início da sessão de treinamento aos exercícios que envolvem os grupamentos musculares considerados mais fragilizados (FIGUEIREDO et al., 2011; SIMÃO et al., 2012a; CARPINELLI, 2013; NUNES et al., 2021a).

Em idosos, contudo, há uma escassez de informações sobre essa temática, o que dificulta a tomada de decisão no momento da prescrição dos programas de TR para essa população. De acordo com o nosso conhecimento, até o presente momento, somente três investigações agudas e quatro investigações crônicas de TR foram conduzidas envolvendo OE em idosos. O Quadro 1 apresenta os delineamentos e os resultados desses trabalhos (FARINATTI; DA SILVA; MONTEIRO, 2013; PINA et al., 2013; TOMELERI et al., 2020; CARDOZO et al., 2019; NUNES et al., 2019; DIB et al., 2020) .

**Quadro 1.** Estudos sobre os efeitos agudos ou crônicos de diferentes ordens dos exercícios em programas de TR em idosos.

<b>Autores</b>	<b>Amostra</b>	<b>Duração e frequência</b>	<b>Grupos</b>	<b>Variáveis</b>	<b>Resultados</b>
Farinatti; Da Silva; Monteiro (2013)	Mulheres jovens e idosas	Cinco dias não consecutivos (agudo)	SEQ A = supino máquina, desenvolvimento máquina e tríceps <i>pulley</i> ;  SEQ B = tríceps <i>pulley</i> , desenvolvimento máquina e supino máquina;  (3 X 10 repetições até a fadiga voluntária)	Nº de rep, VO <sub>2</sub> e percepção de esforço	Redução do número de repetições no último exercício da sequência, independente da sequência.  VO <sub>2</sub> máx. e percepção subjetiva de esforço foram mais altas no grupo de idosas no final da SEQB.
Pina et al. (2013)	Homens idosos	Sete semanas, três vezes por semana (crônico)	SEQ A = supino horizontal, puxada articulada, tríceps <i>pulley</i> , rosca direta, cadeira extensora, mesa flexora, cadeira abduutora e cadeira adutora;  SEQ B = rosca direta, tríceps <i>pulley</i> , puxada articulada, supino horizontal, cadeira adutora, cadeira abduutora, mesa flexora e cadeira extensora.  (2 x 10-15 RM, 3x semana)	Água corporal total, massa corporal magra e massa gorda (Bioimpedância)	Não houve nenhuma diferença nas variáveis analisadas.
Tomeleri et al. (2020a)	Mulheres idosas treinadas	Dois semanas (agudo)	SEQ A = supino vertical, remada baixa, tríceps <i>pulley</i> , rosca <i>scott</i> , <i>leg press</i> horizontal, cadeira extensora, mesa flexora e panturrilha sentado. SEQ B = rosca <i>scott</i> , tríceps <i>pulley</i> , remada baixa, supino vertical, panturrilha sentado, mesa flexora, cadeira extensora e <i>leg press</i> horizontal. (3 x 8-12 RM)	Pressão arterial	O treinamento provocou hipotensão arterial pós exercício, independentemente da ordem realizada.

**Quadro 2.** Estudos sobre os efeitos agudos *ou* crônicos de diferentes ordens dos exercícios em programas de TR em idosos (*Continuação*).

Nunes et al. (2019)	Mulheres idosas treinadas	Duas semanas (agudo)	<p>SEQ A = supino vertical, remada baixa, tríceps <i>pulley</i>, rosca <i>scott</i>, <i>leg press</i> horizontal, cadeira extensora, mesa flexora e panturrilha sentado.</p> <p>SEQ B = rosca <i>scott</i>, tríceps <i>pulley</i>, remada baixa, supino vertical, panturrilha sentado, mesa flexora, cadeira extensora e <i>leg press</i> horizontal.</p> <p>(3 x 8-12 RM)</p>	Volume de treino e percepção de esforço.	Volume-total similar. Menor esforço percebido quando os exercícios para membros inferiores foram realizados primeiro.
Cardozo et al. (2019)	Mulheres idosas não-treinadas	12 semanas	<p>SEQ A = <i>leg press</i>, <i>pull down</i>, cadeira extensora, voador, flexão plantar e tríceps <i>pulley</i>;</p> <p>SEQ B = tríceps <i>pulley</i>, flexão plantar, voador, cadeira extensora, <i>pull down</i> e <i>leg press</i>.</p> <p>(3 x 8-10 repetições em forma de circuito, 2x semana)</p>	Força muscular, composição corporal (dobras cutâneas) e testes funcionais.	Ambos os grupos aumentaram massa muscular e reduziram gordura corporal e melhoraram em alguns testes funcionais. Para força muscular, ambos obtiveram melhoras, contudo, houve diferença para os exercícios que foram realizados no início da sessão. Ou seja, quando realizados no início da sessão, apresentou um maior aumento quando comparado com a outra ordem.

**Quadro 3.** Estudos sobre os efeitos agudos *ou* crônicos de diferentes ordens dos exercícios em programas de TR em idosos (*Continuação*).

Tomeleri et al. (2020b)	Mulheres idosas treinadas	12 semanas (crônico)	<p>SEQ A = supino vertical, remada baixa, tríceps <i>pulley</i>, rosca <i>scott</i>, <i>leg press</i> horizontal, cadeira extensora, mesa flexora e panturrilha sentado.</p> <p>SEQ B = rosca <i>scott</i>, tríceps <i>pulley</i>, remada baixa, supino vertical, panturrilha sentado, mesa flexora, cadeira extensora e <i>leg press</i> horizontal.</p> <p>3 x 10-15 repetições, 3x semana)</p>	Força muscular, massa muscular, testosterona, IGF-1	Ambos os grupos de treinamento melhoraram força e massa muscular após a intervenção quando comparado com o grupo controle, independentemente da ordem executada. Testosterona e IGF-1 não sofreram alterações.
Dib et al. (2020)	Mulheres idosas treinadas	12 semanas (crônico)	<p>SEQ A = supino vertical, remada baixa, tríceps <i>pulley</i>, rosca <i>scott</i>, <i>leg press</i> horizontal, cadeira extensora, mesa flexora e panturrilha sentado.</p> <p>SEQ B = rosca <i>scott</i>, tríceps <i>pulley</i>, remada baixa, supino vertical, panturrilha sentado, mesa flexora, cadeira extensora e <i>leg press</i> horizontal.</p> <p>SEQ C = supino vertical, <i>leg press</i> horizontal, remada baixa, cadeira extensora, tríceps <i>pulley</i>, mesa flexora, rosca <i>scott</i>, panturrilha sentado.</p> <p>(oito exercícios, 15/10/5 repetições, 3x semana)</p>	Força muscular, massa muscular e gordura corporal e capacidade funcional.	Para todas as variáveis exceto para gordura corporal e um teste funcional (levantar-se e caminhar pela casa), foi observado melhora em todos os grupos, sem diferença entre eles. Concluindo que a ordem não impactou nas adaptações observadas.

Os resultados apresentados no Quadro 1 indicam que, na maioria dos estudos, a OE não afetou a magnitude das respostas agudas e crônicas. Entretanto, exceto o estudo de Nunes et al. (2019), as demais investigações se limitaram a comparar somente duas OE. Embora tais análises sejam importantes, a comparação de outras possíveis OE pode conduzir a uma melhor compreensão deste fenômeno, agregando novos elementos para a tomada de decisão mais segura e adequada para a prescrição de programas de TR para idosos.

Vale destacar que no estudo de Nunes et al. (2019), embora nenhuma diferença estatisticamente significativa tenha sido identificada na comparação entre as OE para o número de repetições totais, carga de treino e volume-total, quando os exercícios para membros inferiores foram realizados anteriormente àqueles para membros superiores (condições Multi-Mono-Inf e Mono-Multi-Inf), foi observada uma menor percepção subjetiva de esforço (PSE) em quase todos exercícios, de membros superiores e inferiores, bem como na PSE média da sessão. Portanto, com base na menor PSE acredita-se que seja possível adicionar mais volume-carga em todos os exercícios, podendo assim resultar em um maior progresso ao treinamento e, provavelmente, em adaptações crônicas de maior magnitude para o corpo todo.

Nesse sentido, além do maior ganho de força e massa muscular esperado a partir da adoção de uma OE que possibilite maior volume-total (ACSM, 2009a; SIMÃO et al., 2012a; TOMELERI et al., 2018; NUNES et al., 2021a), estudos recentes indicam que maiores volumes de TR podem também estar associados com maiores reduções na gordura corporal e em indicadores de perfil lipídico, glicêmico e inflamatório (NUNES et al., 2016; SARDELI et al., 2018; CUNHA et al., 2021a). A melhoria de indicadores inflamatórios é um mecanismo-chave para a redução de sintomas de depressão e ansiedade, bem como a melhora de diversas funções cognitivas (JEDRZIEWSKI; LEE; TROJANOWSKI, 2007; KANDOLA et al., 2018, 2019). Portanto, é plausível hipotetizar que programas de TR que iniciem por membros inferiores poderiam acumular maior volume-total e induzir maiores benefícios nesses parâmetros.

Adicionalmente, por conta do princípio da especificidade, iniciar o TR pelos exercícios de membros inferiores talvez possa gerar maiores benefícios para a funcionalidade deste segmento; adaptação que é de suma importância para a população idosa, uma vez que a principal redução de força e massa muscular em idosos ocorre na em membros inferiores (MILJKOVIC et al., 2015). De todo modo, as informações

produzidas por estudos agudos não devem ser extrapoladas para estudos crônicos. Logo, maior esforço deve ser dedicado a realização de estudos crônicos, de intervenção com TR em diferentes OE, especialmente em idosos, enfocando desfechos que envolvem diferentes dimensões da saúde, incluindo aspectos morfológicos, funcionais metabólicos e cognitivos.

Por fim, considerando a grande variabilidades nas respostas adaptativas individuais ao TR, delineamentos experimentais que adotam grupos em paralelo podem limitar uma análise mais robusta do impacto da manipulação das variáveis de treino sobre os desfechos analisados. Portanto, a utilização de delineamentos experimentais que permitam que a amostras sejam expostas as diferentes condições experimentais, sempre que possível, pode fornecer informações mais consistentes para uma melhor compreensão do fenômeno. Neste sentido, de acordo com o nosso conhecimento, até o presente momento nenhum estudo crônico disponível na literatura sobre o efeito de diferentes OE em programas de TR adotou tal delineamento. Tais informações são de extrema relevância para o avanço do conhecimento na área do TR aplicado a população idosa.

## **2 OBJETIVOS**

### **2.1 Objetivo geral**

Analisar o efeito de quatro OE em um programa de TR sobre a composição corporal, força muscular, aptidão funcional, biomarcadores sanguíneos e saúde mental em mulheres idosas treinadas.

### **2.2 Objetivos específicos**

Considerando que a presente tese foi estruturada no modelo escandinavo, pelo qual a contextualização do problema dá origem ao estabelecimento de diferentes objetivos, que por sua vez são analisados a partir da redação de artigos científicos, a proposta envolveu a redação de dois artigos originais, cujos objetivos específicos foram:

ARTIGO 1. Analisar o efeito de quatro OE em programa de TR sobre a força muscular, massa muscular e capacidade funcional em idosas treinadas;

ARTIGO 2. Verificar o efeito de quatro OE em programa de TR sobre a gordura corporal, biomarcadores sanguíneos (perfil lipídico e glicêmico, proteína C-reativa, biomarcadores de estresse oxidativo e BDNF) e parâmetros de saúde mental em idosas treinadas.

### 3 HIPÓTESES

Considerando os quatro grupos experimentais adotados nesta investigação e com base nas informações disponíveis na literatura até o presente momento, as principais hipóteses deste estudo são:

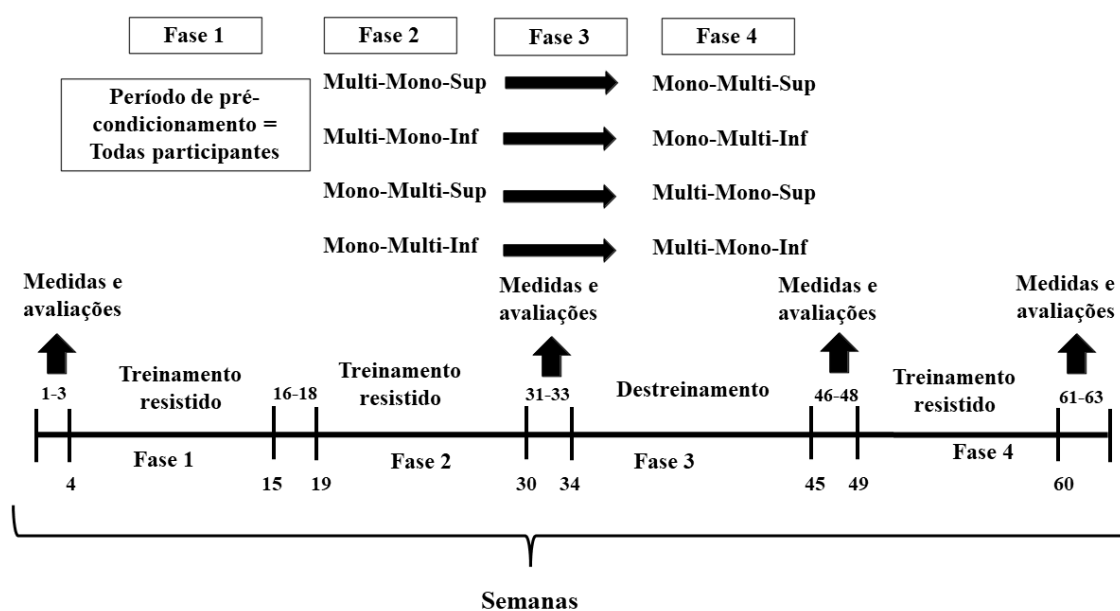
- a) Os ganhos de força de 1RM deveriam seguir o princípio da especificidade, ou seja:
  - O grupo que iniciar o programa de TR por exercícios multiarticulares para membros superiores/tronco deve alcançar maiores ganhos de força muscular no exercício supino vertical;
  - O grupo que iniciar o programa de TR por exercícios mono-articulares para membros inferiores deve alcançar maiores ganhos de força muscular no exercício cadeira extensora;
  - O grupo que iniciar o programa de TR por exercícios mono-articulares para membros superiores/tronco deve alcançar maiores ganhos de força muscular no exercício rosca scott;
  
- b) O maior volume-carga total deve ser registrado nos grupos que começarem o TR por membros inferiores;
  
- c) Respostas adaptativas de maior magnitude para a força, massa muscular e aptidão funcional deverão ser atingidas nos grupos que começarem o TR por membros inferiores;
  
- d) A força e massa muscular de membros superiores deverão ocorrer nos grupos que começarem o programa de TR por membros superiores/tronco;
  
- e) O grupo que alcançar o maior volume-carga total apresentará uma melhor resposta adaptativa nos desfechos metabólicos, na adiposidade corporal e nos parâmetros de saúde mental.

## 4 MÉTODOS

### 4.1 Delineamento experimental

O presente estudo faz parte do projeto de pesquisa denominado *Active Aging Longitudinal Study*, iniciado em 2012, cujos propósitos incluem a análise da eficácia e eficiência de programas de TR supervisionados, estruturados e progressivos sobre desfechos neuromusculares, morfológicos, fisiológicos, metabólicos, cognitivos e comportamentais em mulheres idosas. A amostra do presente estudo foi constituída pela coorte anual de participantes do ano de 2018 deste projeto de pesquisa. Este estudo é um ensaio clínico randomizado com delineamento cruzado.

A presente investigação foi realizada ao longo de 63 semanas, divididas em 4 fases (pré-condicionamento, treinamento em quatro diferentes OE, destreino, retreinamento em diferentes OE). Blocos de três semanas consecutivas (1–3, 16–18, 31–33, 46–48 e 61–63) foram utilizados para medidas, testes e avaliações. A intervenção com TR ocorreu em três blocos de 12 semanas. No primeiro desses três blocos (semanas 4–15), as participantes passaram por uma fase de pré-condicionamento de 12 semanas, cujo programa de TR foi similar para todos as participantes. No segundo bloco (semanas 19–30), as participantes foram separadas aleatoriamente em quatro grupos para realizar um programa de TR, de acordo com quatro diferentes OE, a saber: multi- para mono-articulares, começando por membros superiores/tronco (Multi-Mono-Sup), multi- para mono-articulares, começando por membros inferiores (Multi-Mono-Inf), mono- para multi-articulares, começando por membros superiores/tronco (Mono-Multi-Sup), e mono- para multi-articulares, começando por membros inferiores (Mono-Multi-Inf). Em seguida, as participantes passaram por 12 semanas de destreino (semanas 34–45), nas quais todas as participantes foram solicitadas a não se envolver em nenhum tipo de exercício físico durante este período. Por fim, no terceiro bloco de TR (semanas 49–60), as participantes foram retreinadas, modificando a OE dos exercício mono-articulares para os multi-articulares ou vice-versa, de acordo com o segmento determinado na separação inicial dos grupos para iniciar as sessões de treinamento, ou seja, membros superiores/tronco ou membros inferiores.



## 4.2 Participantes

O recrutamento foi realizado por meio de anúncios em mídias sociais (*Whatsapp*, Facebook e Instagram) e divulgação entre as participantes que já faziam parte do projeto nos anos anteriores. Uma anamnese foi realizada, inicialmente, para conhecimento do histórico de saúde das voluntárias. Somente foram admitidas no estudo as voluntárias que atendessem aos seguintes critérios de inclusão: idade > 60 anos; ser do sexo feminino; ser fisicamente independente; não ter disfunção cardíaca, ortopédica ou musculoesquelética que pudesse impedir a realização de exercícios físicos; não ser portadora de diabetes mellitus ou hipertensão não-controlada; não estar recebendo terapia de reposição hormonal; e estar afastada há pelo menos três meses da prática regular de exercícios físicos. Posteriormente, as participantes deveriam apresentar um laudo favorável de um cardiologista liberando para praticar o TR sem restrições (teste de eletrocardiograma de 12 derivações em repouso, entrevista pessoal e teste de esforço em esteira quando necessário).

O cálculo amostral foi estabelecido por meio do *GPower* software. Para tanto, com base em um poder estatístico (probabilidade de erro  $1 - \beta$ ) de 0,80, um tamanho de efeito  $F = 0,27$  e um nível  $\alpha$  geral de 0,05, e com a utilização da massa muscular esquelética como variável critério e baseado em informações disponíveis na literatura (RIBEIRO et al., 2017), um tamanho de amostra de 56 indivíduos totais (14 participantes por grupo) foi necessário para este estudo. Devido a possíveis perdas e evasões, um adicional de

aproximadamente 25% (+14 participantes) se mostrou necessário, resultando em uma amostra inicial de 72 mulheres.

Portanto, 84 candidatas foram entrevistadas e 72 foram selecionadas. Durante a fase pré-condicionamento, 11 participantes abandonaram o estudo. Em seguida, um pesquisador não envolvido com a investigação ficou responsável por fazer a randomização, por meio do site *random.org*, das 61 participantes em um dos quatro grupos de TR de acordo com as quatro OE adotadas para este estudo. Durante a fase 1, cinco participantes abandonaram o estudo, todas do grupo Mono-Multi-Sup. Após o período de destreinamento, todas participantes voltaram para a fase 2, que iniciou com 56 participantes. Durante a fase 2, oito participantes abandonaram o estudo (Multi-Mono-Sup = 0; Mono-Multi-Sup = 2; Multi-Mono-Inf = 4; Mono-Multi-Inf = 2). Os motivos relatados para o abandono do estudo foram falta de tempo, desmotivação, problemas de transporte, cirurgias de urgência não relacionadas ao treinamento, necessidade de cuidar de familiares e outros motivos pessoais. Portanto, foi analisada uma amostra final de 48 participantes, de modo que 24 participantes compuseram cada um dos quatro grupos experimentais, considerando o delineamento cruzado. Todas as participantes receberam informações sobre a finalidade e os procedimentos do estudo e assinaram um TERMO de Consentimento Livre e Esclarecido (APÊNDICE A). Este estudo foi conduzido de acordo com a Declaração de Helsinque e aprovado pelo Comitê de Ética da Universidade (ANEXO A).

### **4.3 Antropometria**

A massa corporal foi mensurada em uma balança de leitura digital (Balmak Indústria e Comércio Ltda, Santa Bárbara d'Oeste, SP, Brasil), com escala de 0,1 kg, ao passo que a estatura foi determinada por meio de um estadiômetro acoplado à mesma, com escala de 0,1 cm, com selo do INMETRO, de acordo com os procedimentos descritos na literatura (GORDON; CHUNLEA; ROCHE, 1988). A partir dessas medidas, foi calculado o índice de massa corporal (IMC), por meio da razão entre a massa corporal e o quadrado da estatura, sendo a massa corporal expressa em quilogramas (kg) e a estatura em metros (m).

### **4.4 Composição corporal**

Exames de absorptometria radiológica de dupla energia (DXA), com escaneamento de corpo inteiro, foram realizados em um equipamento Lunar, modelo NRL 419900 (GE

Lunar, Madison, WI, USA), para determinação da massa isenta de gordura e osso (MIGO) de tronco, membros superiores e inferiores, gordura corporal absoluta e relativa, bem como a distribuição da gordura (androide e ginoide). Para tanto, as participantes foram instruídas a remover todos os objetos móveis contendo metal, antes de serem avaliadas. Durante o exame as participantes foram posicionadas na mesa do equipamento em decúbito dorsal. Os pés foram fixados paralelamente para imobilizar as pernas por meio de uma fita de velcro, enquanto as mãos foram mantidas na posição pronada dentro da região de varredura. A calibração do equipamento seguiu as recomendações do fabricante. Um software específico gerou linhas padrão que separaram membros, tronco e cabeça, utilizando pontos anatômicos específicos determinados pelo fabricante. Um técnico de laboratório com experiência nesse tipo de exame realizou calibrações do equipamento, ajustes das linhas e as análises. Exames anteriores do nosso laboratório com 13 participantes do projeto conferiram confiabilidade satisfatória para todas as medidas realizadas ( $ICC \geq 0,98$ ).

#### **4.5 Força muscular**

A força dinâmica máxima foi avaliada por meio de testes de 1RM executados nos exercícios supino vertical, cadeira extensora e rosca scott, respectivamente. Uma sessão de familiarização e três sessões de testes de 1RM foram realizadas pela manhã, separadas por 48-72 h. Para a sessão de familiarização, as participantes realizaram 2-3 séries de 10-15 repetições em cada exercício com uma carga leve. Três pesquisadores experientes supervisionaram todas as sessões para a segurança e integridade das participantes. A técnica de execução de cada exercício foi padronizada e continuamente monitorada para garantir a confiabilidade das medidas. Para cada sessão de teste, as participantes realizaram um aquecimento específico (6-10 repetições), em cada exercício, com aproximadamente 50% da carga estimada para a primeira tentativa. No primeiro dia de testes, a carga selecionada foi baseada na experiência dos pesquisadores, na carga utilizada individualmente na familiarização e na percepção da dificuldade (esforço) em que os sujeitos realizaram o aquecimento. Durante os testes de 1RM, as participantes foram incentivadas a tentar executar duas repetições com a carga selecionada. Incentivo verbal, acompanhado de palmas, foi fornecido as participantes pelos avaliadores em todas as tentativas, nos diferentes exercícios (NUNES et al., 2020). Nas situações cujas tentativas foram executadas com sucesso, a carga foi aumentada para a próxima tentativa na ordem de 3-10%. Por outro lado, nas situações cujas

tentativas não foram executadas com sucesso, a carga foi reduzida na mesma proporção. O período de descanso foi de três a cinco minutos entre cada tentativa e cinco minutos entre os exercícios. A carga para a primeira tentativa, na segunda e terceira sessão de testes foi a carga máxima obtida individualmente em cada exercício na sessão anterior. O valor de 1RM em cada exercício foi registrado como a carga mais alta levantada em uma única ação voluntária máxima concêntrica e excêntrica nas três sessões de testes (NASCIMENTO et al., 2013). Os valores de erro padrão de medida (EPM) e o coeficiente de correlação intraclasse (CCI) obtidos da atual amostra foram satisfatórios para o supino vertical (EPM = 1,7 kg; CCI = 0,98), cadeira extensora (EPM = 2,0 kg; CCI = 0,97) e rosca scott (EPM = 0,4 kg; CCI = 0,99).

#### **4.6 Bioquímica sanguínea**

Coletas de sangue venoso (14 ml) foram realizadas na porção antecubital, no período matutino, após jejum de 12 h, por um experiente técnico de laboratório, em sala adaptada para este fim, para a determinação dos seguintes biomarcadores: glicose, hemoglobina glicada, HDL-c, LDL-c, triglicerídeos, colesterol total, proteína C-reativa ultrasensível (PCR), fator neutrótico derivado do cérebro (BDNF), produtos proteicos de oxidação avançada (AOPP), parâmetro antioxidante de radicais totais (TRAP) e metabólitos do óxido nítrico (NOx). As dosagens foram realizadas em laboratório especializado no Hospital Universitário da Universidade Estadual de Londrina. Para a coleta de sangue, as participantes permaneceram sentadas em uma cadeira, com o antebraço apoiado sobre um suporte, localizado aproximadamente na altura dos ombros. Após o braço ser garroteado no ponto médio do úmero foi realizada a assepsia com algodão embebido em álcool 70%. A punção foi realizada com agulha descartável de 25 X 8 mm no referido local.

O sangue venoso foi aspirado em quatro tubos de coleta a vácuo (dois tubos com gel separador, um tubo com fluoreto e um tubo com EDTA como anticoagulantes e conservantes). As agulhas foram descartadas, seguindo o disposto nos procedimentos operacionais padrão do laboratório clínico, assim como todos os outros materiais descartáveis contaminados, tanto no procedimento de coleta, quanto nas análises sanguíneas. As amostras e centrifugadas por 10 min a 3.000 rpm para separação do soro e/ou plasma. Imediatamente após a coleta, foram determinadas as concentrações de triglicerídeos, colesterol total e sua fração HDL-c, proteína PCR-us e glicose em um auto-analisador bioquímico Dimension RxL Max (Siemens Healthcare Diagnostics, Malvern,

PA, USA) de acordo com métodos consagrados na literatura especializada, seguindo os protocolos recomendados pelos fabricantes, utilizando-se kits Siemens. Para a determinação de LDL-c foi utilizada a seguinte equação (FRIEDEWALD; LEVY; FREDRICKSON, 1972):  $LDL-c = CT - HDL-c + (triglicerídeos/5)$ . Para as demais análises, o soro foi liquotado e armazenado em freezer a  $-80^{\circ}C$  (Indrel<sup>®</sup>) até a realização do doseamento. O BDNF foi determinado posteriormente por ensaio imunoenzimático (ELISA), de acordo com as especificações do fabricante (R&D Systems, Minneapolis, MN, USA), utilizando-se kit *Quantikine High Sensitivity*. AOPP e TRAPP foram determinados no plasma usando um método semiautomático (WITKO-SARSAT et al., 1996) REPETTO et al., 1996). Este método detecta antioxidantes plasmáticos hidrossolúveis e / ou lipossolúveis medindo o tempo de inibição da quimioluminescência induzido por 2-amidinopropano. O sistema foi calibrado com o análogo da vitamina E Trolox<sup>®</sup>. As concentrações de metabólitos de óxido nítrico (NOx) sérico foram avaliadas pela concentração de nitrito ( $NO_2^-$ ) e nitrato ( $NO_3^-$ ), de acordo com a reação de Griess, complementada pela redução de nitrato a nitrito com cádmio (GUEVARA et al., 1998).

## **4.7 Avaliações cognitivas**

### **4.7.1 Montreal Cognitive Assessment**

O teste de Avaliação Cognitiva Montreal - *Montreal Cognitive Assessment* (MoCA) foi utilizado para a avaliação de oito domínios cognitivos, os quais foram pontuados dentro de um intervalo de 0 a 30 pontos (scores mais altos indicando melhor função): memória de curto prazo (recordação tardia, cinco pontos); habilidades viso-espaciais (desenho do cubo, um ponto, desenho do relógio, três pontos); função executiva (teste de trilha, um ponto; fluência verbal fonêmica, um ponto; abstração verbal, dois pontos); atenção, concentração e, memória de trabalho (cancelamento, um ponto; subtração, três pontos; amplitude de dígitos, dois pontos); linguagem (nomeação, três pontos; repetição de frase, dois pontos); e orientação ao tempo (três pontos) e espaço (três pontos). O MoCA apresenta alta sensibilidade (81%) e especificidade (77%), conforme determinado em idosos brasileiros (NASREDDINE et al., 2005; MEMÓRIA et al., 2013).

### **4.7.2 Trail Making Test**

O teste de trilhas - *Trail Making Test* (A e B) foi utilizado para avaliação da função executiva e atenção (REITAN, 1958). A parte A determina a velocidade psicomotora e

exige que a avaliada desenhe linhas que conectam números circundados sequencialmente, como desenhar uma linha de 1 a 2, 2 a 3 e 3 a 4. A parte B consiste em números e letras circundados. As participantes foram instruídas a desenhar uma linha o mais rapidamente e com a máxima precisão possível de 1 para A, A para 2, 2 para B, B para 3, e assim por diante, até a finalização da tarefa. O tempo foi registrado em segundos após o término de cada etapa. Após a realização dos testes foram calculadas as diferenças entre os tempos de conclusão da parte B - A. Quanto menor a diferença melhor é o ajuste de deslocamento.

#### **4.7.3 Stroop Test**

Uma versão computadorizada do teste de cores e palavras (*Stroop test*) foi utilizada nesse estudo, usando o programa Testinpacs® (CÓRDOVA et al., 2008). As tarefas foram visualizadas em uma tela de notebook a aproximadamente 90 cm de distância da participante. As respostas para um conjunto de tarefas foram dadas o mais rápido possível por meio de dois botões. A porção cognitiva foi utilizada como teste psicométrico para avaliar a cognição, estando relacionada às funções executivas de tomada de decisão e controle inibitório exercidas pelo córtex pré-frontal. O efeito é baseado em situações de tarefas nas quais os nomes de cores são gravados em diferentes fontes de cores. O indivíduo deve inibir o significado da palavra e escolher a resposta correta correspondente à cor na qual a palavra aparece escrita (SCHACK et al., 1999). O estudo atual utilizou o teste em três estágios: os dois primeiros estágios foram condições de controle (indicar a cor do retângulo; indicar o nome da cor que aparece escrito) e o último estágio foi incongruente (responde à cor que está pintada a palavra). No primeiro estágio, retângulos nas cores verde, azul, preto e vermelho foram exibidos no centro da tela. Ao mesmo tempo, as respostas que corresponderam ou não à cor do retângulo foram exibidas nos cantos inferiores da tela. Cada estímulo foi apresentado até o momento em que a participante indicasse a cor nos cantos inferiores, correspondente à cor do retângulo. Por fim, na terceira e última etapa do teste, o nome de uma das quatro cores foi exibido com uma cor de fonte diferente. As participantes foram instruídas a pressionar o botão correspondente à cor da fonte e ignorar o nome da cor. Os estímulos foram apresentados aleatoriamente em todas as etapas (12 tentativas por estágio). A capacidade de atenção seletiva e controle das respostas foi estimada como a diferença de tempo entre a terceira condição e a segunda condição. As menores diferenças indicaram melhor atenção seletiva e resolução de conflitos.

#### **4.7.4 Fluência Verbal Semântica e Fonológica**

Na modalidade fonológica foi utilizada tarefa de fluência verbal F. A tarefa consistiu na evocação de palavras que começam com a letra “F”, por 60 s. A pontuação final foi determinada de acordo com o número de palavras corretas relatadas em 60 s. Na modalidade semântica as participantes foram instruídas a evocar o maior número possível de animais em 60 s. A pontuação final foi determinada de acordo com o número de nomes de animais relatados em 60 s (ESTEVES et al., 2015).

#### **4.8 Aptidão funcional**

O teste de caminhada de seis minutos (TC6min) foi utilizado como indicador de aptidão cardiorrespiratória. Cada participante percorreu a maior distância possível, sem correr, em torno de um trajeto retangular (4,6 x 18,4 m, perímetro total: 46,0 m) demarcado com fitas e cones no chão. Um avaliador cronometrou o tempo de duração do teste e calculou a distância total percorrida, com precisão de um metro.

Para avaliação da aptidão funcional foram adotados mais três testes motores: teste de caminhada de 4,6 m, teste de agilidade de caminhada e teste sentar e levantar da cadeira por 30 s (RIKLI; JONES, 2013). Para o teste de caminhada de 4,6 m, três avaliadores utilizaram cronômetros para medir o tempo gasto pelas participantes para percorrer um trajeto de 4,6 m na velocidade normal de caminhada. Fitas adesivas no chão demarcaram essa distância com remendos adicionais de 2 m antes e depois do remendo principal de 4,6 m. As participantes caminharam 8,6 m completos, mas apenas o tempo gasto para caminhar 4,6 m do meio foi cronometrado com aproximação de 0,01 s. As participantes completaram três tentativas, sendo registrado o valor médio entre as tentativas. Para o teste de agilidade, as participantes foram sentadas em uma cadeira apoiada em uma parede, com as costas em contato com o encosto, os pés totalmente apoiados no chão e as mãos apoiadas nas coxas. As participantes foram solicitadas a levantar-se, caminhar ao redor de um cone a uma distância de 2,44 m em frente à cadeira, retornar à cadeira e sentar-se. As participantes foram instruídas a completar o trajeto no menor tempo possível, sem correr. O tempo foi registrado com precisão de 0,01 s com um cronômetro do movimento inicial para se levantar da cadeira até o retorno para sentar-se, novamente. As participantes completaram três tentativas, sendo registrada a melhor tentativa. Para o teste sentar e levantar da cadeira de 30 s, as participantes foram posicionadas sentadas em uma cadeira apoiada em uma parede, com as costas em

contato com o encosto, os pés totalmente apoiados no chão e as mãos cruzadas para repousar sobre os ombros opostos. As participantes realizaram o máximo de repetições possíveis em 30 s.

#### **4.9 Sintomas de depressão e ansiedade**

Os níveis de sintomas de depressão e ansiedade foram avaliados por meio de dois questionários: Escala de Depressão Geriátrica (GDS-15) (YESAVAGE et al., 1982) e Inventário de Ansiedade de Beck (BAI) (BECK et al., 1988). O GDS-15 é composto por 15 itens dicotômicos (sim ou não) relativos a diferentes características da depressão geriátrica como declínio cognitivo e sintomas somáticos, com pontuação final variando de 0 a 15. O BAI é composto por 21 itens (afirmações) sobre diferentes sintomas de ansiedade com um Escala Likert de 4 pontos, com pontuação final variando de 0 a 63.

#### **4.10 Hábitos alimentares**

A ingestão alimentar foi estimada a partir de recordatórios de 24 h, nas duas primeiras e nas duas últimas semanas de cada etapa do estudo. As entrevistas foram realizadas em dois dias diferentes, sendo um dia de semana e outro do fim de semana. Para auxiliar as entrevistas, foi utilizado um registro fotográfico padronizado contendo fotos dos alimentos e porções. O valor energético total e a quantidade de macronutrientes ingeridos foram calculados por meio do programa de análise nutricional Virtual Nutri Plus (Keeple, Rio de Janeiro, RJ, Brasil). Todos os alimentos que não fossem encontrados no banco de dados do programa foram adicionados nas tabelas de alimentos. O programa estatístico do método de fontes múltiplas foi utilizado para reduzir erros na estimativa do consumo alimentar habitual (<https://msm.dife.de>). Esse programa gera informações sobre a ingestão habitual estimada, a partir da combinação das probabilidades, usando repetições de recordatórios alimentares de 24 h (HAUBROCK et al., 2011).

#### **4.11 Programa de treinamento resistido**

O programa de treinamento foi estruturado com a finalidade de proporcionar melhoria da força e da massa muscular em idosos (ACSM, 2009a, 2009b). Todas as participantes foram supervisionadas individualmente por profissionais e estudantes de Educação Física com experiência em TR (dois por exercício), na tentativa de manter a

qualidade de execução dos exercícios e garantir a segurança das participantes. O programa de TR foi executado em máquinas e pesos livres (Ipiranga Fitness, Presidente Prudente, SP, Brasil) e incluiu oito exercícios para os diferentes segmentos corporais (braços, pernas e tronco). Na fase pré-condicionamento, as participantes realizaram três séries de 10-15 repetições, ao passo que nas fases específicas (fase 1 e 2), as participantes realizaram as séries em 8-12 repetições. As participantes foram instruídas a manterem a velocidade de execução dos movimentos na razão de 1:2 (ação muscular concêntrica e excêntrica, respectivamente). O intervalo de descanso entre as séries foi de um a dois minutos, ao passo que o intervalo de transição entre os exercícios foi de dois a três minutos. Durante todo o período de treinamento, as cargas foram ajustadas individualmente em cada exercício sempre que o limite superior de repetições da zona-alvo estabelecida fosse atingido (10-15 ou 8-12 repetições) por duas sessões consecutivas, nas três séries. Os aumentos de carga foram na ordem de 2% a 5% para os exercícios de membros superiores e 5% a 10% para os exercícios de membros inferiores, conforme as recomendações da literatura (ACSM, 2009a). A organização do programa em cada grupo nas fases específicas do experimento é apresentada no Quadro 2.

**Quadro 4.** Ordem dos exercícios realizados, de acordo com cada grupo experimental.

	<b>Multi-Mono-Sup</b>	<b>Mono-Multi-Sup</b>	<b>Multi-Mono-Inf</b>	<b>Mono-Multi-Inf</b>
1	Supino vertical	Rosca <i>scott</i>	<i>Leg press</i> horizontal	Panturrilha sentada
2	Remada baixa	Tríceps na polia	Cadeira extensora	Cadeira flexora
3	Tríceps na polia	Remada baixa	Cadeira flexora	Cadeira extensora
4	Rosca <i>scott</i>	Supino vertical	Panturrilha sentada	<i>Leg press</i> horizontal
5	<i>Leg press</i> horizontal	Panturrilha sentada	Supino vertical	Rosca <i>scott</i>
6	Cadeira extensora	Cadeira flexora	Remada baixa	Tríceps na polia
7	Cadeira flexora	Cadeira extensora	Tríceps na polia	Remada baixa
8	Panturrilha sentada	<i>Leg press</i> horizontal	Rosca <i>scott</i>	Supino vertical

**Nota:** Multi-Mono-Sup = grupo que realizou o treinamento na ordem dos exercícios multi- para os mono-articulares, iniciando pelos membros superiores. Mono-Multi-Sup = grupo que realizou o treinamento na ordem dos exercícios mono- para os multi-articulares, iniciando pelos membros superiores. Multi-Mono-Inf = grupo que realizou o treinamento na ordem dos exercícios multi- para os mono-articulares, iniciando pelos membros inferiores. Mono-Multi-Inf = grupo que

realizou o treinamento na ordem dos exercícios mono- para os multi-articulares, iniciando pelos membros inferiores.

#### **4.12 Tratamento estatístico**

O teste de Shapiro-Wilk foi utilizado para análise da distribuição dos dados. As características gerais das participantes foram comparadas por meio ANOVA *one-way* e qui-quadrado, para variáveis contínuas e categóricas, respectivamente. Análise de covariância (ANCOVA) da diferença bruta entre as medidas pré e pós-intervenção foi empregada para comparar as mudanças dentro e entre os grupos, com os valores de linha de base usados como covariável. A interpretação dos dados foi baseada no intervalo de confiança de 95%, ou seja, quando o IC95% do delta bruto não se sobrepôs a 0, houve uma diferença significativa entre a pontuação da linha de base. Embora tenhamos apresentado dados ajustados e não ajustados pela ANCOVA para os desfechos principais, as interpretações estatísticas foram feitas com os resultados da ANCOVA. Para todas as análises foi adotado um nível de significância de 5%. O tamanho do efeito foi calculado como a média pós menos a média pré dividida pelo desvio-padrão agrupado (COHEN, 1988). Tamanho do efeito de 0,00–0,19 foi considerado trivial, 0,20–0,49 foi considerado pequeno, 0,50–0,79 foi considerado moderado e  $\geq 0,80$  foi considerado grande. Os dados foram analisados pelo software Statistica para Windows, versão 10.0 (Statsoft Inc., Tulsa, OK, USA).

## 5 RESULTADOS

Os resultados do presente estudo foram organizados a partir da redação de dois artigos originais. As variáveis força muscular, massa muscular e aptidão funcional foram tratadas no primeiro artigo. Por outro lado, as variáveis gordura corporal, biomarcadores sanguíneos e testes relacionados à saúde mental (testes cognitivos, questionários relacionados a sintomas de depressão e ansiedade) foram analisadas no segundo artigo.

Na sequência são apresentados os dois artigos que tratam de informações complementares.

## 5.1 Artigo original 1

### **Effects of four resistance exercise orders on muscular strength, muscle mass, and functional fitness in trained older women: A randomized crossover study**

**Running head:** Exercise order and muscular development in older women

**Authors:** Paolo M. Cunha<sup>1,\*§</sup>, João Pedro Nunes<sup>1,§</sup>, Alex S. Ribeiro<sup>1,2</sup>, Witalo Kassiano<sup>1</sup>, Bruna D. V. Costa<sup>1</sup>, Leticia T. Cyrino<sup>1</sup>, Melissa Antunes<sup>1</sup>, Gabriel Kunevaliki<sup>1</sup>, Denilson C. Teixeira<sup>3</sup>, Jerry L. Mayhew<sup>4</sup>, Edilson S. Cyrino<sup>1</sup>.

**Affiliations:**

1. Metabolism, Nutrition, and Exercise Laboratory. Physical Education and Sport Center, State University of Londrina. Londrina, PR, Brazil;
2. Center for Research in Health Sciences. University of Northern Paraná. Londrina, PR, Brazil;
3. Study and Research Group on Human Aging and Physical Activity. Physical Education and Sport Center, State University of Londrina. Londrina, PR, Brazil;
4. Exercise Science Program, Truman State University. Kirksville, MO, USA.

§Paolo M. Cunha and João Pedro Nunes share the first authorship for contributing equally to this work.

**\*Corresponding author:** Paolo M. Cunha. Metabolism, Nutrition, and Exercise Laboratory. Physical Education and Sport Center, State University of Londrina. Rodovia Celso Garcia Cid, km 380, Londrina, PR, Brazil. Zip-code: 86057-970. e-mail: pcunha88@hotmail.com.

## ABSTRACT

**Background:** The manipulation of acute variables in resistance training (RT) programs is necessary to obtain adequate adaptations for older adults. The influence of exercise order is underexplored in the literature. **Aim:** To compare the effects of different exercise orders on muscular strength, muscle mass, and functional fitness in trained older women. **Methods:** Physically independent women (> 60 years) completed a 12-week RT pre-conditioning phase (eight exercises, 3 X 10-15 repetitions, 3x/week). Before this period, the participants were randomized to four different exercise orders groups to 12-week RT (eight exercises, 3 X 8-12 repetitions, 3x/week), 12-week detraining, and 12-week RT in a cross-over design. The exercise orders were the following: multi- to single-joint and upper- to lower-body (MJ-SJ-U, n = 24); single- to multi-joint and upper- to lower-body (SJ-MJ-U, n = 24); multi- to single-joint and lower- to upper-body (MJ-SJ-L, n = 24); and single- to multi-joint and lower- to upper-body (SJ-MJ-L, n = 24). Muscle mass was determined from DXA, muscular strength was assessed by 1RM tests, and functional fitness was analyzed from three motor tests. **Results:** Following the final training period, all groups presented significant improvements in almost all analyzed variables (effect size: muscular strength = 0.17–0.58; muscle mass = 0.16–0.22; functional fitness = -0.11–0.50). However, no significant difference was observed between conditions ( $P > 0.05$ ; effect size of trivial-to-small magnitudes). **Conclusion:** Our results suggest that exercise order does not significantly affect the magnitude of their adaptations in trained older women.

**Keywords:** aging; strength training; volume-load; exercise sequence; hypertrophy.

## INTRODUCTION

Resistance training (RT) is an effective strategy to counteract several adverse effects of the aging process (WESTCOTT, 2012b; FRAGALA et al., 2019). RT can contribute with improvement of functional fitness (SANTOS et al., 2017; FRAGALA et al., 2019), potentially providing a more active lifestyle with greater autonomy and quality (BRIAN C., CLARK E MANINI, 2010; EVANS, 2010; MCGREGOR; CAMERON-SMITH; POPPITT, 2014), which may ultimately increase life expectancy (DANKEL; LOENNEKE; LOPRINZI, 2016). Manipulating the variables that compose the RT programs may be necessary to obtain the main benefits of RT (ACSM, 2009a; FRAGALA et al., 2019), which are related to volume (SCHOENFELD et al., 2018; NUNES et al., 2021a), intensity (SCHOENFELD et al., 2017), and structure, such as the variables exercise selection and exercise order (EO) (RIBEIRO et al., 2019; RIBEIRO; NUNES; SCHOENFELD, 2020; NUNES et al., 2021a).

The EO is an essential element to consider in the RT prescription. It can influence acute training volume and intensity and, consequently, chronic adaptations (RIBEIRO et al., 2019; NUNES et al., 2021a). The American College of Sports Medicine recommends performing multi-joint (MJ) exercises that involve larger muscle groups first, followed by single-joint (SJ) exercises that involve smaller muscle groups (ACSM, 2009a). This guideline was based on acute studies, which observed that higher training loads and volume-loads were achieved when MJ-to-SJ EO is employed, compared to SJ-to-MJ EO (SFORZO; TOUEY, 1996; SPREUWENBERG et al., 2006; SIMÃO et al., 2007; ACSM, 2009a). However, in a recent meta-analysis, Nunes et al. (2021) verified that higher maximum strength gains tend to be obtained in exercises performed at the beginning of the RT sessions. This indicates the presence of an EO effect and follows the specificity principle (RIBEIRO; SCHOENFELD; NUNES, 2017; NUNES et al., 2019, 2021a). Therefore, these findings seem to contradict the ACSM's recommendation.

In older adults, only a few studies have analyzed the effect of RT EO, and the results have been conflicting (PINA et al., 2013; CARDOZO et al., 2019; DIB et al., 2020; TOMELERI et al., 2020b). Pina et al. (2013) observed similar changes in body composition between two EOs that prioritized large or small muscle groups in older men. After a circuit RT program in untrained older women, Cardozo et al. (2019) found similar adaptations in body composition and functional fitness. However, in single- and multi-joint exercises, higher strength gains were identified for SJ-to-MJ and MJ-to-SJ groups, respectively. Tomeleri et al. (2020b) found similar results between MJ-to-SJ and SJ-to-MJ

EOs in untrained older women. Nonetheless, the MJ-to-SJ group showed slightly greater benefits in the lower limbs, attributed to the higher accumulated training volume. More recently, Dib et al. (2020) observed similar responses in muscular strength, body composition, and functional fitness between three EOs in trained older women (MJ-to-SJ, SJ-to-MJ, and a group that performed the exercises alternating between upper and lower body in a large-to-small-muscle sequence).

Since recent studies have failed to determine a superiority for MJ-to-SJ or SJ-to-MJ EOs, different EO approaches should be explored further. One possibility would be testing the prioritization of lower or upper body muscles. Saraiva et al. (2014) compared such an approach in male athletes. They observed significantly greater strength gains when starting training sessions with lower-body exercises than with upper-body exercises. This EO would be interesting to apply to older adults since the more expressive reductions in strength levels and muscle mass induced by aging occur in the lower limbs, especially in women (JANSSEN et al., 2000; MANINI; CLARK, 2012; MILJKOVIC et al., 2015). Thus, if performing RT starting with exercises for the lower body presents advantages, this would reflect greater functionality in this population (SANTOS et al., 2017; FRAGALA et al., 2019; NUNES et al., 2019). Therefore, further studies are needed. In addition, the parallel-group design of the previous studies (SARAIVA et al., 2014; CARDOZO et al., 2019; DIB et al., 2020; TOMELERI et al., 2020b) does not account for the inter-subject variability in responses to RT. Given that individually inherent responsiveness to RT largely influences the magnitude of the results (ROBERTS et al., 2018; HAMMARSTRÖM et al., 2020; NUNES et al., 2021c), and considering that such variability may be affected by the manipulation of training variables (DAMAS et al., 2019a; PICKERING; KIELY, 2019). Despite some divergent results (HAMMARSTRÖM et al., 2020; ROBERTS; NUCKOLS; KRIEGER, 2020; NUNES et al., 2021b), an experimental protocol that corrects such bias would help the understanding of the influence of EO in the older adults (e.g., as it is the crossover design).

Therefore, the purpose of this study was to compare the effects of four EOs that prioritized exercises for the upper or lower body and MJ or SJ on muscular strength, muscle mass, and functional fitness in resistance-trained older women according to a crossover trial. EOs were the following: multi- to single-joint and upper- to lower-body (MJ-SJ-U), single- to multi-joint and upper- to lower-body (SJ-MJ-U), multi- to single-joint and lower- to upper-body (MJ-SJ-L), and single- to multi-joint and lower- to upper-body (SJ-MJ-L). We hypothesized that adaptations would follow the specificity principle, that MJ-

SJ-U and SJ-MJ-U groups would present greater adaptations in upper-body muscular groups, whereas MJ-SJ-L and SJ-MJ-L would elicit greater improvements on lower limbs, with the latter reflecting better changes on functional fitness tests which involved the lower limbs.

## **METHODS**

### **Experimental approach to the problem**

This work is part of the “Active Aging Longitudinal Study” research project, initiated in 2012 to analyze the effects of supervised, structured, and progressive RT programs on neuromuscular, morphological, physiological, metabolic, cognitive, and behavioral outcomes in older women. The sample in the present study consisted of the 2018-annual cohort of participants from this research project. The current investigation was carried out over 63 weeks, divided into 4 phases (preconditioning, phase 1, detraining, phase 2). Weeks 1–3, 16–18, 31–33, 46–48, and 61–63 were used for measurements, testing, and evaluations. In weeks 4–15, participants underwent a 12-week preconditioning phase, where they all received the same training. At weeks 19–30, phase 1, participants were randomly assigned to four groups to perform a 12-week RT program according to the respective OEs (MJ-SJ-U, SJ-MJ-U, MJ-SJ-L, and SJ-MJ-L). Then, participants underwent 12 weeks of detraining (weeks 34–45), in which they were asked not to engage in any physical exercise program during this period. Finally, in weeks 49–60, phase 2, a crossover between the MJ-SJ and SJ-MJ conditions was carried out, as follow: participants who had performed MJ-SJ-U in phase 1 then performed SJ-MJ-U; those who had performed SJ-MJ-U then performed MJ-SJ-U; those who had performed MJ-SJ-L then performed SJ-MJ-L, and those who had performed SJ-MJ-L then performed MJ-SJ-L. The present study was conducted according to the Declaration of Helsinki and was approved by the local University Ethics Committee.

### **Participants**

Recruitment was carried out through social media (*Whatsapp*, *Facebook*, and *Instagram*). Interested subjects completed detailed health history questionnaires and were subsequently admitted to the study if they met the following inclusion criteria: women aged > 60 years old, physically independent, not having cardiac, orthopedic, or musculoskeletal dysfunction that could impede physical exercise, not having uncontrolled diabetes mellitus

or hypertension, not receiving hormonal replacement therapy, and not being involved in the practice of regular physical activity performed more than once a week over the last five months before the start of the study. Selected volunteers were evaluated by a cardiologist (resting 12-lead electrocardiogram test, personal interview, and treadmill stress test when deemed necessary) and were released with no exclusions to participate in vigorous exercise practice. Written informed consent was obtained from all participants after providing a detailed description of the study procedures.

Of the 84 interviewed volunteers, 72 were selected and initiated the preconditioning phase. During the preconditioning phase, 11 participants dropped out of the study. Then, a blind researcher was responsible for randomizing, through the random.org website, the 61 participants in one of the four RT groups according to the OEs. During phase 1, 5 participants dropped out of the study (SJ-MJ-U = 5). After the detraining period, 56 participants returned to initiate phase 2 (i.e., no dropouts). During phase 2, 8 participants dropped out of the study (SJ-MJ-U = 2; SJ-MJ-L = 4; MJ-SJ-L = 2). The reasons reported for leaving the study were lack of time (n = 6), lack of motivation (n = 1), transport issues (n = 1), emergency surgeries not related to training (n = 2), the need to take care of family members (n = 3), and other personal reasons (n = 11). The final sample was composed of 48 participants, considering the crossover data gathering, consisting of 24 subjects per group. This sample size is considered satisfactory to achieve significance with a moderate effect size (effect size = 0.34, power = 0.8; alpha = 0.05; time = 2; groups = 4; G\*Power v. 3.1.9.7, Germany). A flowchart of the experimental design of the present work is displayed in Figure 1.

**\*\*\*INSERT FIGURE 1 NEAR HERE\*\*\***

### **Muscular strength**

Maximal dynamic strength was evaluated using one-repetition maximum (1RM) tests on the chest press, knee extension, and preacher curl exercises (Ipiranga Fitness, Presidente Prudente, Brazil), in that order, following standard procedures (AMARANTE DO NASCIMENTO et al., 2013; NUNES et al., 2020). Three 1RM testing sessions were performed in the morning hours, separated by 48 h. In each session, participants performed a warm-up of 10-15 repetitions with approximately 50% of their estimated load for the first attempt, followed by three maximal attempts. For the first day of testing, the first selected load was based on the researchers' experience and perception of the

difficulty (effort) with which participants performed the warm-up. If the first attempt was completed, weight was added for the next attempts (3-10% of the previous attempt). If an attempt was unsuccessful, weight was removed in the same proportion. The rest period between attempts was three to five minutes and five minutes between exercises. The load for the first attempt in the second and third sessions was the maximal obtained in the previous session. Participants were encouraged to attempt to accomplish two repetitions with the selected load during all tests. The 1RM was recorded as the heaviest load lifted, in which participants were able to complete only one repetition among the three sessions (NUNES et al., 2020). In addition, a total muscular strength score was calculated as the sum of the highest scores in each of the three exercises. Three experienced researchers supervised each exercise during testing sessions to standardize technique reliability and help ensure the safety of participants. Standard error of measurement (SEM) and intraclass correlation coefficient (ICC) were satisfactory for chest press (SEM = 1.7 kg; ICC = 0.98), knee extension (SEM = 2.0 kg; ICC = 0.97), and preacher curl (SEM = 0.4 kg; ICC = 0.99).

### **Muscle mass**

Muscle mass was determined from appendicular lean soft tissue (LST) assessed by dual-energy X-ray absorptiometry scanning in a Lunar Prodigy equipment, model NRL 41990 (General Electric, Madison, WI, USA). Participants were instructed to remove all objects containing metal, empty their bladder about 30 min before measurement, abstain from eating or drinking in the previous four hours, avoid vigorous physical exercise for at least 24 h, and abstain from alcoholic and caffeinated beverages for at least 48 h before scanning. Scans were performed with participants lying in the supine position along the table's longitudinal centerline axis. Feet were secured together at the toes to immobilize the legs. The hands were maintained in a pronated position within the scanning region. Both calibration and analysis were carried out by a skilled researcher, following the manufacturer's recommendations. The software generated standard lines that set apart the limbs from the trunk and head. The same technician adjusted these lines using specific anatomical points determined by the manufacturer and performed all analyses during the intervention. Values of LST were determined from upper limbs, lower limbs, and trunk. The SEM and ICC were satisfactory for upper limbs LST (SEM = 0.1 kg; ICC = 0.99), lower limbs LST (SEM = 0.2 kg; ICC = 0.99), and trunk LST (SEM = 0.3 kg; ICC = 0.99).

### **Functional fitness tests**

Functional fitness was determined from three motor tests: 4.6 m walking, walking agility, and 30 s chair standing (RIKLI; JONES, 2013). For the 4.6 m walking test, three evaluators used stopwatches to measure the time spent by participants to walk a 4.6 m path at normal walking speed. Adhesive tapes on the floor demarcated this distance with additional 2 m patches before and after the 4.6 m main patch. Participants walked the full 8.6 m, but only the time spent to walk the middle 4.6 m was timed to the nearest 0.01 s. Participants completed three attempts, with the mean used for analysis. For the agility test, participants were seated on a chair supported by a wall, with their back in contact with the backrest, feet fully supported on the floor, and hands rested on the thighs. Participants were requested to stand up, walk around a cone at a distance of 2.44 m in front of the chair, return to the chair and sit down. Participants were instructed to complete the path as quickly as possible without running. Time was recorded to the nearest 0.01 s with a stopwatch from the initial movement to rise from the chair until returning to sit down again. Participants completed three trials, with the best one recorded for analysis. For the 30 s chair standing test, participants were seated on a chair supported by a wall, with their back in contact with the backrest, feet fully supported on the floor, and hands crossed to rest on their opposite shoulders. Participants performed the maximum sit-to-stand repetitions possible within the 30 s. An evaluator recorded the time and counted the number of completed repetitions performed.

### **Resistance training program**

In the 12-week pre-conditioning phase, all participants underwent a standard RT protocol based on recommendations to improve muscular endurance and strength in older adults (ACSM, 2009b; FRAGALA et al., 2019). The training was carried out three days a week (Mondays, Wednesdays, and Fridays) in the morning hours (8-11 a.m.) at the University fitness facility. The training program comprised eight exercises for the whole body in an EO alternating between upper and lower body exercises, with each performed in 3 sets of 10-15 repetitions using free-weights and pin-loaded machines (Ipiranga Fitness, Presidente Prudente, SP, Brazil). Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant movement velocity at a ratio of approximately 1:2 s (concentric and eccentric muscle actions, respectively). Rest intervals were one to two minutes between sets and two to

three minutes between exercises. Training load was increased weekly by 2–5% for upper-limb exercises and 5–10% for the lower-limb exercises, according to the number of repetitions performed during each training session to ensure that participants maintained ideal intensity in the repetition zone (ACSM, 2009a). Participants were supervised individually throughout each training session by Physical Education professionals with experience in RT (two professionals per exercise) to standardize intensity and technique reliability and help ensure safety. Adherence to the program was satisfactory, with all participants attending a minimum of 85% of the sessions.

In phases 1 and 2, in which the EOs were compared, RT was similar to the pre-conditioning RT phase (8 exercises, 3x/week, 12 weeks), differing only for the RM-target-zone used in the exercises, where an increase in RM-intensity was employed (3 sets of 8-12 repetitions), and the EOs. Participants carried out the following EOs: MJ-SJ-U = chest press, seated row, triceps pushdown, preacher curl, horizontal leg press, leg extension, lying leg curl, seated calf raise; SJ-MJ-U = preacher curl, triceps pushdown, seated row, chest press, seated calf raise, lying leg curl, leg extension, horizontal leg press; MJ-SJ-L = horizontal leg press, leg extension, lying leg curl, seated calf raise, chest press, seated row, triceps pushdown, preacher curl; SJ-MJ-L = seated calf raise, lying leg curl, leg extension, horizontal leg press, preacher curl, triceps pushdown, seated row, chest press. During every RT session, the loads and number of repetitions performed during each set of the eight exercises were recorded. This allowed calculation of the volume-load by multiplying the total number of repetitions in all sets by load:  $\text{volume-load} = \text{load (kg)} \times \text{sets (no.)} \times \text{repetitions (no.)}$  (CUNHA et al., 2020).

### **Dietary intake**

Food consumption was assessed by the 24 h dietary recall method to analyze the participants' habitual intake throughout the study. Assessments were performed on two non-consecutive days of the week. During the initial interview, a photographic manual of food portion size was presented by experienced nutritionists to improve the quality of food intake reports. Homemade measurements of the nutritional values of food and supplementation were converted into grams and milliliters by the online software Virtual Nutri Plus (Keeple®, Rio de Janeiro, RJ, Brazil) for diet analysis. Some foods were not found in the program database, and, therefore, several items were added from food tables.

## Statistical analyses

Shapiro-Wilk test was used to check the data distribution. Comparisons between groups regarding participants' general characteristics and overall training volume data were made with one-way ANOVA. For medical history, categorical data, Pearson's chi-square was used. Muscular strength, muscle mass, and functional fitness data were analyzed with ANCOVA, comparing the raw difference between pre-and post-intervention values. Baseline values were used as a covariate. Interpretations were based on 95% confidence intervals (i.e., when 95% CI of the raw delta did not overlap 0, there was a significant difference between baseline values). Although both ANCOVA-adjusted and unadjusted data were presented, statistical interpretations for between-group comparisons were made with ANCOVA results. The *P*-values for group comparisons in ANCOVA were displayed. For dietary intake and weekly volume-load data, repeated-measures ANOVA was used. For all analyses, a *P* < 0.05 was accepted as statistically significant. Effect size (ES) was calculated as the post-training mean minus the pre-training means divided by the pooled groups' pre-training standard deviation (COHEN, 1992). An ES of 0.00–0.19 was considered trivial, 0.20–0.49 was considered small, 0.50–0.79 was considered moderate, and  $\geq 0.80$  was considered large. Data were stored and analyzed in Statistica software, version 10.0 (Statsoft Inc., Tulsa, OK, USA).

## RESULTS

General characteristics and medical history of the participants are described in Table 1. There was no significant difference between groups for all variables at baseline (*P* > 0.05). Also, no changes were found within- and between groups for macronutrients and energy intake (time x group interaction *P*-values: 0.16 – 0.66). Average values during the intervention were the following: energy =  $25.5 \pm 5.8$  kcal/kg/d; carbohydrate =  $3.3 \pm 0.8$  g/kg/d; protein =  $1.1 \pm 0.2$  g/kg/d; lipid =  $0.8 \pm 0.2$  g/kg/d (data are shown in the Supplementary Material 1).

**\*\*\*INSERT TABLE 1 NEAR HERE\*\*\***

Table 2 presents the muscular strength and muscle mass according to the different EO conditions. Significant improvements following RT were observed in all groups (*P* < 0.05) for total strength, chest press, leg extension, preacher curl, total LST, upper limbs

LST, and lower limbs LST, but not for trunk LST ( $P > 0.05$ ). Table 3 presents the results of functional fitness. Significant improvement ( $P < 0.05$ ) was observed for the 30 s standing chair test but not for the 4.6 m walking and agility tests ( $P > 0.05$ ). No significant difference between groups was found for the magnitude of the changes in all variables ( $P > 0.05$ ). Values of ES are presented in Table 4. Additionally, comparisons among participants who started with the upper limbs exercises (MJ-SJ-U + SJ-MJ-U) vs. those who started training sessions with the lower limbs exercises (MJ-SJ-L + SJ-MJ-L) are presented in Supplementary Material 2. No difference between groups was found ( $P > 0.05$ ).

**\*\*\*INSERT TABLES 2, 3, AND 4 NEAR HERE\*\*\***

Volume-load at 1 e 12 weeks are presented in Figure 2. All groups progressed similarly throughout the intervention. The same patterns were observed when volume-loads of the exercises for upper and lower limbs were analyzed separately.

**\*\*\*INSERT FIGURE 2 NEAR HERE\*\*\***

Results for the 12-week detraining period are available in Supplementary Materials 3, 4, and 5. For most measures of muscle mass (except for trunk LST) and 1RM tests, significant reductions were found ( $P < 0.05$ ). Also, a decline in the performance was found only in the 30 s chair standing test ( $P < 0.05$ ). No differences between groups were found ( $P > 0.05$ ).

## **DISCUSSION**

The main finding of this study was that all EO investigated promoted similar increases in muscular strength and muscle mass. Our results indicate that the EO does not seem to influence the magnitude of neuromuscular adaptations in resistance-trained older women. Therefore, our initial hypothesis was not confirmed. We expected that different EOs could generate different adaptations. However, these findings are in agreement with previous studies in untrained young (NAZARI; AZARBAYJANI; AZIZBEIGI, 2016) and untrained (TOMELERI et al., 2020b) and trained (DIB et al., 2020) older women. While these works have already explored MJ-SJ and SJ-MJ Eos (AZIZBEIGI; AZARBAYJANI; ATASHAK, 2015; NAZARI; AZARBAYJANI; AZIZBEIGI,

2016; DIB et al., 2020; TOMELERI et al., 2020b), the present study confirms that prioritizing the upper or lower body does not influence the magnitude of changes in the selected variables. Also, due to the crossover design, the current study confirms the results of previous works that showed null or minor differences between MJ-SJ or SJ-MJ EOs in older women following traditional RT (DIB et al., 2020; TOMELERI et al., 2020b). Moreover, although upper-body (MJ-SJ-U + SJ-MJ-U) and lower-body (MJ-SJ-L + SJ-MJ-L) groups were not crossed-over, which would increase the power of the analyses, the final sample sizes of upper vs. lower groups (Table 4) were large ( $n = 48$ ), adding support to the non-significant results and trivial effect sizes for the differences between groups ( $ES = 0.00-0.15$ ).

It was expected that EO would significantly influence strength gains, which was not the case here. Increases in strength during chronic RT follow the SAID principle (specific adaptations to impose demand) and are highly related to the load used during acute RT sessions (SCHOENFELD; OGBORN; KRIEGER, 2017a; NUNES et al., 2019, 2021a). The similar results in strength gains among EO groups may be related to the lack of difference in acute training loads (NUNES et al., 2019). That is, EO-induced fatigue could result in reduced levels of motor unit recruitment, hence lowering the capacity to move large loads and maintain higher volume loads (RIBEIRO et al., 2019). For example, local fatigue induced by the triceps extension exercise could result in lower performance on the chest press exercise for groups that performed SJ-MJ EOs, resulting in fewer strength gains compared to MJ-SJ groups (BRANDÃO et al., 2020; NUNES et al., 2021a). This pattern, however, was not observed in the current study, even for other pairs of exercises that could have been influenced, such as preacher curl followed by seated row or leg extension followed by leg-press. It was also expected to be differences between upper- and lower-body prioritization groups. For example, the non-local fatigue, i.e., impairments in non-exercised muscles (HALPERIN; CHAPMAN; BEHM, 2015), induced by lower-body exercises could result in lower performance on upper-body exercises for EO groups that performed lower-body for first, thus producing reduced strength gains compared to upper-body groups (SARAIVA et al., 2014; NUNES et al., 2021a). This effect was not observed in the present study. At this point, it is essential to note that the results of EO in the present study are restricted to the exercises included in the current protocol. Future studies may consider whether performing different exercises or greater exercise volume per trained muscle group would influence the results and manifest the existence of an EO effect.

The lack of influence of EO on 1RM tests and measures of muscle hypertrophy in women (AZIZBEIGI; AZARBAYJANI; ATASHAK, 2015; NAZARI; AZARBAYJANI; AZIZBEIGI, 2016; CARDOZO et al., 2019; DIB et al., 2020; TOMELERI et al., 2020b), in contrast to the significant effects observed in men in previous works (NUNES et al., 2021a), suggests that the EO effect may be sex-dependent, although more studies are warranted. Given that women are more fatigue-tolerant than men (GRGIC; SCHOENFELD, 2019) and that the EO effect seems to be dependent on fatigue presence throughout the exercises (NUNES et al., 2019, 2021a), the participants could not be acutely fatigued during training sessions to the point of decreasing the performance in the latter exercises of an EO. Nonetheless, even if some degree of fatigue was present throughout the exercises, this did not seem to primarily affect the chronic responses to traditional RT in this population (PINA et al., 2013; NUNES et al., 2019; DIB et al., 2020; TOMELERI et al., 2020b). Indeed, Nunes et al. (2019) found no difference in volume-load among MJ-SJ-U, SJ-MJ-U, MJ-SJ-L, and SJ-MJ-L EOs following acute sessions of RT (3x8-12RM). In addition, Dib et al. (2020) noted no difference in accumulated volume-load between MJ-SJ-U and SJ-MJ-U conditions (3x15/10/5RM) following a 12-week RT intervention. Conversely, Tomeleri et al. (2020b) showed advantages for MJ-SJ-U compared to SJ-MJ-U on volume-load in some exercises (3x10-15RM), and this offered small benefits on gains in 1RM and LST after 12 weeks of RT. Perhaps the reason why Tomeleri et al. (2020b) found an influence of EO on training volume while others, including the present study, did not, might be because they used higher repetitions sets, which can produce greater fatigue (STUART et al., 2018). The similar training volumes might be translated into similar gains in strength, mass, and functionality. This is especially valid for changes in LST, given that hypertrophy is highly influenced by training volume (SCHOENFELD; OGBORN; KRIEGER, 2017b; LONGO et al., 2020) .

Literature indicates that RT can induce transfer effects where lower limb exercises on gym machines produce increased maximum strength and improve other lower-limb motor tasks such as walking agility and sit-to-stand performance (SUCHOMEL et al., 2018; FRAGALA et al., 2019). Since the EO did not influence strength and mass gains in the current study, it would be plausible that it did not affect the functional measures either, given the relationship between these outcomes (BRIAN C., CLARK E MANINI, 2010; SANTOS et al., 2017). The small pre-to-post-training effect sizes observed for the functional measures might have hampered any possible influence of EO. This lack of effect may be due to the high fitness level of the participants at baseline. That is, a ceiling

effect may have been reached for performance in walking and sit-to-stand tasks for most participants. Indeed, based on the maximum strength tests, the current sample presented high conditioning level compared to the previous works (DIB et al., 2020; TOMELERI et al., 2020b). It is important to note that EO did not influence responses in physically independent older women with different training status (DIB et al., 2020; TOMELERI et al., 2020). Whether EO would affect older individuals with a certain degree of frailty still needs to be tested. On the other hand, greater changes could occur if the training program included specific functional motor tasks required in the functional tests (FRAGALA et al., 2019).

The present investigation has some issues to be addressed. First, although DXA is well established as a valid instrument to assess the effects of RT on muscle hypertrophy (BUCKINX et al., 2018; HAUN et al., 2019), the use of site-specific imaging techniques (e.g., ultrasound or MRI) could contribute to the exploration of the effects of EO on specifically trained muscles and muscle regions separately, especially given that different exercises and/or EO may influence region-specific muscle hypertrophy (HAUN et al., 2019; BRANDÃO et al., 2020; NUNES et al., 2021a). Moreover, participants in the current study presented a low protein intake which might have influenced the magnitude of the adaptations (MORTON et al., 2017; NABUCO et al., 2019). Future studies may consider providing standard doses of protein supplementation to participants.

Conversely, some positive points of the present investigation deserve to be highlighted. The long duration of the study, with a pre-conditioning phase (to adapt the subjects to RT), and a crossover design (to minimize the influence of inter-individual differences on the comparisons), strengthen the application of the results. The large sample size provided excellent power for the analyzes. The presence of Physical Education professionals to follow participants during the sessions closely, in a 2:1 ratio, helped guarantee the safety and high compliance to the training program.

## **CONCLUSION**

Our results suggest that the EO does not influence muscular strength, muscle mass, and functional fitness responses in trained older women following 12 weeks of RT. Therefore, EO does not seem to play a significant role in the magnitude of the responses to RT in this population. This lack of EO effect in adaptations allows for more options in choosing the EO during RT sessions. Trainers, exercise professionals, and researchers can be flexible in the prescription of EO for older women, allowing practitioners to choose

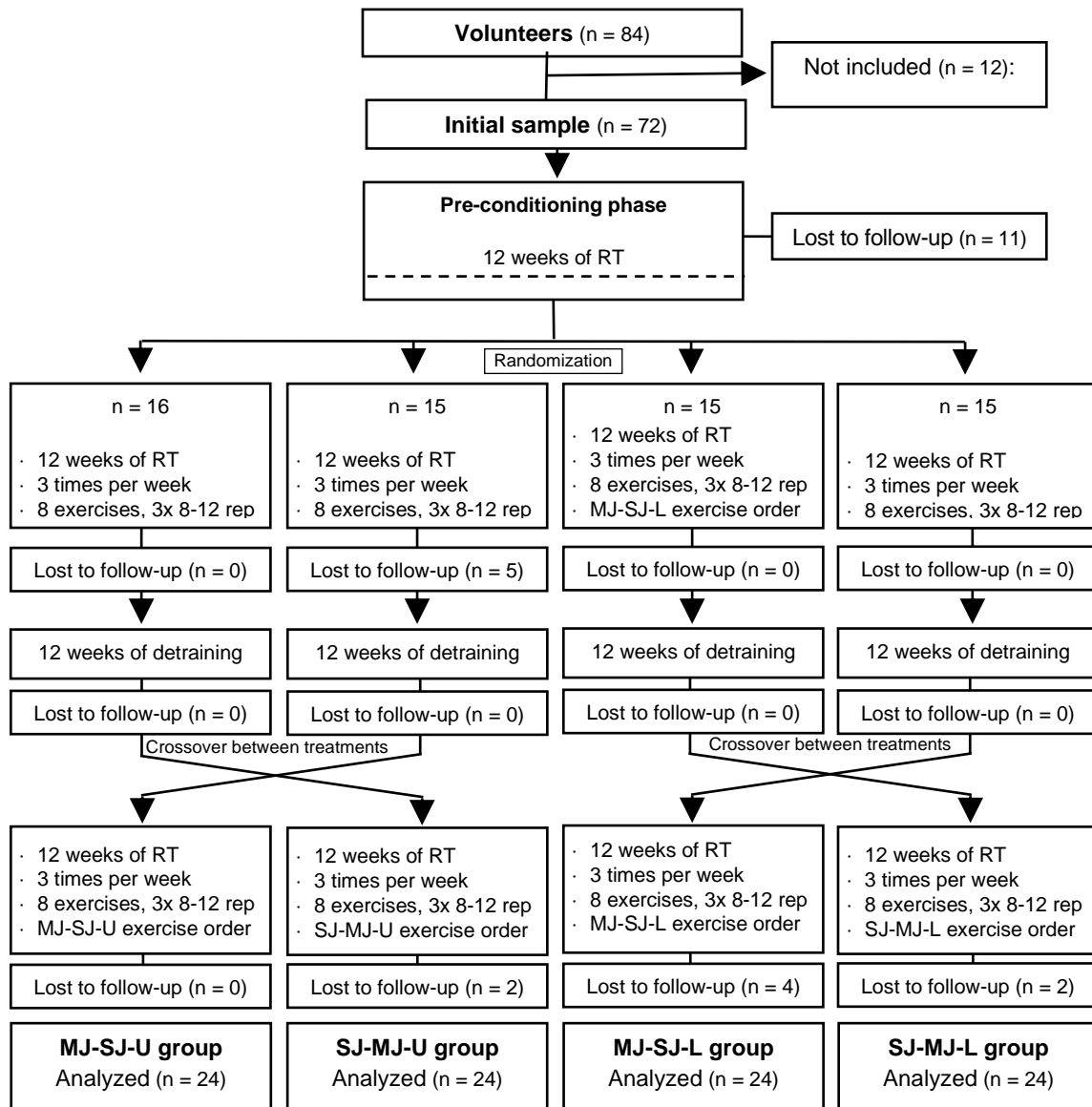
the EO suited to their preference. Training based on preferences may help ensure adherence to RT programs, making it possible to obtain better long-term results.

## **ACKNOWLEDGMENTS**

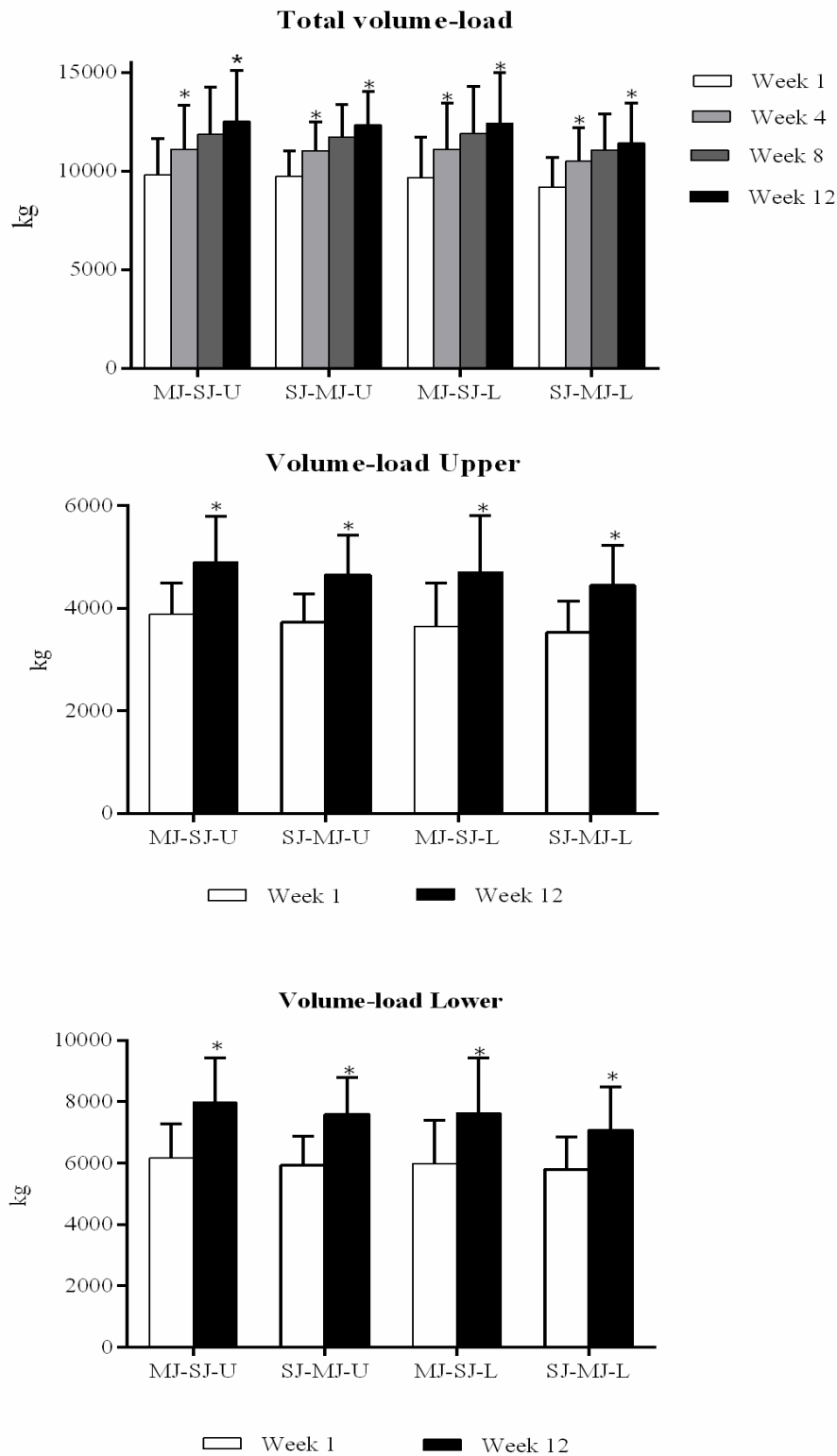
The authors thank all subjects for their engagement in the study, the Coordination of Improvement of Higher Education Personnel (CAPES/Brazil) for the scholarship conferred to JPN, WK (master), PMC, and BDVC (doctoral), and the National Council of Technological and Scientific Development (CNPq/Brazil) for the grants conceded to ESC. This work was partially supported by the Ministry of Education (MEC/Brazil) and CNPq/Brazil.

**Compliance with Ethical Standards:** The present study was conducted according to the Declaration of Helsinki. **Ethical approval:** The present study was approved by the State University of Londrina Ethics (Review Board) Committee. **Conflict of interest:** The authors declare that they have no conflict of interest regarding the publication of this paper. **Informed consent:** All participants provided their written informed consent before participating in the study. **Funding:** None.

**Authors' contributions:** PMC, JPN, and ESC conceptualized the idea of the study. PMC and JPN analyzed the data, supervised the study, and drafted the first version of the manuscript. PMC, JPN, WK, BDVC, MA, and LTC conducted the data collection. ESC conceived, designed, and supervised the research project. All authors read, revised critically, and approved the final version of the manuscript.



**Figure 1.** Experimental design of the study. MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. RT = resistance training.



**Figure 2.** Volume-load values at weeks 1 and 12 of the training program. Data are expressed as mean  $\pm$  standard deviation. MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. No difference was found between groups. \* $P < 0.05$  vs. Week 1.

**Table 1.** General characteristics of the four training groups at baseline of the study.

	<b>MJ-SJ-U</b> (n = 24)	<b>SJ-MJ-U</b> (n = 24)	<b>MJ-SJ-L</b> (n = 24)	<b>SJ-MJ-L</b> (n = 24)	<b>P</b>
Age (years)	69 ± 6	68 ± 5	68 ± 6	69 ± 6	0.98
Body mass (kg)	67.8 ± 13.7	68.4 ± 12.9	67.4 ± 12.5	67.9 ± 12.6	0.99
Stature (cm)	154.3 ± 5.9	155.2 ± 6.2	155.4 ± 6.3	155.2 ± 6.8	0.83
Body mass index (kg.m <sup>-2</sup> )	28.4 ± 4.9	28.2 ± 4.5	28.0 ± 3.9	28.0 ± 3.9	0.98
Medical history					
Type 2 diabetes (%)	20.0	20.0	35.0	25.0	0.69
Hypertension (%)	25.0	23.7	27.6	23.7	0.73
Dyslipidemia (%)	26.5	24.5	28.6	20.4	0.64
Hypoglycemic (%)	26.3	21.1	21.1	31.6	0.90
Antihypertensive (%)	24.6	21.7	29.0	24.6	0.59
Statins (%)	28.8	23.1	26.9	21.2	0.57
<b>Note:</b> Data are expressed as mean ± standard deviation, or percentages (%). MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order.					

**Table 2.** Raw pre-and post-training values and adjusted mean changes for the measures of muscular strength and muscle mass according to the different exercise order conditions.

Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	P
Total strength (kg)					
Pre	146.7 ± 27.4	142.9 ± 27.6	147.1 ± 30.4	148.3 ± 29.7	
Post	157.2 ± 26.4*	157.0 ± 28.3*	158.8 ± 35.1*	156.2 ± 33.1*	
Adjusted mean change	10.6 (5.3–15.9)	13.9 (8.8–19.0)	11.7 (6.5–17)	8.0 (3.0–13.0)	0.43
Chest press 1RM (kg)					
Pre	59.2 ± 12.7	56.2 ± 11.2	58.3 ± 11.9	58.2 ± 12.4	
Post	65.1 ± 12.8*	63.1 ± 11.3*	65.3 ± 15.3*	62.4 ± 14.2*	
Adjusted mean change	6.0 (3.1–8.8)	6.7 (4.0–9.4)	7.0 (4.3–9.9)	4.2 (1.6–6.9)	0.48
Leg extension 1RM (kg)					
Pre	59.5 ± 14.3	59.3 ± 13.9	61.2 ± 16.9	62.0 ± 16.8	
Post	62.6 ± 13.9*	64.3 ± 17.1*	64.0 ± 18.6*	64.7 ± 17.2*	
Adjusted mean change	2.9 (0.2–5.6)	4.9 (2.3–7.5)	2.9 (0.3–5.6)	2.7 (0.2–5.2)	0.10
Preacher curl 1RM (kg)					
Pre	28.0 ± 3.9	28.0 ± 4.2	27.7 ± 4.3	28.1 ± 4.2	
Post	29.6 ± 4.4*	29.4 ± 4.0*	29.5 ± 5.1*	30.0 ± 4.5*	
Adjusted mean change	1.6 (0.6–2.6)	1.3 (0.4–2.3)	1.8 (0.8–2.8)	2.0 (1.0–2.9)	0.10
Total LST (kg)					
Pre	35.5 ± 4.5	35.8 ± 4.8	35.1 ± 5.1	35.6 ± 5.3	
Post	36.4 ± 5.1*	36.6 ± 4.5*	35.9 ± 5.1*	36.7 ± 5.1*	
Adjusted mean change	1.0 (0.1–2.4)	1.6 (0.3–3.0)	0.5 (0.1–1.9)	1.2 (0.1–2.6)	0.80
Upper limbs LST (kg)					
Pre	4.1 ± 0.6	4.2 ± 0.6	4.1 ± 0.8	4.1 ± 0.7	
Post	4.4 ± 0.7*	4.5 ± 0.7*	4.3 ± 0.7*	4.3 ± 0.7*	
Adjusted mean change	0.3 (0.1–0.4)	0.3 (0.2–0.4)	0.2 (0.1–0.4)	0.2 (0.1–0.4)	0.89
Lower limbs LST (kg)					
Pre	12.4 ± 1.7	12.5 ± 1.9	12.4 ± 2.2	12.6 ± 2.1	
Post	12.8 ± 2.0*	13.0 ± 1.8*	12.8 ± 2.1*	13.1 ± 2.2*	
Adjusted mean change	0.5 (0.2–0.7)	0.5 (0.3–0.7)	0.4 (0.2–0.6)	0.5 (0.3–0.7)	0.86
Trunk LST (kg)					
Pre	19.0 ± 2.4	19.0 ± 2.5	18.6 ± 2.4	18.9 ± 2.7	
Post	19.2 ± 2.7	19.1 ± 2.3	18.8 ± 2.7	19.3 ± 2.5	
Adjusted mean change	0.2 (-0.1–0.6)	0.1 (-0.2–0.5)	0.2 (-0.2–0.5)	0.4 (-0.1–0.7)	0.53

**Note:** Data are expressed as mean ± standard deviation or mean (lower – upper bounds of 95% confidence interval). MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. 1RM = one-repetition maximum. LST = lean soft tissue. *P*-values refer to groups' comparisons from ANCOVA. \**P* < 0.05 vs. Pre.

**Table 3.** Raw pre-and post-training values and adjusted mean changes for the measures of functional fitness according to the different exercise order conditions.

Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	<i>P</i>
4.6 m walking test (s)					
Pre	3.23 ± 0.46	3.34 ± 0.59	3.32 ± 0.44	3.31 ± 0.36	
Post	3.22 ± 0.50	3.37 ± 0.52	3.29 ± 0.38	3.36 ± 0.36	
Adjusted mean change	-0.02 (-0.1–0.1)	0.05 (-0.1–0.1)	-0.05 (-0.1–0.1)	0.05 (-0.1–0.1)	0.58
Agility test (s)					
Pre	6.39 ± 1.23	6.41 ± 1.03	6.47 ± 0.89	6.43 ± 0.98	
Post	6.28 ± 1.05	6.18 ± 0.90	6.25 ± 0.75	6.24 ± 0.77	
Adjusted mean change	-0.09 (-0.3–0.1)	-0.16 (-0.4–0.1)	-0.17 (-0.4–0.1)	-0.17 (-0.4–0.1)	0.95
30s chair standing (reps)					
Pre	13 ± 2	13 ± 2	13 ± 2	13 ± 2	
Post	14 ± 3*	14 ± 2*	14 ± 2	14 ± 2	
Adjusted mean change	0.8 (0.1–1.4)	0.8 (0.2–1.5)	0.6 (-0.1–1.3)	0.4 (-0.3–1.0)	0.74
<p><b>Note:</b> MJ-SJ-U = group that performed the exercises in a multi- to single-joint, upper- to lower-body order. SJ-MJ-U = group that performed the exercises in a single- to multi-joint, upper- to lower-body order. MJ-SJ-L = group that performed the exercises in a multi- to single-joint, lower- to upper-body order. SJ-MJ-L = group that performed the exercises in a single- to multi-joint, lower- to upper-body order. Data are expressed as mean ± standard deviation, or mean (lower–upper bounds of 95% confidence interval). *<i>P</i> &lt; 0.05 vs. Pre.</p>					

**Table 4.** Effect size values for the measures of muscular strength, muscle mass, and functional fitness according to the different exercise order conditions.

Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	Additional comparisons	
					Upper (n = 48)	Lower (n = 48)
Total strength	0.36	0.49	0.41	0.27	0.43	0.34
Chest press 1RM	0.49	0.57	0.58	0.35	0.53	0.46
Leg extension 1RM	0.20	0.32	0.18	0.17	0.26	0.18
Preacher curl 1RM	0.39	0.34	0.43	0.46	0.36	0.45
Total LST	0.18	0.16	0.16	0.22	0.17	0.19
Upper limbs LST	0.44	0.44	0.30	0.30	0.44	0.30
Lower limbs LST	0.20	0.25	0.20	0.25	0.23	0.23
Trunk LST	0.08	0.04	0.08	0.16	0.06	0.12
4.6m walking test	-0.02	0.06	-0.06	0.11	0.02	0.02
Agility test	-0.11	-0.22	-0.21	-0.18	-0.16	-0.20
30s chair standing	0.28	0.29	0.25	0.18	0.29	0.22

**Note:** MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. 1RM = one-repetition maximum. LST = lean soft tissue. Upper = mean between MJ-SJ-U and SJ-MJ-U. Lower = mean between MJ-S-L and SJ-MJ-L.

## SUPPLEMENTARY MATERIALS

**Supplementary material 1.** Energy and macronutrients intake of older women during the study period according to groups.

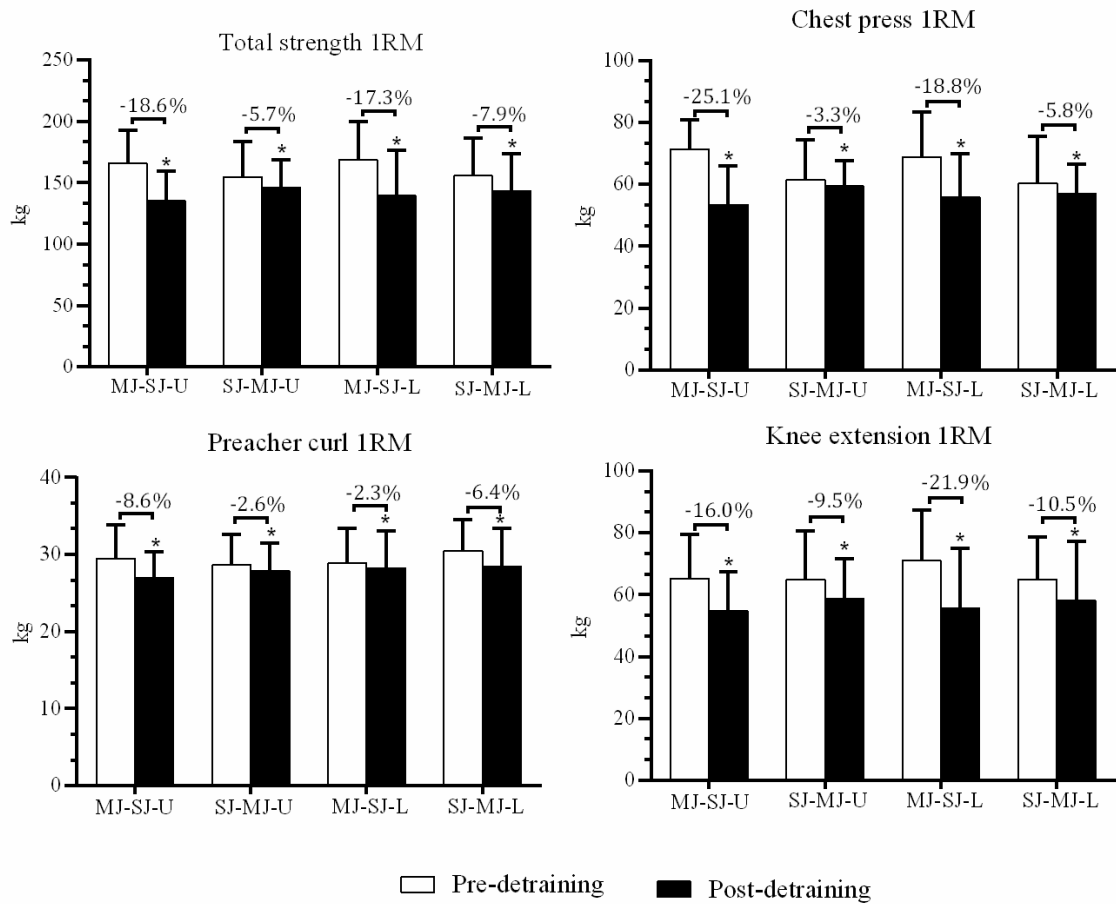
Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	<i>P</i>
Energy (kcal/kg/d)					
Pre	26.1 ± 4.7	24.8 ± 5.4	26.8 ± 6.1	25.9 ± 6.3	
Post	25.6 ± 6.1	24.5 ± 5.5	24.3 ± 5.6	25.7 ± 6.8	0.40
Protein (g/kg/d)					
Pre	1.1 ± 0.1	1.0 ± 0.3	1.0 ± 0.2	1.0 ± 0.2	
Post	1.0 ± 0.2	1.0 ± 0.2	0.9 ± 0.2	1.0 ± 0.2	0.66
Carbohydrate (g/kg/d)					
Pre	3.4 ± 0.7	3.4 ± 0.7	3.4 ± 0.9	3.4 ± 0.9	
Post	3.4 ± 0.9	3.3 ± 0.9	3.0 ± 0.9	3.3 ± 0.8	0.16
Lipid (g/kg/d)					
Pre	0.8 ± 0.2	0.8 ± 0.2	0.9 ± 0.2	0.8 ± 0.2	
Post	0.8 ± 0.2	1.0 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.16

**Note:** Data are expressed as mean ± standard deviation. MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order.

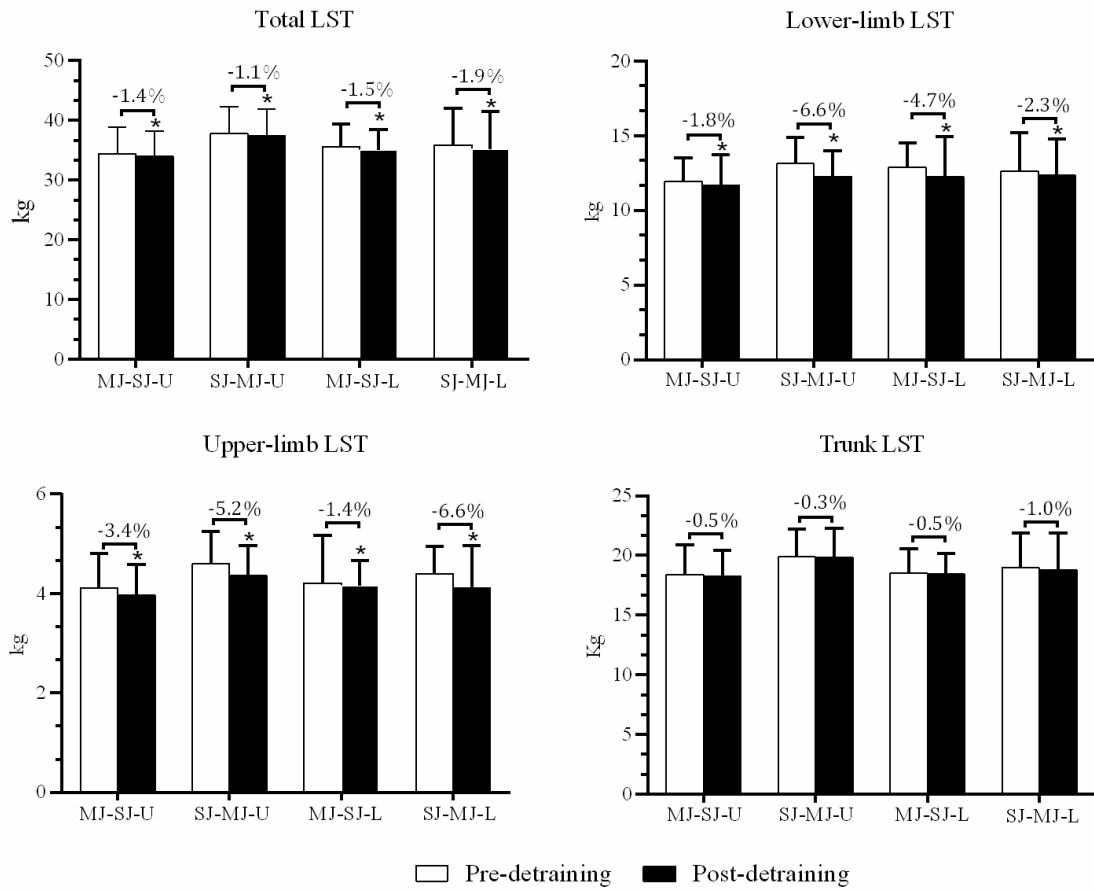
**Supplementary material 2.** Results of the muscle mass and muscular strength at pre-and post-training for the Upper vs. Lower additional analyzes.

Variables	Upper (n = 48)	Lower (n = 48)	P
Total strength (kg)			
Pre	144.8 ± 27.4	147.7 ± 29.8	
Post	157.1 ± 27.2*	157.4 ± 33.8*	0.34
Δ%	+8.5	+6.6	
Chest press 1RM (kg)			
Pre	57.7 ± 12.0	58.2 ± 12.1	
Post	64.0 ± 12.0*	63.8 ± 14.7*	0.58
Δ%	+11.0	+9.5	
Leg extension 1RM (kg)			
Pre	59.4 ± 14.0	61.4 ± 16.8	
Post	63.4 ± 15.5*	64.2 ± 18.2*	0.16
Δ%	+6.7	+4.6	
Preacher curl 1RM (kg)			
Pre	28.0 ± 4.0	27.9 ± 4.2	
Post	29.5 ± 4.2*	29.8 ± 4.8*	0.41
Δ%	+5.1	+6.7	
Total LST (kg)			
Pre	35.5 ± 4.5	35.1 ± 5.1	
Post	36.4 ± 5.1*	35.9 ± 5.1*	0.80
Δ%	+2.4	+2.1	
Upper limbs LST (kg)			
Pre	4.2 ± 0.6	4.1 ± 0.7	
Post	4.4 ± 0.7*	4.3 ± 0.7*	0.45
Δ%	+6.2	+5.6	
Lower limbs LST (kg)			
Pre	12.4 ± 1.7	12.4 ± 2.2	
Post	12.8 ± 2.0*	12.8 ± 2.1*	0.86
Δ%	+3.2	+3.0	
Trunk LST (kg)			
Pre	19.0 ± 2.4	18.8 ± 2.6	
Post	19.1 ± 2.5	19.0 ± 2.6	0.46
Δ%	+0.7	+1.4	

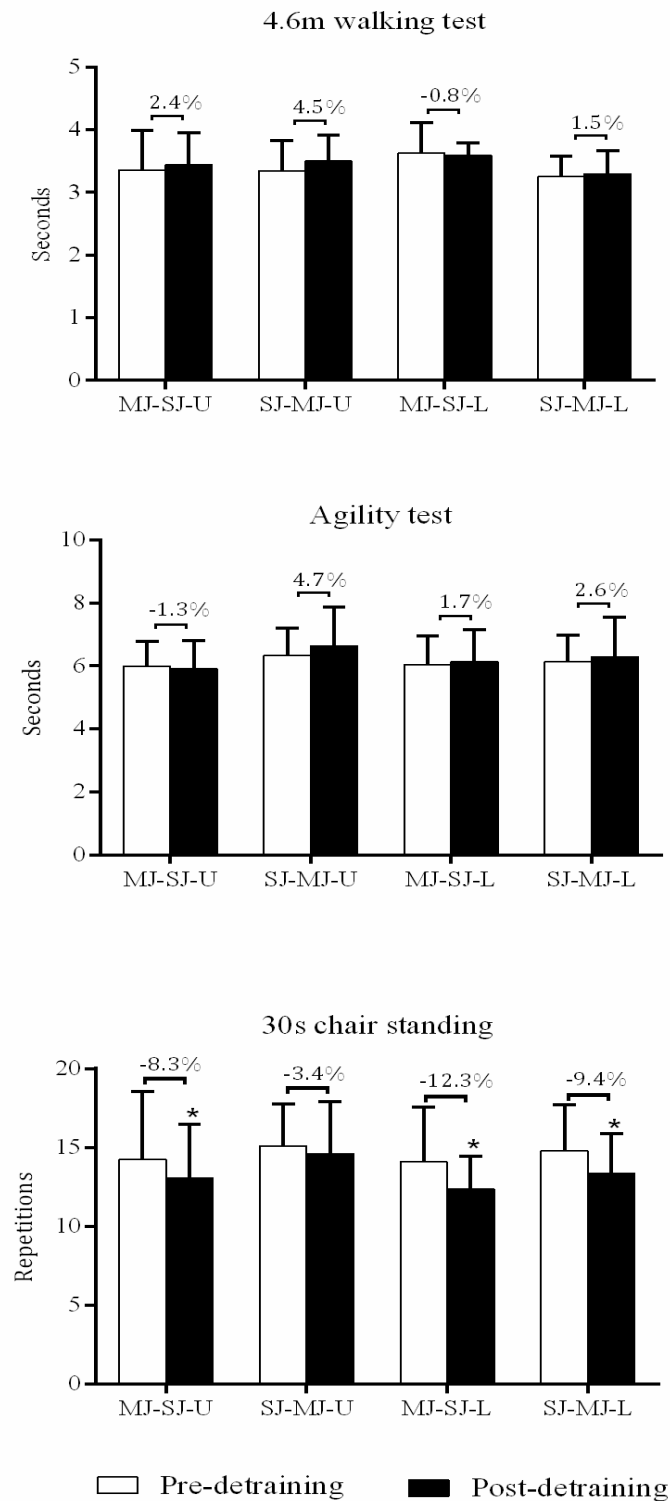
**Notes:** Data are expressed as mean ± standard deviation. 1RM = one-repetition maximum. LST = lean soft tissue. P-values refer to groups' comparisons from ANCOVA. \* $P < 0.05$  vs. Pre. Upper = mean between MJ-SJ-U and SJ-MJ-U. Lower = mean between MJ-S-L and SJ-MJ-L.



**Supplementary material 3. Results of the detraining period for 1RM. \* $P < 0.05$  vs. Pre.**



**Supplementary material 4.** Results of the detraining period for LST. \* $P < 0.05$  vs. Pre.



**Supplementary material 3.** Results of the detraining period for functional fitness. \* $P < 0.05$  vs. Pre.

## 5.2 Artigo original 2

### **Different exercise order of resistance training does not influence the adaptations on cardiovascular risk, cognition, depressive, and anxiety symptoms among trained older women. A randomized crossover study.**

**Running head:** exercise order, cardiovascular risk, and mental health

**Authors:** Paolo M. Cunha<sup>1\*</sup>, João Pedro Nunes<sup>1</sup>, André O. Werneck<sup>2</sup>, Daniel Gomes da Silva Machado<sup>3</sup>, Gabriel Kunevaliki<sup>1</sup>, Danielle Venturini<sup>4</sup>, Décio S. Barbosa<sup>4</sup>, Yu Qian<sup>5</sup>, Fabian Herold<sup>6,7</sup>, Liye Zou<sup>5</sup>, Brendon Stubbs<sup>8,9</sup>, Edilson S. Cyrino<sup>1</sup>.

1. Metabolism, Nutrition, and Exercise Laboratory. Physical Education and Sport Center, State University of Londrina. Londrina, PR, Brazil;
2. Center for Epidemiological Research in Nutrition and Health, Department of Nutrition, School of Public Health, University of São Paulo. São Paulo, SP, Brazil;
3. Department of Physical Education, Federal University do Rio Grande do Norte. Natal, RN, Brazil;
4. Clinical Analyses Laboratory. State University of Londrina. Londrina, PR, Brazil;
5. Exercise & Mental Health Laboratory, Institute of KEEP Collaborative Innovation, School of Psychology. Shenzhen University, 518060, China;
6. Department of Neurology, Medical Faculty, Otto von Guericke University. Leipziger Str. 44, 39120 Magdeburg, Germany;
7. Research Group Neuroprotection, German Center for Neurodegenerative Diseases (DZNE). Leipziger Str. 44, 39120 Magdeburg, Germany;
8. South London and Maudsley NHS Foundation Trust, Denmark Hill, London, United Kingdom; Institute of Psychiatry, Psychology and Neuroscience (IoPPN), King's College London. London, United Kingdom;
9. Institute of Psychiatry, Psychology and Neuroscience (IoPPN), King's College London. London, United Kingdom.

**\*Corresponding author:** Paolo M. Cunha. Metabolism, Nutrition, and Exercise Laboratory. Physical Education and Sport Center, State University of Londrina. Rodovia Celso Garcia Cid, km 380, Londrina, PR, Brazil. Zip-code: 86057-970. e-mail: pcunha88@hotmail.com

## ABSTRACT

**Introduction:** Resistance training (RT) may improve mental health and cardiovascular parameters. However, little is known about the response of RT variables on these outcomes, notably the influence of exercise order. **Aim:** To compare the effect of four exercises orders on cardiovascular risk, mental health, and cognitive performance in trained older women. **Methods:** Physically independent women (> 60 years) completed a 12-week RT pre-conditioning phase (eight exercises, 3 X 10-15 repetitions, 3x/week). Before this period, the participants were randomized to four different exercise orders groups to 12-week RT (eight exercises, 3 X 8-12 repetitions, 3x/week), 12-week detraining, and 12-week RT in a cross-over design. The exercise orders were the following: multi- to single-joint and upper- to lower-body (MJ-SJ-U, n = 24); single- to multi-joint and upper- to lower-body (SJ-MJ-U, n = 24); multi- to single-joint and lower- to upper-body (MJ-SJ-L, n = 24); and single- to multi-joint and lower- to upper-body (SJ-MJ-L, n = 24). The co-primary outcomes were cardiovascular risk factors (body fat, glucose, triglycerides, total cholesterol, LDL-c, HDL-c, C-reactive protein, BDNF, AOPP, TRAP, and NOx), depressive (GDS-scale) and anxiety symptoms (BAI), and cognitive performance (MoCA, Trail Making tests, verbal fluency, and Stroop test). **Results:** A main effect of time ( $P < 0.05$ ) revealed reductions in the body fat (total, android, and gynoid), glucose, glycated hemoglobin, total cholesterol, C-reactive protein, BDNF, AOPP, and NOx. Also, improvements were found ( $P < 0.05$ ) in the cognitive performance (MoCA, semantic, and phonetic verbal fluency) and mental health (BAI). There was no difference between the magnitudes of adaptations between groups ( $P > 0.05$ ). **Conclusion:** Our results suggest that RT can improve cardiovascular risk, mental health, and cognitive performance regardless of the exercise order in trained older women.

**Keywords:** aging; strength training; cognition; metabolic biomarkers; body fat.

## INTRODUCTION

Resistance training (RT) is an exercise type that plays an essential role in counteracting the negative health consequences of the aging process (FRAGALA et al., 2019), especially for post-menopause women (MALTAIS; DESROCHES; DIONNE, 2009; ZAMBONI et al., 2014). This includes improving muscle and brain morphofunctionalities (FRAGALA et al., 2019b; HEROLD et al., 2019b), improving cardiometabolic and neurotrophic blood biomarkers (MARSTON et al., 2019; ASHTON et al., 2020), reducing body fat (CUNHA et al., 2021a), and attenuating the burden of aging-induced mental and cognitive disorders, such as depression, anxiety, mild cognitive impairment, and dementia (LIU-AMBROSE; DONALDSON, 2009; LANDRIGAN et al., 2020).

In this regard, the biological adaptations induced by RT appear to depend on manipulating variables that compose the training prescription (ACSM, 2009a). The impact of training variables, such as the training volume (PADILHA et al., 2015; NUNES et al., 2016; CUNHA et al., 2021a), intensity (FORTI et al., 2016), and exercise order [EO] (DIB et al., 2020), has been studied in older adults. Specifically, the EO is an essential element to consider on training prescription because it can acutely influence both volume and training intensity, affecting the chronic adaptations (RIBEIRO et al., 2019; NUNES et al., 2021a). The American College of Sports Medicine recommends performing multi-joint (MJ) exercises that involve larger muscle groups firstly, followed by the single-joint (SJ) exercises and smaller muscle groups (ACSM, 2009a). This guidance, however, was based on acute studies that observed that greater training loads and volume-loads were carried out during training sessions that employed an MJ-to-SJ EO (SFORZO; TOUEY, 1996; SPREUWENBERG et al., 2006; SIMÃO et al., 2007). In a recent meta-analytic review of longitudinal studies, Nunes et al. (2021a) reported that EO influenced the maximum strength gains but not the muscle hypertrophy.

Although there is some evidence that EO may influence muscular adaptations, little is known about the impact of this variable on other outcomes highly prevalent in older age, such as cardiovascular risk and mental health. Recent works suggest that the higher training volume (multiple-sets vs. single-set) can improve body fat and glycemic-lipidemic profiles (NUNES et al., 2016; CUNHA et al., 2021a). Thus, it remains to be explored whether the effects of EO on training volume could result in better cardiometabolic adaptations. Therefore, given that a higher volume is associated with more pronounced reductions in inflammation (SARDELI et al., 2018) and that this process is a crucial mechanism to lowering anxiety and depressive symptoms (KÖHLER et al., 2017) and

improving cognition (KANDOLA et al., 2018), it seems plausible to hypothesize that an EO allowing a higher training volume would lead to more pronounced changes in mental health-related outcomes.

Furthermore, changes in the EO can also influence the ratings of perceived exertion, which is crucial for exercise adherence among people with some depressive and anxiety symptoms (FIRTH et al., 2016; NUNES et al., 2019). Additionally, previous studies have not accounted for the inter-subject variability in responses to RT (SARAIVA et al., 2014; CARDOZO et al., 2019; TOMELERI et al., 2020b; DIB et al., 2020), i.e., some older women benefit more than other (NUNES et al., 2021b). In this sense, the crossover study design has been proposed to consider such variability since all participants experience the different intervention groups.

The purpose of this study was to compare the effects of four EOs that prioritized MJ or SJ exercises for the upper or lower body on body fat, blood biomarkers, cognitive function, depressive and anxiety symptoms in trained older women in a randomized crossover trial. EOs were the following: multi- to single-joint and upper- to lower-body (MJ-SJ-U), single- to multi-joint and upper- to lower-body (SJ-MJ-U), multi- to single-joint and lower- to upper-body (MJ-SJ-L), and single- to multi-joint and lower- to upper-body (SJ-MJ-L). We hypothesized that the MJ-SJ-L and SJ-MJ-L order would elicit greater improvements in those outcomes because this EO would allow for a higher RT volume load.

## **METHODS**

### **Study overview: setting, recruitment, and protocol**

This crossover randomized clinical trial is part of the “Active Aging Longitudinal Study” research project, initiated in 2012 to analyze the effects of supervised, structured, and progressive RT programs on neuromuscular, morphological, physiological, metabolic, cognitive, and behavioral outcomes in older women. The present investigation was carried out over 63 weeks, divided into 4 phases (preconditioning, phase 1, detraining, phase 2). Weeks 1–3, 16–18, 31–33, 46–48, and 61–63 were used for measurements, testing, and evaluations. In weeks 4–15, participants underwent a 12-week preconditioning phase, where they all received the same training. Thereafter, at weeks 19–30, phase 1, participants were randomly assigned to four groups to perform a 12-week RT program according to the respective OEs (MJ-SJ-U, SJ-MJ-U, MJ-SJ-L, and SJ-MJ-L). Then,

participants underwent 12 weeks of detraining (weeks 34–45), in which they were asked not to engage in any physical exercise during this period. Finally, in weeks 49–60, phase 2, a crossover between the MJ-SJ and SJ-MJ conditions was carried out, as follow: participants who had performed MJ-SJ-U in phase 1 then performed SJ-MJ-U; those who had completed SJ-MJ-U then performed MJ-SJ-U; those who had performed MJ-SJ-L then performed SJ-MJ-L, and those who had performed SJ-MJ-L then performed MJ-SJ-L. The present study was conducted according to the Declaration of Helsinki and was approved by the local University Ethics Committee.

### **Participants: recruitment, screening, and eligibility**

Recruitment was undertaken through advertising social media (Whatsapp, Facebook, and Instagram). Participants signed informed consent after understanding the detailed description of the study procedures. Potential participants were then screened for eligibility completed detailed health history questionnaires and were subsequently admitted to the study if they met the following inclusion criteria: women aged > 60 years old; physically independent; not having cardiac, orthopedic, or musculoskeletal dysfunction that could impede physical exercise; not having uncontrolled diabetes mellitus or hypertension; not receiving hormonal replacement therapy, and not being involved in the practice of regular physical activity performed more than once a week over the last five months before the start of the study. Selected volunteers were evaluated by a cardiologist (resting 12-lead electrocardiogram test, personal interview, and treadmill stress test when deemed necessary) to ensure they were safe to take part and were released with no exclusions to exercise practice.

Eighty-four volunteers were interviewed, and only the 72 selected initiated the preconditioning phase. During the preconditioning phase, 11 participants dropped out of the study. Then, a blind researcher was responsible for randomizing, through the random.org website, the 61 participants in one of the four RT groups according to the OEs. During phase 1, 5 participants dropped out of the study (SJ-MJ-U = 5). After the detraining period, 56 participants returned to initiate phase 2 (i.e., no dropouts). During phase 2, 8 participants dropped out of the study (SJ-MJ-U = 2; SJ-MJ-L = 4; MJ-SJ-L = 2). The reasons reported for leaving the study were lack of time (n = 6), lack of motivation (n = 1), transport issues (n = 1), emergency surgeries not related to training (n = 2), the need to take care of family members (n = 3), and other personal reasons (n = 11). According to the crossover design, the final sample consisted of 24 subjects per group. This sample

size is considered satisfactory to achieve significance with a moderate effect size (effect size = 0.34, power = 0.8; alpha = 0.05; time = 2; groups = 4; G\*Power v. 3.1.9.7, Germany). A flowchart of the experimental design of the present work is displayed in Figure 1.

**\*\*\*INSERT FIGURE 1 NEAR HERE\*\*\***

**Co-primary outcomes:** (1) Cardiovascular risk factors, (2) cognitive function, and (3) depressive and anxiety symptoms.

### **Cardiovascular risk factors**

#### ***Six-minute walking test (6MWT)***

Estimated aerobic capacity was measured using a 6-min walking test (6MWT). Each participant was instructed to walk as far as possible, without running, around a rectangular path (4.6 x 18.4 m, total perimeter: 46.0 m) marked with ribbons and cones on the floor for six minutes. An appraiser timed the test time, counted the number of laps, as well as calculated the total distance covered, with an accuracy of one meter (ENRIGHT, 2003). A longer distance achieved in 6MWT indicates a better aerobic capacity (ENRIGHT, 2003).

#### ***Body fat***

Whole-body body fat, trunk fat, gynoid, and android fat measurements were carried out using a dual-energy X-ray absorptiometry scan from Lunar Prodigy equipment, model NRL 419900 (GE Lunar, Madison, WI, USA). Calibration of the equipment followed the manufacturer's recommendations, and both calibration and analysis were performed by a laboratory technician with experience in this type of evaluation. Subjects were submitted to the examinations wearing light clothes, barefoot, and without any metallic object or any other accessory items on their body. Those surveyed lay flat on the scanning table until the finalization of the measure. Individual scans were evaluated for lean and soft tissues for the whole body and specific regions (trunk and upper and lower limbs). The limbs were separated from the trunk and head by standard lines generated by the software of the equipment. The technician adjusted the demarcation lines through specific anatomical points, as denoted in the equipment manual (from 1:00 to 4:00 p.m).

### ***Blood biomarkers***

The blood sample (venous) was collected in a tube containing a dipotassium ethylenediaminetetraacetic acid (12 ml, vacuum-sealed system; Vacutainer, England) between 7:00 and 9:00 a.m., after an overnight fast of at least 12 h. Participants rested in a seated position for at least five minutes before withdrawing 5 ml of blood from a prominent superficial vein in the antecubital space. All samples were centrifuged at 3000 rpm for 15 min, and plasma or serum aliquots were stored at -80° C until assayed. Inter- and intra-assay coefficients of variation were < 10%. Measurements of serum levels of high-sensitivity C-reactive protein, glucose, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), and triglycerides (TG) were determined by standard methods in a specialized laboratory at University Hospital. The low-density lipoprotein cholesterol (LDL-c) was calculated using the following equation (FRIEDEWALD; LEVY; FREDRICKSON, 1972):  $LDL-c = TC - (HDL-c + TG/5)$ . The analyses were performed using a biochemical auto-analyzer system Dimension RxL Max (Siemens Healthcare Diagnostics, Malvern, PA, USA) according to established methods in the literature consistent with the manufacturer's protocol. BDNF (serum) was determined by enzyme-linked immunosorbent assay (ELISA), according to the specifications of the manufacturer (R&D Systems, Minneapolis, MN, USA). Advanced oxidation protein products (AOPP) were determined in the plasma using a semiautomatic method described by Witko-Sarsat et al. (1996). The total radical-trapping antioxidant parameter (TRAP) was determined, as reported by Repetto et al. (1996). This method detects hydrosoluble and/or liposoluble plasma antioxidants by measuring the chemiluminescence inhibition time induced by 2,2-azobis (2-amidinopropane). The system was calibrated with the vitamin E analog Trolox®. Serum nitric oxide metabolites (NOx) concentrations were assessed by nitrite (NO<sub>2</sub><sup>-</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>) concentration according to the Griess reaction, supplemented by the reduction of nitrate to nitrite with cadmium (GUEVARA et al., 1998).

### **Cognitive function**

#### ***Montreal Cognitive Assessment (MoCA)***

The Brazilian version of the MoCA was used to analyze the global cognitive function. The MoCA is a screening tool composed of 12 tasks, individually punctuated, which are grouped into eight different cognitive domains, and the total score ranges from 0 to 30 (higher values reflecting better cognition). Cognitive domains and their respective

punctuation are Short-term memory (delayed recall, 5 points); visuospatial abilities (cube drawing, 1 point, clock drawing, 3 points); executive function (trail making test, 1 point; phonemic verbal fluency, 1 point; verbal abstraction, 2 points); attention, concentration and, working memory (cancelation, 1 point; subtraction, 3 points; digit span, 2 points); language (naming, 3 points; sentence repetition, 2 points); and orientation to time (3 points) and space 3 points). MoCA psychometric properties indicate a high sensitivity (81%) and specificity (77%) for detecting mild cognitive impairment (MCI) states in Brazilian older individuals (using cut-off points < 26 points) (NASREDDINE et al., 2005).

### ***Set-Shifting***

The Trail Making Tests parts A and B were used to assess set-shifting (REITAN, 1958). Part A assesses the psychomotor speed and requires the participant to draw lines that connect encircled numbers sequentially, such as drawing a line from 1 to 2, 2 to 3, 3 to 4, and so on. Part B consists of encircled numbers and letters. Participants were instructed to draw a line as quickly and accurately as possible from 1 to A, A to 2, 2 to B, B to 3, and so on, until they completed the task. Time (in seconds) were recorded, they took to complete each task. Difference were calculated between part B and part A completion times to index set-shifting. Smaller difference scores indicate better-set shifting.

### ***Stroop Test***

A computerized version of the Stroop color-word test (Testinpac<sup>®</sup>) (CÓRDOVA et al., 2008), with the monitor screen in front of the volunteer at 90 cm distance, was applied to evaluate the executive functions, mainly inhibitory control. Responses for a set of tasks were given as fast as possible through two directional buttons on the keyboard. The Stroop effect is based on task situations in which color names are written in different color fonts. The individual should inhibit the meaning of the word and choose the correct answer corresponding to the color in which the word is written (SCHACK et al., 1999). Before performing the test, participants received verbal instructions as well as were familiarized with the test.

The Stroop test version used in the present study consisted of 36 tasks. In every trial, one cue appeared at the top part of the screen, and at the bottom, two response options, one matched and one mismatched. Participants had to press the directional button (< or >) corresponding to the position of the correct response as quickly and

accurately as possible. The test consisted of three stages with 12 trials each: (I – congruent) an inked rectangle (green, black, red, or blue) appeared, and participants had to choose the response corresponding to the ink name; (II – neutral) a color name (green, black, red or blue) appeared in white ink and participants had to choose the option corresponding to the color name; (III – incongruent) a color name appeared at the top of the screen in a different ink color (e.g., the word black in green ink), and the participants had to respond to the ink color, not the color name (e.g., green in this example). Each stimulus remained on the screen until the participant entered a response. The trials were randomized within each phase. The software registered the response time (RT) and accuracy, which were used for the analysis. The Stroop effect or interference (i.e., ability to inhibit irrelevant stimulus) was calculated as the difference in RT between the third and the second phase. Shorter time differences indicate better selective attention and conflict resolution.

### ***Verbal Fluency Tasks***

Participants were asked to say as many words as possible within 60 s. On the first trial, participants had to produce words starting with the letter “F” (letter fluency) and to make the name of animals (category fluency). The final score refers to the number of words correctly spoken out in 60 s (ESTEVES et al., 2015).

### **Depression and anxiety symptoms**

The levels of depressive and anxiety symptoms were assessed using two self-administered questionnaires: the 15-item Geriatric Depression Scale (GDS-15) (YESAVAGE et al., 1982) and the Beck Anxiety Inventory (BAI), respectively (BECK et al., 1988). The GDS-15 comprises 15 dichotomic items (yes or not) concerning different characteristics of geriatric depression as cognitive decline and somatic symptoms, with the final score ranging from 0 to 15. The BAI comprises 21 items (statements) about different anxiety symptoms with a 4-point Likert scale, with the final score ranging from 0 to 63.

**Secondary outcomes:** (1) Anthropometry, (2) dietary intake and (3) volume-load.

### **Anthropometry**

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale Balmak (Laboratory Equipment Labstore, Curitiba, PR, Brazil). Height was measured with a stadiometer attached to scale to the nearest 0.1 cm. All participants wore light workout clothing and no shoes during the measurements. Body mass index (BMI) was calculated as body mass in kilograms divided by the square of height in meters.

### **Dietary intake**

Food consumption was assessed by the 24 h of dietary recall method to analyze the subjects' habitual intake throughout the study. Assessments were realized on two non-consecutive days of the week. During the initial interview, a photographic manual of food portion size was presented by experienced nutritionists to improve the quality of food intake reports. The homemade measurements of the nutritional values of food and supplementation were converted into grams and milliliters by the online software Virtual Nutri Plus (Keeple®, Rio de Janeiro, RJ, Brazil) for diet analysis. Some foods were not found in the program database, and, therefore, several items were added from food tables.

### **Volume-load**

The loads and the number of repetitions performed during every RT session were recorded during each set of the eight exercises. With this, the volume-load was calculated by the exercise's load multiplied by the total number of repetitions in all sets: volume-load = load (kg) x sets (no.) x repetitions (no.) (CUNHA et al., 2020).

### **Resistance training program**

In the 12-week pre-conditioning phase, all participants underwent a standard RT protocol, which was based on recommendations to improve muscular endurance and strength in older adults (ACSM, 2009b; FRAGALA et al., 2019). The training was carried out three days a week (Mondays, Wednesdays, and Fridays) in the morning hours (8:00-10:00 a.m.) at the University fitness facility. The training program was comprised of eight exercises for the whole body in an EO alternating between upper and lower body exercises, with each performed in 3 sets of 10-15 repetitions using free-weights and pin-loaded machines (Ipiranga Fitness, Presidente Prudente, SP, Brazil). Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant movement velocity at a ratio of approximately 1:2 s

(concentric and eccentric muscle actions, respectively). Rest intervals were one to two minutes between sets and two to three minutes between exercises. Training load was increased weekly by 2–5% for upper-limb exercises and 5–10% for the lower-limb exercises, according to the number of repetitions performed during each training session to ensure that participants maintained ideal intensity in the repetition zone (ACSM, 2009a). Participants were supervised individually throughout each training session by Physical Education professionals with experience in RT (two professionals per exercise) to standardize intensity and technique reliability and help ensure safety. Adherence to the program was satisfactory, with all participants attending a minimum of 85% of the sessions.

In phases 1 and 2, in which the EOs were compared, RT was similar to the pre-conditioning RT phase (eight exercises, 3x/week, 12 weeks), differing only for the RM-target-zone used in the exercises, where an increase in RM-intensity was employed (3 sets of 8-12 repetitions), and the EOs. Participants carried out the following EOs: MJ-SJ-U = chest press, seated row, triceps pushdown, preacher curl, horizontal leg press, leg extension, lying leg curl, seated calf raise; SJ-MJ-U = preacher curl, triceps pushdown, seated row, chest press, seated calf raise, lying leg curl, leg extension, horizontal leg press; MJ-SJ-L = horizontal leg press, leg extension, lying leg curl, seated calf raise, chest press, seated row, triceps pushdown, preacher curl; SJ-MJ-L = seated calf raise, lying leg curl, leg extension, horizontal leg press, preacher curl, triceps pushdown, seated row, chest press.

### **Statistical analyses**

The Shapiro-Wilk test was used to verify the data distribution. The participants' general characteristics were compared using the one-way analysis of variance (ANOVA) and chi-square for continuous and categorical variables, respectively. Analysis of covariance (ANCOVA) of the raw difference between pre- to post-intervention measures was employed for comparing changes within- and between groups, with the baseline values used as a covariate. Interpretation of data was based on 95% confidence intervals (i.e., when 95% CI of the raw delta did not overlap the 0, there was a significant difference between baseline scores). Although we presented both ANCOVA-adjusted and unadjusted data for the primary outcomes, statistically meaningful interpretations were made with results from ANCOVA. For all analyses was accept a  $P < 0.05$ . The data were stored and analyzed in STATISTICA software v. 10.0 (Statsoft Inc., Tulsa, OK, USA).

## RESULTS

No difference was observed between groups for baseline age (MJ-SJ-U =  $69 \pm 6$ , SJ-MJ-U =  $68 \pm 5$ , MJ-SJ-L =  $68 \pm 6$ , SJ-MJ-L =  $69 \pm 6$  years,  $P = 0.98$ ), body mass (MJ-SJ-U =  $68 \pm 14$ , SJ-MJ-U =  $68 \pm 13$ , MJ-SJ-L =  $67 \pm 13$ , SJ-MJ-L =  $68 \pm 13$  kg,  $P = 0.99$ ), stature (MJ-SJ-U =  $154 \pm 6$ , SJ-MJ-U =  $155 \pm 6$ , MJ-SJ-L =  $155 \pm 6$ , SJ-MJ-L =  $155 \pm 7$  cm,  $P = 0.83$ ), body mass index (MJ-SJ-U =  $28 \pm 5$ , SJ-MJ-U =  $28 \pm 5$ , MJ-SJ-L =  $28 \pm 4$ , SJ-MJ-L =  $28 \pm 4$  kg.m<sup>-2</sup>,  $P = 0.98$ ), as well as the groups' prevalence of type 2 diabetes ( $P = 0.69$ ), hypertension ( $P = 0.73$ ), dyslipidemia ( $P = 0.64$ ), hypoglycemic ( $P = 0.90$ ), intake of antihypertensive medicine ( $P = 0.59$ ), and statins ( $P = 0.57$ ).

### Co-primary outcomes

#### Cardiovascular risk factor

The cardiorespiratory fitness represented by 6MWT is shown in Figure 1. All groups improved their performances after the intervention ( $P < 0.05$ ). However, no difference was found between groups ( $P = 0.84$ ). Table 1 presented the total and relative body fat, trunk fat, android, and gynoid fat pre-and post-intervention. After the training, all groups showed significant decreases in total body fat, relative body fat, trunk fat, android, and gynoid fat, no difference between them ( $P > 0.05$ ). Results of glycemic and lipid profiles are shown in Table 2. All groups presented significant healthy effects in glucose, glycated hemoglobin, LDL-c, and total cholesterol ( $P < 0.05$ ). Additionally, in Table 3, we showed results of C-reactive protein, BDNF, and oxidative biomarkers. We observed improvements in C-reactive protein, BDNF, AOPP, and NOx in all groups ( $P < 0.05$ ). However, no changes were found for HDL-c, triglycerides, and TRAP in any group ( $P > 0.05$ ). No difference between groups was found ( $P > 0.05$ ).

\*\*\*INSERT FIGURE 1 NEAR HERE\*\*\*

\*\*\*INSERT TABLE 1 NEAR HERE\*\*\*

\*\*\*INSERT TABLE 2 NEAR HERE\*\*\*

### **Depressive and anxiety symptoms and cognitive function**

The results for cognitive tests, depressive, and anxiety symptoms pre-and post-intervention are presented in Table 3. All groups demonstrated significant improvements in MoCA, semantic, and phonetic verbal fluency and BAI. However, no changes were found for the GDS scale in any group ( $P > 0.05$ ). No difference between groups was found ( $P > 0.05$ ).

**\*\*\*INSERT TABLE 3 NEAR HERE\*\*\***

The results of detraining period for all variables are shown in Supplementary Materials 1, 2, and 3). Significant effects, in the reverse direction of the training adaptations, were observed in body fat (absolute, relative, trunk, android, and gynoid), blood biomarkers (glucose, glycated hemoglobin, total cholesterol, LDL-c, C-reactive protein, BDNF, and AOPP), and mental health (MoCA, Stroop test, verbal fluency semantic, phonemic, and BAI). No difference between groups was found ( $P > 0.05$ ).

### **Secondary outcomes**

No changes were found within- and between groups for macronutrients and energy intake (time\*group interaction  $P$ -values = 0.16–0.66). Average values during the intervention were the following: energy =  $25.5 \pm 5.8$  kcal/kg/d; carbohydrate =  $3.3 \pm 0.8$  g/kg/d; protein =  $1.1 \pm 0.2$  g/kg/d; lipid =  $0.8 \pm 0.2$  g/kg/d.

All groups progressed (MJ-SJ-U = 27%; SJ-MJ-U = 26.9%; MJ-SJ-L = 28.6%; SJ-MJ-L = 24.3%;  $P = 0.03$ ) and accumulated (MJ-SJ-U =  $12524.9 \pm 2577.5$ ; SJ-MJ-U =  $12336.7 \pm 1685.6$ ; MJ-SJ-L =  $12431.6 \pm 2553.1$ ; SJ-MJ-L =  $11429.5 \pm 2021.7$  ton;  $P = 0.03$ ) training volume-load similarly throughout the intervention.

## **DISCUSSION**

The main findings of this investigation were that all four RT EO promote (i) a similar decrease in body fat (absolute, relative, and regional) and increase in 6MWT performance, (ii) comparable changes in metabolic biomarkers (glucose, glycated hemoglobin, LDL-c, total cholesterol, BDNF, AOPP, and NOx), and (iii) improvements in cognitive performance, anxiety, and depressive symptoms (MoCA, verbal fluency semantic and phonetic, Stroop test, and BAI). Based on these observations, it can be suggested that EO does not in itself influence the magnitude of body fat, blood biomarkers, and mental

health changes in trained older women. Moreover, it seems that simply engaging in the RT program can achieve these benefits.

Our findings contrast the initial hypothesis postulating that different EO would influence alterations in health-related parameters due to possible differences in volume load. Interestingly, our results did not show differences in volume-load among groups. Given that all four EOs were able to improve the various outcome parameters, our findings strongly support the assumption that RT is an important strategy to ensure the overall health of older adults (FRAGALA et al., 2019). To the best of our knowledge, this is the first study directly comparing the influence of different EO on cardiovascular risk factors and mental health parameters. In this regard, we did not find significant differences in volume-load between other EO groups, which could be one reason explaining the absence of differences in our outcomes between the EO groups. These findings suggest that an adequate exercise prescription with correct control of training variable is paramount to achieve cognitive improvements and to characterize the dose of a physical intervention appropriately (HEROLD et al., 2019b, 2019a).

Concerning body fat (absolute, relative, and regional), we noticed a decrease in all training groups after the intervention period, except for the trunk fat. These findings agree with other studies that observed a reduction in body fat after an RT intervention in older adults (NUNES et al., 2016; CUNHA et al., 2021a). The volume/intensity produced by RT-intervention was sufficient to cause higher energy expenditure, which may have triggered a decrease in body fat. It should be noted that there was no difference in energy and macronutrient intake throughout the study (controlled by 24 h of dietary recall method), which suggests that RT induced the reductions in body fat.

Furthermore, our study revealed improvements in several blood biomarkers related to cardiovascular risk and mental health, such as glucose, glycated hemoglobin, LDL-c, total cholesterol, C-reactive protein, AOPP, NOx, and BDNF. These results agree with available studies investigating the effect of RT interventions in older adults (COELHO et al., 2013; IHALAINEN et al., 2019; CUNHA et al., 2021a). Different and complex biological mechanisms can explain the effect of RT on different indicators associated with cardiovascular risk. Firstly, the benefits of RT on cardiovascular outcomes can be related to the decrease in body fat content and the improvement in cardiorespiratory fitness level (HOLLINGS et al., 2017). Secondly, also the frequent muscle contractions (due to regular RT) are important (i) to trigger anti-inflammatory processes, (ii) to increase the glucose and lipids uptake (e.g., for energy production) (PEDERSEN; FEBBRAIO, 2008), (iii) to

improve the insulin sensitivity (PHILLIPS; WINETT, 2010), and (iv) to induce adaptations in the antioxidant system with favorable adjustments to the endogenous antioxidant system (ALIKHANI; SHEIKHOLESAMI-VATANI, 2019) which, in turn, can increase the body's defense capacity.

The observed increase in serum BDNF concentration is in line with previous studies investigating the effect of RT on this neurotrophic factor (COELHO et al., 2013; MARINUS et al., 2019). BDNF plays an essential role in regulating food intake, energy expenditure, and brain health (MARSTON et al., 2019). Moreover, although no significant correlation had been observed between body fat and blood biomarkers (data not shown), it is possible to speculate which changes in these blood biomarkers can be associated with changes in body fat (CUNHA et al., 2021a).

Furthermore, the results of the present study are in accordance with previous findings on the RT-induced cognitive improvements in older adults (LIU-AMBROSE et al., 2010; SMOLAREK et al., 2016; MAVROS et al., 2017). Li et al. (2018) showed in their systematic review that RT with different types of volume and intensity had a significant positive effect on cognitive function in older adults, with the most consistent impact for executive function, intermediate for global cognitive function, and weak for memory. In this present investigation, we found improvement in MoCA, semantic and phonetic verbal fluency, and no changes were observed for the Stroop and Trail Making tests. Our results showed that RT had a positive effect on global cognitive performance in older women, which is in line with three recent studies that reported improvements in several cognitive domains in older adults after the RT program (SMOLAREK et al., 2016; MAVROS et al., 2017). Contrarily, Hong et al. (2017) found no changes in the Controlled Oral Word Association Test (COWAT), Stroop test, digit span test, and Rey 15-Item Memory Test in older adults with mild cognitive impairments. One possible explanation for the different results is that in the present study, machines and free weights with progressive loads were used, whereas Hong et al. used an elastic band as resistance, making an adjustment of the load more difficult (HONG; KIM; JUN, 2018).

The inconsistent findings concerning performance changes in the executive function being observed in this study are similar to the findings of previous studies (LIU-AMBROSE et al., 2010; IULIANO et al., 2015; MAVROS et al., 2017; HONG; KIM; JUN, 2018) and lending credit to the assumption that exercise does not improve all domains of cognitive function, at least not to the same extent. Additionally, there was no change in depressive symptoms (GDS-scale) while there was a decrease in anxiety symptoms (BAI)

after the intervention. Previous findings regarding the effect of RT on depressive and anxiety symptoms are inconclusive among older adults (SCHUCH et al., 2016; MILLER et al., 2020), and there are multiple reasons for these inconsistent findings. For instance, our sample consists of older women who were not diagnosed with mild or severe depression or anxiety. Additionally, previous studies had a shorter training duration (6-10 weeks) and used different protocols (e.g., lower load or weekly frequency) (MILLER et al., 2020). A possible explanation for the null effect of RT on depressive symptoms can be that the baseline condition of depressive symptoms was already relatively low, which consequently makes it not prone to a further reduction.

It is well-established in the literature that complex biological mechanisms drive the effect of RT on cognitive function and anxiety symptoms (HEROLD et al., 2019b). Considering the general picture of our findings, many of the potential mechanisms were also affected by the RT. In this sense, we found that RT was associated with factors that are also indirectly and directly related to cognitive function and lower anxiety symptoms, as reduction of body fat, increments in cardiorespiratory fitness, muscle mass, and muscular strength (MAVROS et al., 2017; KANDOLA et al., 2018). Also, we found that the RT intervention was efficient in improving possible direct mechanisms linking exercise with cognition and anxiety symptoms, including a neuroplasticity indicator (BDNF), different inflammation indicators (C-reactive protein), and improvements in oxidative stress (AOPP), which are all associated with better cognitive performance and lower anxiety symptoms (ALLEY et al., 2008; FEDOCE et al., 2018; KANDOLA et al., 2019). Moreover, we assume that the decrease in the anxiety symptoms has been fostered (i) by the improvements in cognitive performance (BEAUDREAU; O'HARA, 2008) and (ii) by more social interactions (e.g., due to interactions with the research team and other participants during the RT) (EVANS et al., 2018) as both factors has been linked to a reduction in previous studies.

Finally, it should be noted that the 12-week detraining period resulted in an increase in body fat (absolute, relative, trunk, android, and gynoid), worsened cognitive performance (MoCA, Stroop test, Trail Making test, semantic, and phonetic verbal fluency), increased depressive symptoms (GDS) and anxiety (BAI) with no differences between groups. These results show that EO did not influence the retention of RT-induced changes in the outcome measures. More important, these results reinforce the idea that regular RT practice is an important determinant to maintain or further improve RT-induced adaptations in body composition, cognitive function, and mental health. From a practical

perspective, RT interruption, such as training vacation, should be kept as short as possible. Future studies should test different detraining durations to identify how long RT-induced adaptation lasts after training interruption to provide better guidance in this regard.

Importantly, our investigation had some limitations. Firstly, our findings should not be extrapolated to other populations as untrained older women, younger individuals or males. Second, we did not control regular physical activity levels outside of the investigation environment, which may have confounded results. However, the participants were asked to maintain their regular activities of daily living throughout the intervention period to minimize to confounding influence of other lifestyle changes. The current study also has several strengths. This investigation was conducted in a crossover design with a washout period allowing control for the interindividual variability of responses. Furthermore, based on our strict inclusion criteria, the effects of EO were studied in a homogenous sample reducing the bias risks due to heterogeneous sample characteristics. The RT load and frequency ( $\geq 85\%$  in RT sessions in all groups) and correct execution of the exercise (technique) were carefully controlled by specialized and experienced experts over the whole intervention period. Additionally, we account for other lifestyle factors such as dietary intake at the experiment's beginning and end.

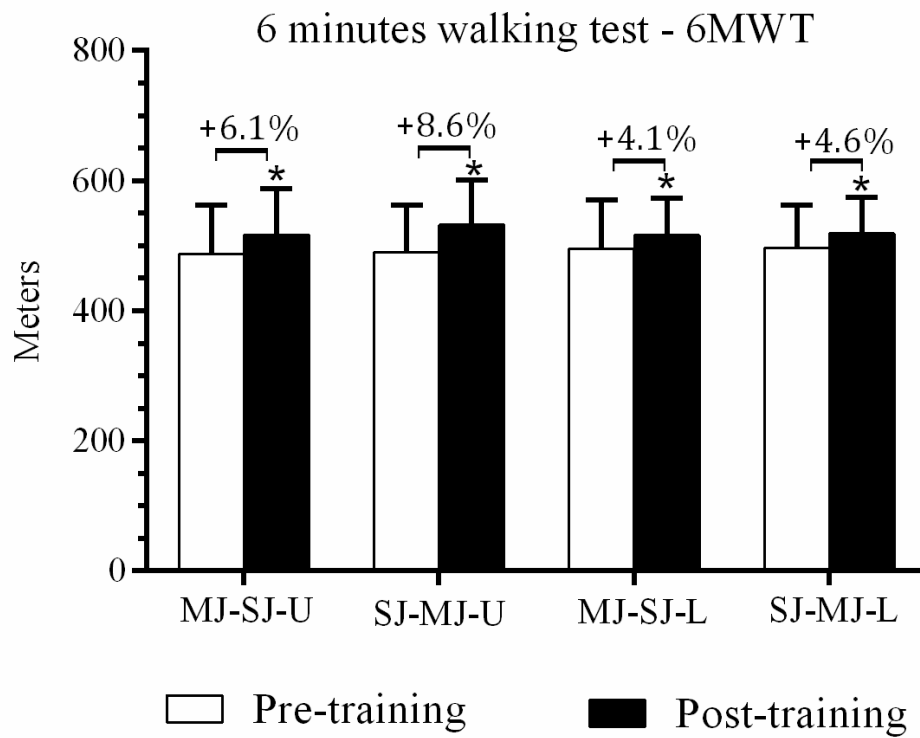
## **CONCLUSION**

Our results suggest that regardless of EO used, improvements in cardiovascular risk factors, mental health parameters, and cognitive performance can be observed in resistance-trained older women. Thus, from a practical standpoint, our findings strongly support the notion that regular RT is an important strategy to counteract age-related changes and ensure healthy aging in older women. Additionally, the professionals can be flexible in the prescription of EO for older women, allowing them to choose the exercise order based on preference, which may impact exercise adherence.

**Acknowledgments:** The authors thank all subjects for their engagement in the study, the Coordination of Improvement of Higher Education Personnel (CAPES/Brazil) for the scholarship conferred to JPN, GK (master), PMC, and AOW (doctoral), and the National Council of Technological and Scientific Development (CNPq/Brazil) for the grants conceded to ESC.

**Compliance with Ethical Standards:** The present study was conducted according to the Declaration of Helsinki. **Ethical approval:** The present study was approved by the Londrina State University Ethics (Review Board) Committee. **Conflict of interests:** Brendon Stubbs is funded by an NIHR Advanced fellowship (NIHR301206). Brendon is also a lead/co-investigator of the following active grants 1) NIHR program grant: Supporting Physical and Activity through Co-production in people with Severe Mental Illness (SPACES,2021-2027); 2) TB multimorbidity with the Medical Research Council (GCRF call (2020-2022); 3) Determinants of MLTCs among young adults with mental disorders: a data-linkage study, Guy's & St Thomas' Charity (2020-2022); 4) Mechanisms underlying the role of gut-microbiota in exercise-induced changes in cognitive function in middle-age, Reta Lila Weston Trust For Medical Research (2021-2024). Brendon Stubbs has coauthored a book on exercise and mental illness, is on the Editorial Board of Ageing Research Reviews, Mental Health and Physical Activity, The Journal of Evidence-Based Medicine, and The Brazilian Journal of Psychiatry. Brendon Stubbs has received an honorarium for advisory work from ASICS Europe BV & ParachuteBH for unrelated work. The views expressed are those of the author(s) and not necessarily those mentioned above, the NHS, the NIHR, the Department of Health and Social Care, the MRC, or GSTT. The other authors declare that they have no conflict of interest regarding the publication of this paper. **Informed consent:** All participants provided their written informed consent before participating in the study. **Funding:** This work was partially supported by the Ministry of Education (MEC/Brazil) and CNPq/Brazil.

**Authors' contributions:** PMC, JPN, and ESC conceptualized the idea of the study. PMC analyzed the data and drafted the first version of the manuscript. PMC, JPN, GK, and DV conducted the data collection. ESC conceived, designed, and supervised the research project. All authors read, revised critically, and approved the final version of the manuscript.



**Figure 1.** Results of the 6MWT at pre-and post-training according to the groups. Data are expressed as mean  $\pm$  standard deviation. \* $P < 0.05$  vs. Pre.

**Table 1.** Results of the body fat at pre-and post-training according to groups.

Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	P
Total body fat (kg)					
Pre	26.9 ± 8.0	28.3 ± 8.3	28.4 ± 7.9	28.1 ± 8.7	
Post	26.4 ± 8.3*	27.8 ± 8.6*	27.7 ± 8.1*	27.6 ± 8.7*	0.95
Covariate mean = 27.9	27.5 (27.0–27.8)	27.4 (27.0–27.8)	27.3 (26.9–27.6)	27.4 (27.0–27.7)	
Relative body fat (%)					
Pre	39.5 ± 5.9	41.0 ± 6.0	41.4 ± 6.9	40.5 ± 8.1	
Post	38.3 ± 6.3*	39.6 ± 6.5*	39.7 ± 7.0*	39.0 ± 8.1*	0.65
Covariate mean = 40.6	39.3 (38.8–39.9)	39.2 (38.7–39.8)	38.9 (38.4–39.5)	39.0 (38.5–39.5)	
Trunk fat (kg)					
Pre	13.9 ± 4.6	14.3 ± 4.17	15.1 ± 4.21	15.0 ± 4.7	
Post	13.6 ± 4.8*	14.0 ± 4.24*	14.8 ± 4.41*	14.7 ± 4.7*	0.99
Covariate mean = 14.6	14.3 (14.0–14.5)	14.3 (14.1–14.5)	14.3 (14.0–14.5)	14.3 (14.0–14.5)	
Android fat (kg)					
Pre	2.5 ± 0.9	2.6 ± 0.9	2.7 ± 0.8	2.7 ± 0.8	
Post	2.4 ± 0.8*	2.5 ± 0.8*	2.6 ± 0.7*	2.6 ± 0.8*	0.96
Covariate mean = 2.6	2.5 (2.4–2.5)	2.5 (2.4–2.6)	2.5 (2.4–2.5)	2.5 (2.4–2.5)	
Gynoid fat (kg)					
Pre	4.9 ± 1.2	5.2 ± 1.5	5.1 ± 1.2	5.1 ± 1.4	
Post	4.8 ± 1.2*	5.1 ± 1.5*	5.0 ± 1.3*	5.0 ± 1.5*	0.82
Covariate mean = 5.1	5.0 (4.9–5.0)	5.0 (4.8–5.0)	5.0 (4.9–5.0)	5.0 (4.9–5.0)	

**Note:** Data are expressed as mean ± standard deviation or mean (lower – upper bounds of 95% confidence interval). MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. \* $P < 0.05$  vs. Pre.

**Table 2.** Glycemic and lipid profile at pre- and post-training according to groups.

Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	P
Glucose (mg/dL)					
Pre	103.3 ± 17.2	102.9 ± 18.1	107.4 ± 32.1	103.5 ± 22.6	
Post	97.9 ± 16.3*	98.7 ± 17.0*	102.3 ± 28.7*	100.0 ± 20.8*	0.67
Covariate mean = 104.3	98.7 (96.4–101.0)	99.9 (97.6–102.1)	99.6 (97.3–101.8)	100.7 (98.5–102.8)	
Glycated hemoglobin (mg/dL)					
Pre	6.1 ± 0.5	6.1 ± 0.4	6.1 ± 0.7	6.1 ± 0.5	
Post	5.9 ± 0.6*	5.9 ± 0.5*	5.9 ± 0.8*	5.9 ± 0.6*	0.95
Covariate mean = 6.1	5.9 (5.7–6.0)	5.9 (5.7–6.0)	5.9 (5.7–6.0)	5.9 (5.7–6.0)	
HDL-c (mg/dL)					
Pre	56.8 ± 15.3	54.6 ± 14.0	60.2 ± 12.9	61.1 ± 15.1	
Post	58.5 ± 15.0	56.6 ± 13.4	61.7 ± 12.9	62.3 ± 13.3	0.89
Covariate mean = 58.3	59.7 (57.7–61.7)	59.7 (57.7–61.6)	59.9 (58.0–61.8)	59.8 (57.9–61.7)	
LDL-c (mg/dL)					
Pre	122.7 ± 31.2	125.8 ± 31.1	115.8 ± 26.5	117.3 ± 29.9	
Post	113.8 ± 29.6*	119.6 ± 26.9*	111.2 ± 24.1*	112.4 ± 28.3*	0.72
Covariate mean = 120.3	111.9 (107.3–116.5)	115.2 (110.7–119.7)	114.8 (110.3–119.3)	114.8 (110.4–119.1)	
Triglycerides (mg/dL)					
Pre	115.4 ± 60.1	120.7 ± 41.9	108.2 ± 34.1	109.1 ± 44.5	
Post	105.5 ± 54.0	112.0 ± 45.2	105.0 ± 39.6	105.1 ± 39.2	0.96
Covariate mean = 113.4	104.4 (93.0–115.7)	108.0 (97.0–118.8)	107.7 (96.5–118.9)	107.4 (96.8–117.9)	
Total cholesterol (mg/dL)					
Pre	202.5 ± 36.7	202.7 ± 45.6	198.6 ± 32.9	202.8 ± 38.0	
Post	189.6 ± 38.0*	195.9 ± 41.1*	193.1 ± 31.0*	194.5 ± 35.7*	0.30
Covariate mean = 201.7	188.9 (183.3–194.4)	195.1 (189.6–200.4)	195.7 (190.3–201.0)	193.5 (188.3–198.7)	

**Note:** Data are expressed as mean ± standard deviation or mean (lower – upper bounds of 95% confidence interval). MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. \* $P < 0.05$  vs. Pre.

**Table 3.** C-reactive protein, BDNF, and oxidative biomarkers at pre-and post-training according to groups.

Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 24)	SJ-MJ-L (n = 24)	P
C-reactive protein (mg/dL)					
Pre	3.3 ± 2.0	3.5 ± 2.0	3.2 ± 1.9	2.9 ± 1.6	
Post	2.8 ± 1.3*	2.9 ± 1.7*	2.7 ± 1.5*	2.6 ± 1.4*	0.98
Covariate mean = 3.2	2.7 (2.4–3.0)	2.8 (2.4–3.1)	2.7 (2.3–3.0)	2.8 (2.4–3.1)	
BDNF (pg/ml)					
Pre	1308.3 ± 199.3	1367.7 ± 173.5	1464.1 ± 346.5	1496.4 ± 419.1	
Post	1821.5 ± 168.5*	1835.9 ± 154.6*	1775.9 ± 201.7*	1801.2 ± 465.8*	0.76
Covariate mean = 1411.6	1857.4 (1763.5–1951.3)	1851.1 (1762.3–1939.9)	1757.7 (1667.5–1847.8)	1771.7 (1683.5–1860.0)	
AOPP (µmol·L <sup>-1</sup> )					
Pre	116.8 ± 14.2	118.5 ± 36.1	108.4 ± 27.2	112.6 ± 31.6	
Post	105.6 ± 15.6*	101.2 ± 15.0*	98.3 ± 20.1*	102.4 ± 15.4*	0.41
Covariate mean = 114.0	105.0 (99.8–110.1)	100.2 (95.2–105.0)	99.6 (94.6–104.5)	102.8 (97.9–107.5)	
TRAP (µmol·Trolox)					
Pre	1011.3 ± 222.0	1051.5 ± 145.9	985.8 ± 240.5	1128.5 ± 400.9	
Post	999.6 ± 153.7	998.9 ± 182.8	1017.9 ± 148.5	1040.7 ± 143.1	0.71
Covariate mean = 1052.3	999.8 (939.3–1060.2)	998.9 (938.5–1059.1)	1018.2 (951.0–1085.3)	1040.3 (985.9–1094.6)	
NOx (µmol·L <sup>-1</sup> )					
Pre	6.6 ± 2.2	6.8 ± 2.5	7.1 ± 2.6	7.0 ± 2.3	
Post	7.6 ± 1.9*	7.8 ± 2.3*	7.6 ± 2.0*	8.1 ± 1.3*	0.54
Covariate mean = 6.9	7.7 (7.0–8.2)	7.9 (7.3–8.4)	7.5 (6.9–8.0)	8.0 (7.4–8.6)	

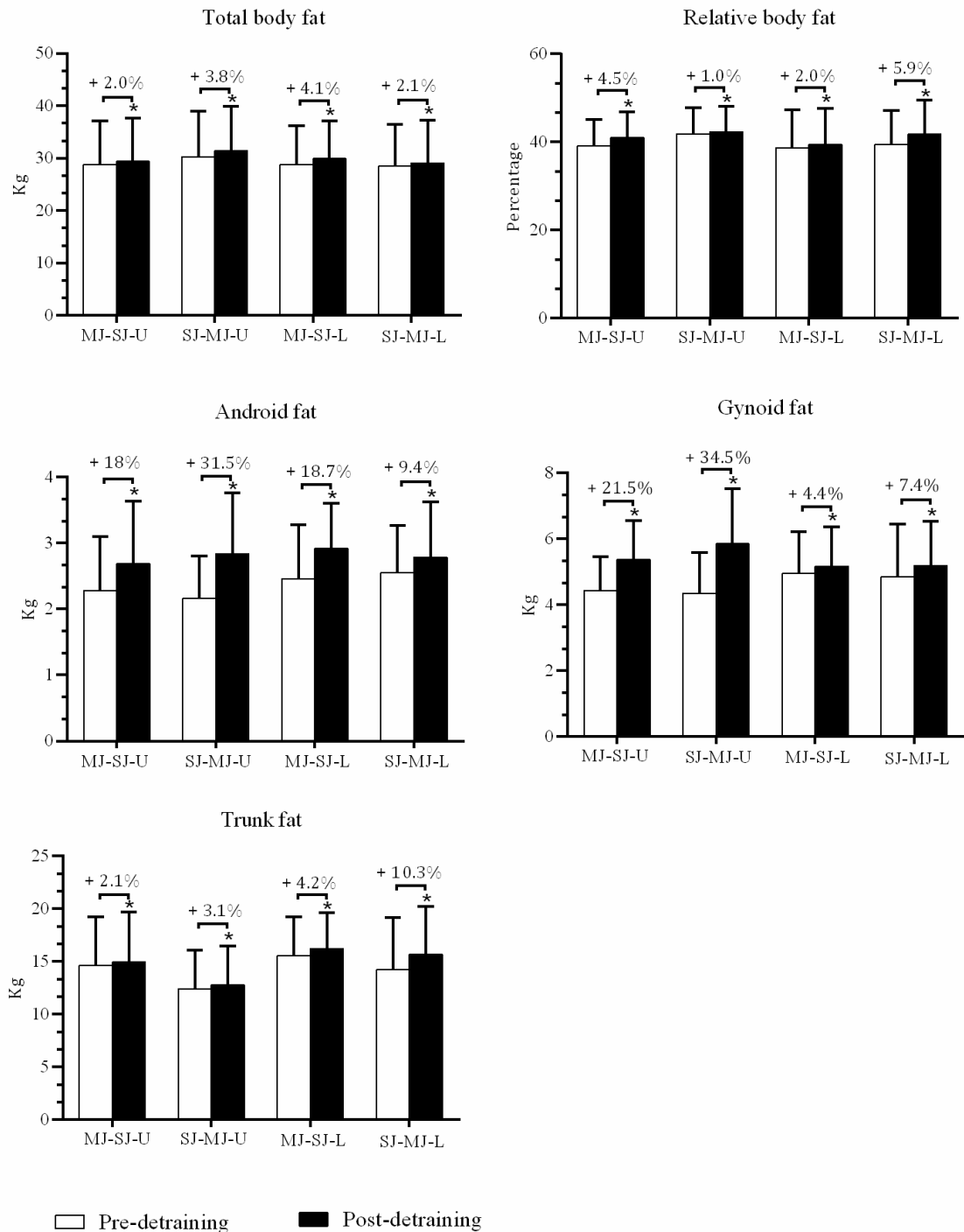
**Note:** Data are expressed as mean ± standard deviation or mean (lower – upper bounds of 95% confidence interval). MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. \*P < 0.05 vs. Pre.

**Table 4.** Cognitive functions, depression, and anxiety at pre-and post-training according to groups.

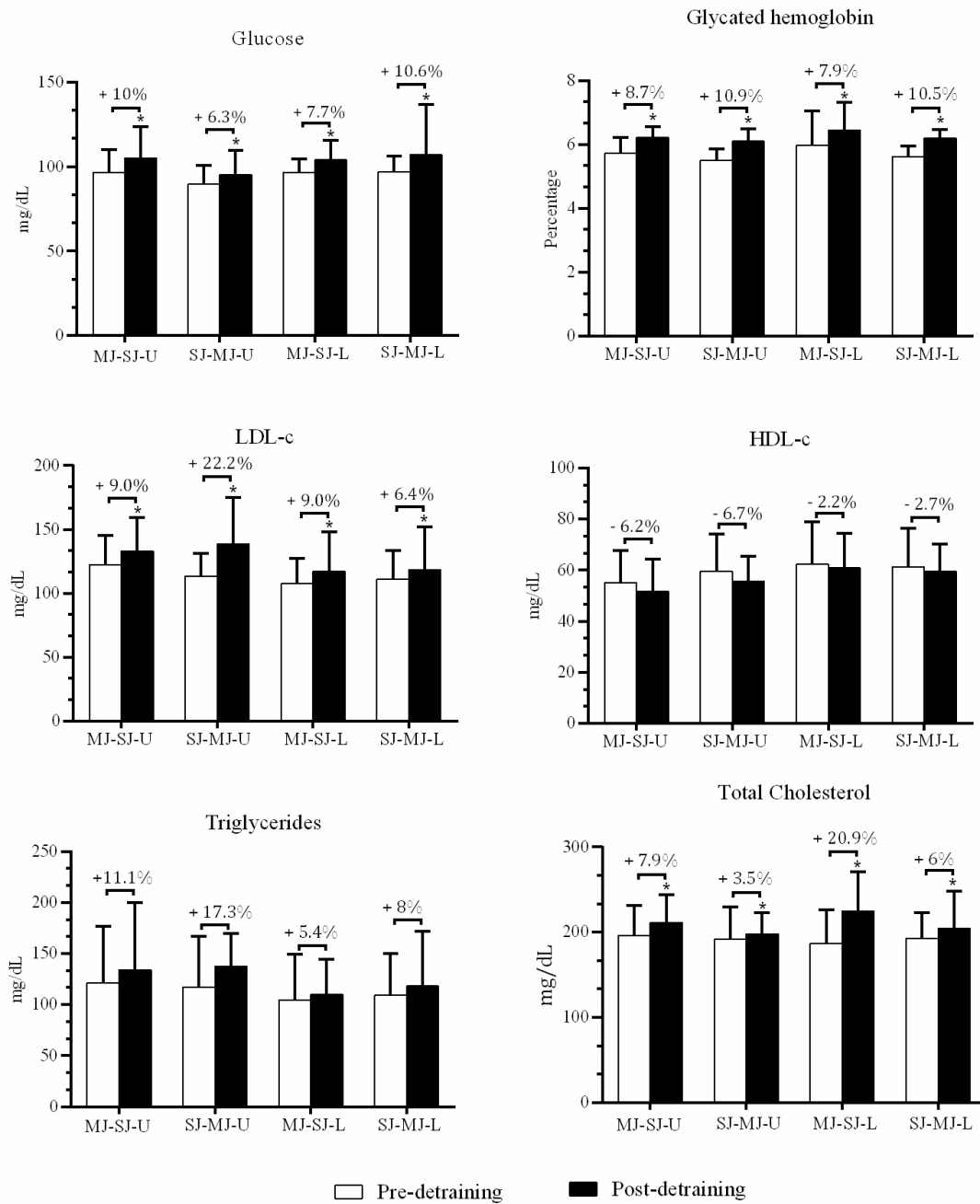
Variables	MJ-SJ-U (n = 24)	SJ-MJ-U (n = 24)	MJ-SJ-L (n = 15)	SJ-MJ-L (n = 24)	P
<b>MoCA</b>					
Pre	22.1 ± 4.0	21.8 ± 4.6	22.2 ± 4.4	22.2 ± 4.7	
Post	23.0 ± 3.5*	23.0 ± 3.6*	23.1 ± 4.0*	23.1 ± 3.9*	0.99
Covariate mean = 22.1	23.0 (22.3–23.8)	23.2 (22.4–23.9)	23.0 (22.3–23.8)	23.0 (22.3–23.8)	
<b>TM B-A</b>					
Pre	46.7 ± 41.0	51.3 ± 37.7	61.1 ± 46.3	55.7 ± 33.9	
Post	47.6 ± 36.3	45.3 ± 33.9	53.5 ± 38.7	52.6 ± 29.4	0.69
Covariate mean = 53.8	52.5 (45.1–59.8)	46.9 (39.7–54.1)	48.4 (41.1–55.7)	51.3 (44.3–58.1)	
<b>Fluency Verbal Semantic</b>					
Pre	15.0 ± 3.9	15.8 ± 3.9	16.1 ± 2.7	16.4 ± 4.5	
Post	17.0 ± 3.2*	16.8 ± 3.8*	17.3 ± 4.2*	17.4 ± 4.3*	0.77
Covariate mean = 15.9	17.6 (16.6–18.6)	16.8 (15.9–17.8)	17.1 (16.1–18.2)	17.0 (16.1–18.0)	
<b>Fluency Verbal Phonetic</b>					
Pre	12.0 ± 3.3	10.6 ± 3.8	10.7 ± 4.2	11.6 ± 4.4	
Post	12.6 ± 3.6*	11.5 ± 4.2*	11.9 ± 4.0*	12.4 ± 4.2*	0.91
Covariate mean = 11.2	12.0 (11.3–12.7)	12.0 (11.3–12.8)	12.3 (11.6–13.1)	12.1 (11.4–12.8)	
<b>Stroop Test</b>					
Pre	0.6 ± 0.4	0.6 ± 0.4	0.7 ± 0.3	0.5 ± 0.4	
Post	0.5 ± 0.4	0.5 ± 0.4	0.5 ± 0.3	0.4 ± 0.4	0.99
Covariate mean = 0.6	0.5 (0.3–0.6)	0.5 (0.3–0.6)	0.5 (0.3–0.6)	0.5 (0.3–0.6)	
<b>GDS-scale</b>					
Pre	2.1 ± 1.5	2.1 ± 1.7	2.1 ± 1.3	2.5 ± 1.7	
Post	2.0 ± 1.4	2.0 ± 1.3	2.1 ± 1.9	2.2 ± 1.8	0.95
Covariate mean = 2.2	2.1 (1.6–2.5)	2.0 (1.6–2.4)	2.2 (1.7–2.6)	2.0 (1.6–2.5)	
<b>BAI</b>					
Pre	3.4 ± 4.0	2.9 ± 3.5	3.5 ± 3.3	4.4 ± 5.0	
Post	2.8 ± 2.5*	1.8 ± 1.7*	2.7 ± 1.7*	2.6 ± 2.5*	0.30
Covariate mean = 3.6	2.8 (2.1–3.6)	2.0 (1.3–2.7)	2.7 (2.0–3.4)	2.4 (1.7–3.1)	

**Note:** Data are expressed as mean ± standard deviation or mean (lower – upper bounds of 95% confidence interval). MJ-SJ-U = multi- to single-joint, upper- to lower-body order. SJ-MJ-U = single- to multi-joint, upper- to lower-body order. MJ-SJ-L = multi- to single-joint, lower- to upper-body order. SJ-MJ-L = single- to multi-joint, lower- to upper-body order. \* $P < 0.05$  vs. Pre.

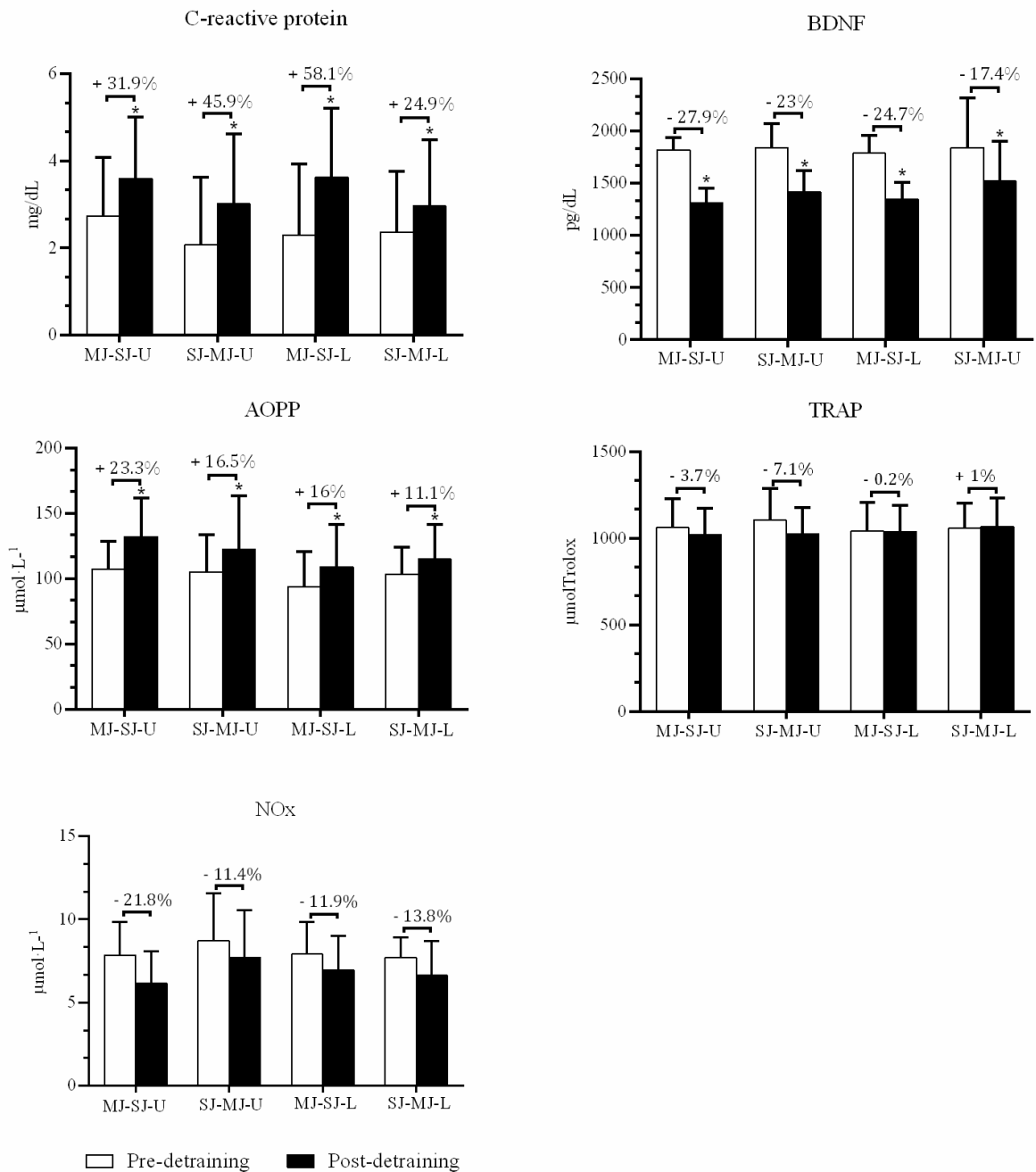
## SUPPLEMENTARY MATERIALS



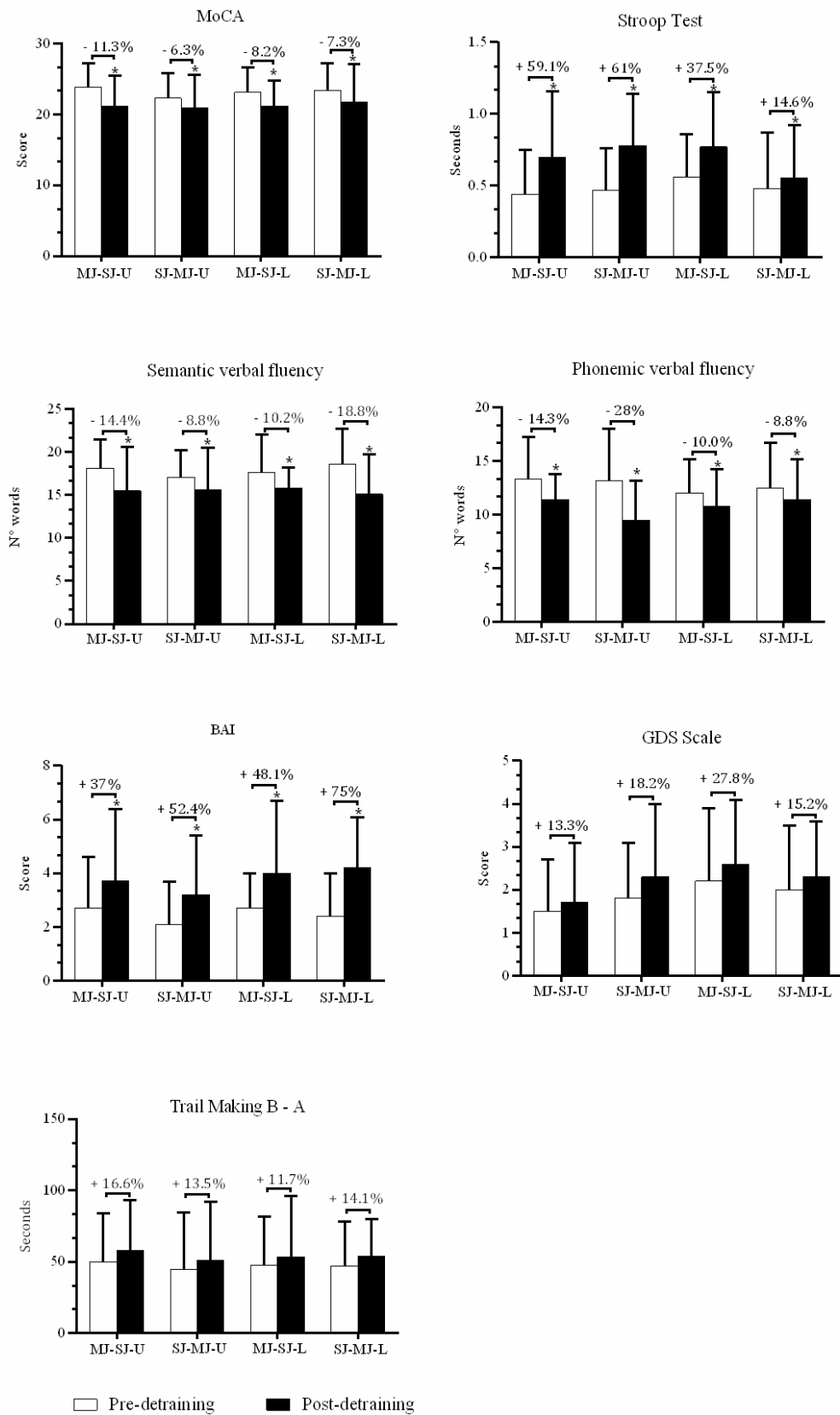
**Supplementary material 1.** Results of the detraining period for body fat. Data are expressed as mean  $\pm$  standard deviation. \* $P < 0.05$  vs. Pre.



**Supplementary material 2.** Results of the detraining period for glycemic and lipid profile. Data are expressed as mean  $\pm$  standard deviation. \* $P < 0.05$  vs. Pre.



**Supplementary material 3.** Results of the detraining period for C-reactive protein, BDNF, and oxidative biomarkers (AOPP, TRAP, and NOx). \* $P < 0.05$  vs. Pre.



**Supplementary material 4.** Results of the detraining period for the cognitive test, depressive and anxiety symptoms. \* Data are expressed as mean  $\pm$  standard deviation. \* $P < 0.05$  vs. Pre.

## 6 CONSIDERAÇÕES FINAIS

Com o aumento da expectativa de vida da população e, conseqüentemente, um aumento no número de pessoas idosas, na maioria dos países do mundo, faz-se necessário a busca por estratégias farmacológicas e não-farmacológicas que possam atenuar ou até mesmo reverter diversas modificações associadas ao processo de envelhecimento e que colocam em risco à saúde tanto de homens quanto de mulheres. De acordo com o conhecimento produzido até o momento, a prática de programas de atividade física de diferentes naturezas e, sobretudo, de exercícios físicos é bastante recomendada para a melhoria da aptidão funcional, composição corporal, perfil metabólico, interação social, saúde mental, entre outras tantas mudanças importantes para a qualidade de vida, autonomia e bem-estar, colaborando sobremaneira com a redução de gastos com consultas médicas, medicamentos, internações e cirurgias.

Diante disso, a presente investigação analisou o efeito de quatro diferentes OE em um programa de TR sobre diversos parâmetros de saúde como a força muscular, massa muscular, gordura corporal, biomarcadores metabólicos e indicadores de saúde mental em mulheres idosas previamente treinadas. Essa tomada de decisão se pautou em um conjunto de informações disponíveis na literatura sobre a manipulação de diferentes variáveis que compõem programas de TR, de modo que identificamos uma lacuna importante a ser preenchida na área desse tipo de treinamento em mulheres idosas.

Diante do cenário atual, tivemos a preocupação de estruturar um estudo longitudinal e que fosse mais robusto do que aqueles desenvolvidos até o presente momento. Para tanto, o primeiro passo foi a adoção de um delineamento cruzado, relativamente comum para estudos transversais mas pouco explorado em estudos longitudinais pela dificuldade de manter os indivíduos nas diferentes condições experimentais que são necessárias para a sua efetivação. Esse tipo de delineamento experimental permite o controle das diferenças individuais associadas ao maior ou menor grau de responsividade ao tratamento, neste caso o TR. Adicionalmente, o período de pré-condicionamento das participantes com base em um programa similar de TR com duração de 12 semanas de TR favoreceu a equiparação do nível de aptidão física, variável fundamental a ser controlada para a proposta da presente investigação.

A randomização das participantes em quatro grupos distintos, com iguais períodos de treino, destreino e retreino em um sistema cruzado é algo inédito na área do TR, em estudos longitudinais. Considerando que a adoção de modelos de progressão tem sido

amplamente defendida pela literatura para evitar um possível efeito platô das respostas adaptativas induzidas pelo TR, estabelecemos um critério único para ajustes das cargas de treinamento que foi aplicado periodicamente em todos os exercícios que compuseram o programa de treinamento, de modo que a intensidade pudesse ser preservada com base na evolução individual de cada participante ao longo da intervenção. Além disso, para garantir que todas as participantes realizassem cada sessão de TR de forma segura e eficiente, profissionais de Educação Física supervisionaram todas as sessões de treinamento. Desse modo, o programa de TR utilizado pode ser caracterizado como progressivo e supervisionado, o que garante maior consistência aos resultados encontrados.

Somado a todos esses fatores citados acima, outro ponto que merece destaque foi o monitoramento dos hábitos alimentares das participantes nas primeiras e últimas semanas de cada etapa de intervenção. Embora, não sejam esperadas mudanças drásticas no padrão alimentar em idosos, o processo de envelhecimento pode provocar algumas mudanças no consumo alimentar, tais como redução do apetite, diminuição da sensação de sede, dificuldade de mastigação, redução ou perda do olfato e paladar e problemas gastrointestinais que podem afetar os hábitos alimentares. Diante dos nossos resultados, o padrão alimentar das participantes se manteve similar ao longo da investigação, sugerindo que a ingestão alimentar não influenciou os resultados encontrados aqui.

Para finalizar, resumimos a seguir os principais resultados encontrados, tentando possibilitar uma análise combinada dos efeitos produzidos pela intervenção realizada. Nossos resultados, de forma combinada, revelaram que as quatro diferentes OE adotadas, em idosas previamente treinadas, promoveu:

1. Aumento da força muscular de membros superiores, tronco, membros inferiores;
2. Progressão do volume-carga de TR;
3. Aumento da massa muscular, da massa isenta de gordura e de osso de membros superiores e membros inferiores;
4. Redução da gordura corporal (absoluta e relativa) e regional (tronco, androide e ginoide);
5. Melhora de diversos biomarcadores sanguíneos (perfil lipídico, glicêmico, Proteína C-reativa, BDNF, estresse oxidativo);
6. Melhora de indicadores de saúde mental.

Em contrapartida, não foi observado influência da OE sobre nenhuma das variáveis analisadas, sugerindo que independente da EO executada as adaptações promovidas pelo TR parecem ocorrer de maneira similar na população investigada. Baseado nos nossos achados, a prescrição do TR pode ser mais flexível, não havendo necessidade de seguir, rigorosamente, uma ordem específica e dessa forma deixando a sessão de treinamento mais dinâmica, podendo a OE ser estruturada de acordo com as necessidades ou preferências da praticante ou, ainda, com as condições disponíveis no ambiente de prática, considerando o número de equipamentos disponíveis, horários das sessões de treinamento, disponibilidade de tempo, entre outras variáveis. Como exemplo, podemos nos pautar no cotidiano das salas de TR localizadas em academias, clubes, clínicas e estúdios. Nesses locais existem determinados períodos do dia que abarcam um grande fluxo de alunos em um mesmo horário. Para essas situações, os nossos resultados apresentam uma grande aplicação prática, visto que a adoção de diferentes OE permite a otimização do espaço, do tempo e do atendimento, sem comprometer os estímulos necessários, visando as melhores respostas adaptativas. O mesmo se aplica as situações de pesquisa, nas quais um conjunto de participantes devem ser submetidos a intervenção, de forma padronizada, combinando equipamentos disponíveis e tempo de duração das sessões de treinamento.

## REFERÊNCIAS

ACSM. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. **Medicine and Science in Sports and Exercise**, v. 41, n. 3, p. 687–708, 2009a.

ACSM. American College of Sports Medicine position stand. Exercise and physical activity for older adults. **Medicine and Science in Sports and Exercise**, v. 41, n. 7, p. 1510–1530, 2009b.

ALIKHANI, S.; SHEIKHOLESLAMI-VATANI, D. Oxidative stress and anti-oxidant responses to regular resistance training in young and older adult women. **Geriatrics and Gerontology International**, v. 19, n. 5, p. 419–422, 2019.

ALLEY, D. E. et al. Inflammation and rate of cognitive change in high-functioning older adults. **The Journals of Gerontology Series A: Biological Sciences and Medical Sciences**, v. 63, n. 1, p. 50–55, 2008.

AMARANTE DO NASCIMENTO, M. et al. Familiarization and reliability of one repetition maximum strength testing in older women. **Journal of Strength and Conditioning Research**, v. 27, n. 6, p. 1636–1642, 2013.

ANDERSON-HANLEY, C. et al. The aerobic and Cognitive Exercise Study (ACES) for community-dwelling older adults with or at-risk for mild cognitive impairment (MCI): neuropsychological, neurobiological and neuroimaging outcomes of a randomized clinical trial. **Frontiers in Aging Neuroscience**, v. 10, n. 5, p. 76, 2018.

ASHTON, R. E. et al. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: systematic review with meta-analysis. **British Journal of Sports Medicine**, v. 54, n. 6, p. 341–348, 2020.

AZIZBEIGI, K.; AZARBAYJANI, M. A.; ATASHAK, S. Effect of moderate and high resistance training intensity on indices of inflammatory and oxidative stress. **Research in Sports Medicine**, v. 23, n. 1, p. 73-87, 2015.

BARBAT-ARTIGAS, S. et al. Clinical relevance of different muscle strength indexes and functional impairment in women aged 75 years and older. **The Journals of Gerontology Series A: Biological Sciences and Medical Sciences**, v. 68, n. 7, p. 811–819, 2013.

BASTARD, J.-P. et al. Recent advances in the relationship between obesity, inflammation, and insulin resistance. **European Cytokine Network**, v. 17, n. 1, p. 4–12, 2006.

BEAUDREAU, S. A.; O'HARA, R. Late-life anxiety and cognitive impairment: a review. **The American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry**, v. 16, n. 10, p. 790–803, 2008.

BECK et al. An inventory for measuring clinical anxiety: psychometric properties. **Clinical Psychology**, v. 56, n. 6, p. 893–897, 1988.

BEYDOUN, M. A. et al. Epidemiologic studies of modifiable factors associated with cognition and dementia: systematic review and meta-analysis. **BMC Public Health**, v. 14, n. 1, p. 643, 2014.

BORDE, R.; HORTOBÁGYI, T.; GRANACHER, U. Dose-response relationships of resistance training in healthy old adults: a systematic review and meta-analysis. **Sports Medicine**, v. 45, n. 12, p. 1693–720, 2015.

BRANDÃO, L. et al. Varying the order of combinations of single- and multi-joint exercises differentially affects resistance training adaptations. **Journal of Strength and Conditioning Research**, v. 34, n. 5, p. 1254-1263, 2020.

BRIAN C., CLARK E MANINI, T. Functional consequences of sarcopenia and dynapenia in the elderly. **Current Opinion Clinical Nutrition and Metabolism Care**, v.13, n. 3 p. 271–276, 2010.

BUCKINX, F. et al. The authors reply: “Dual energy X-ray absorptiometry: gold standard for muscle mass?” by Scafoglieri et al. **Journal of Cachexia, Sarcopenia and Muscle**, v. 9, n. 4, p. 788–790, 2018.

CARDOZO, D. C. et al. The Effect of exercise order in circuit training on muscular strength and functional fitness in older women. **International journal of exercise science**, v. 12, n. 4, p. 657–665, 2019.

CARPINELLI, R. Does the sequence of exercise in a resistance training session affect strength gains and muscular hypertrophy? A critical examination of the evidence, **Medicina Sportiva**, v. 17, n. 1, p. 37–50, 2013.

CAVALCANTE, E. F. et al. Effects of different resistance training frequencies on fat in overweight/obese older women. **International Journal of Sports Medicine**, v. 39, n. 7, p. 527–534, 2018.

CHANG, K.-V. et al. Is sarcopenia associated with depression? A systematic review and meta-analysis of observational studies. **Age and Ageing**, v. 46, n. 5, p. 738–746, 2017.

COELHO, F. G. de M. et al. Physical exercise modulates peripheral levels of brain-derived neurotrophic factor (BDNF): A systematic review of experimental studies in the elderly. **Archives of Gerontology and Geriatrics**, v. 56, n. 1, p. 10–15, 2013.

COHEN, J. **Statistical power analysis for the behavioral sciences**. 2. ed. Hillsdale: Routledge, 1988.

COHEN, J. Quantitative Methods in Psychology. **Psychological Bulletin**, v. 112, n. 1, p. 155–159, 1992.

CÓRDOVA, C. et al. Caracterização de respostas comportamentais para o teste de Stroop computadorizado - Testinpacs characterization of behavioral responses to the computerized. **Neurociências**, v. 4, n. 2, p. 75–79, 2008.

CSAPO, R.; ALEGRE, L. M. Effects of resistance training with moderate vs heavy loads on muscle mass and strength in the elderly: a meta-analysis. **Scandinavian Journal of Medicine & Science in Sports**, v. 26, n. 9, p. 995–1006, 2016.

CUNHA, P. M. et al. Resistance training performed with single and multiple sets induces similar improvements in muscular strength, muscle mass, muscle quality, and IGF-1 in older women. **Journal of Strength and Conditioning Research**, v. 34, n. 4, p. 1008–1016, 2020.

CUNHA, P. M. et al. Comparison of low and high volume of resistance training on body fat and blood biomarkers in untrained older women: a randomized clinical trial. **Journal of Strength and Conditioning Research**, v. 35, n. 1, p. 1–8, 2021a.

CUNHA, P. M. et al. Resistance training reduces depressive and anxiety symptoms in older women: a pilot study. **Aging & Mental Health**, ahead print, 2021b.

DANKEL, S. J.; LOENNEKE, J. P.; LOPRINZI, P. D. Dose-dependent association between muscle-strengthening activities and all-cause mortality: Prospective cohort study among a national sample of adults in the USA. **Archives of Cardiovascular Diseases**, 2016.

DIB, M. M. et al. Effects of three resistance exercise orders on muscular function and body composition in older women. **International Journal of Sports Medicine**, v. 41, n. 14, p. 1024–1031, 2020.

ENRIGHT, P. L. The six-minute walk test. **Respiratory Care**, v. 48, n. 8, p. 783–785, ago. 2003.

ESTEVES, C. S. et al. Phonemic and semantic verbal fluency tasks: normative data for elderly Brazilians. **Psicologia: Reflexão e Crítica**, v. 28, n. 2, p. 350–355, 2015.

EVANS, I. E. M. et al. Social isolation, cognitive reserve, and cognition in healthy older people. **PLOS ONE**, v. 13, n. 8, p. e0201008, 2018.

EVANS, W. J. Skeletal muscle loss: cachexia, sarcopenia, and inactivity. **The American Journal of Clinical Nutrition**, v. 91, n. 4, p. 1123S-1127S, 2010.

FARINATTI, P. T. V.; DA SILVA, N. S. L.; MONTEIRO, W. D. Influence of exercise order on the number of repetitions, oxygen uptake, and rate of perceived exertion during strength training in younger and older women. **Journal of Strength and Conditioning Research**, v. 27, n. 3, p. 776–785, 2013.

FEDOCE, A. das G. et al. The role of oxidative stress in anxiety disorder: cause or consequence? **Free Radical Research**, v. 52, n. 7, p. 737–750, 2018.

FIGUEIREDO, T. et al. The influence of exercise order on local muscular endurance during resistance training in women. **Human Movement**, v. 12, n. 3, p. 237–241, 2011.

FIRTH, J. et al. Motivating factors and barriers towards exercise in severe mental illness: a systematic review and meta-analysis. **Psychological Medicine**, v. 46, n. 14, p. 2869–2881, 2016.

FORTI, L. N. et al. Load-specific inflammation mediating effects of resistance training in older persons. **Journal of the American Medical Directors Association**, v. 17, n. 6, p. 547–552, 2016.

FRAGALA, M. S. et al. Resistance training for older adults: Position statement from the National Strength and Conditioning Association. **Journal of Strength and Conditioning Research**, v. 33, n. 8, p. 2019–2052, 2019.

FRIEDEWALD, W. T.; LEVY, R. I.; FREDRICKSON, D. S. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. **Clinical Chemistry**, v. 18, n. 6, p. 499–502, 1972.

FRITH, E.; LOPRINZI, P. D. The association between lower extremity muscular strength and cognitive function in a national sample of older adults. **Journal of Lifestyle Medicine**, v. 8, n. 2, p. 99–104, 2018.

GERAGE, A. et al. Cardiovascular adaptations to resistance training in elderly postmenopausal women. **International Journal of Sports Medicine**, v. 34, n. 09, p. 806–813, 2013.

GERMAIN, C. M. et al. Sex, race and age differences in muscle strength and limitations in community dwelling older adults: Data from the Health and Retirement Survey (HRS). **Archives of Gerontology and Geriatrics**, v. 65, p. 98–103, 2016.

GORDON, C.; CHUNLEA, W. C.; ROCHE, A. F. Stature, recumbent length, and weight. In: LOHMAN, T. G.; ROCHE, A. F.; MARTORELL, R. (Ed.). **Anthropometric standardization reference manual**. Champaign: Human Kinetics, 1988. p. 177.

GRGIC, J.; SCHOENFELD, B. J. A case for considering age and sex when prescribing rest intervals in resistance training. **Kinesiology**, v. 51, n. 1, p. 78–82, 2019.

GUEVARA, I. et al. Determination of nitrite/nitrate in human biological material by the simple Griess reaction. **Clinica Chimica Acta**, v. 274, n. 2, p. 177–188, 1998.

HALPERIN, I.; CHAPMAN, D. W.; BEHM, D. G. Non-local muscle fatigue: effects and possible mechanisms. **European Journal of Applied Physiology**, v. 115, n. 10, p. 2031–2048, 2015.

HAMMARSTRÖM, D. et al. Benefits of higher resistance-training volume are related to ribosome biogenesis. **The Journal of Physiology**, v. 598, n. 3, p. 543–565, 2020.

HAUBROCK, J. et al. Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam Calibration Study. **The Journal of Nutrition**, v. 141, n. 5, p. 914–920, 2011.

HAUN, C. T. et al. A critical evaluation of the biological construct skeletal muscle hypertrophy: size matters but so does the measurement. **Frontiers in Physiology**, v. 10, n. 3, p. 1–23, 2019.

HEROLD, F. et al. Dose–Response Matters! – a perspective on the exercise prescription in exercise–cognition research. **Frontiers in Psychology**, v. 10, n. 11, p. 1–17, 2019a.

HEROLD, F. et al. Functional and/or structural brain changes in response to resistance exercises and resistance training lead to cognitive improvements – a systematic review. **European Review of Aging and Physical Activity**, v. 16, n. 1, p. 10, 2019b.

HOLLINGS, M. et al. The effect of progressive resistance training on aerobic fitness and strength in adults with coronary heart disease: a systematic review and meta-analysis of randomised controlled trials. **European Journal of Preventive Cardiology**, v. 24, n. 12, p. 1242–1259, 2017.

HONG, S.-G.; KIM, J.-H.; JUN, T.-W. Effects of 12-week resistance exercise on electroencephalogram patterns and cognitive function in the elderly with mild cognitive impairment: a randomized controlled trial. **Clinical Journal of Sport Medicine**, v. 28, n. 6, p. 500–508, 2018.

IULIANO, E. et al. Effects of different types of physical activity on the cognitive functions and attention in older people: a randomized controlled study. **Experimental Gerontology**, v. 70, p. 105–110, 2015.

JANSSEN, I. et al. Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. **Journal of Applied Physiology**, v. 89, n. 1, p. 81–88, 2000.

JEDRZIEWSKI, M. K.; LEE, V. M.-Y.; TROJANOWSKI, J. Q. Physical activity and cognitive health. **Alzheimer's & Dementia**, v. 3, n. 2, p. 98–108, 2007.

KANDOLA, A. et al. Moving to Beat Anxiety: Epidemiology and therapeutic issues with physical activity for anxiety. **Current Psychiatry Reports**, v. 20, n. 8, p. 63, 2018.

KANDOLA, A. et al. Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. **Neuroscience and Biobehavioral Reviews**, v. 107, n. 9, p. 525–539, 2019.

KANG, S. Y.; LIM, J.; PARK, H. S. Relationship between low handgrip strength and quality of life in Korean men and women. **Quality of Life Research**, v. 27, n. 10, p. 2571–2580, 2018.

KELLEY, G.; KELLEY, K. S. Resistance training and bone mineral density in women. **American Journal of Physical Medicine & Rehabilitation**, v. 80, n. 1, p.65-77, 2001.

KÖHLER, C. A. et al. Peripheral cytokine and chemokine alterations in depression: a meta-analysis of 82 studies. **Acta Psychiatrica Scandinavica**, v. 135, n. 5, p. 373–387, 2017.

LANDRIGAN, J.-F. et al. Lifting cognition: a meta-analysis of effects of resistance exercise on cognition. **Psychological Research**, v. 84, n. 5, p. 1167–1183, 2020.

LIU-AMBROSE, T. et al. Resistance training and executive functions. **Archives International of Medicine**, v. 170, n. 2, p. 170–178, 2010.

LIU-AMBROSE, T.; DONALDSON, M. G. Exercise and cognition in older adults: Is there a role for resistance training programmes? **British Journal of Sports Medicine**, v. 43, n. 1, p. 25–27, 2009.

LONGO, A. R. et al. Volume load rather than resting interval influences muscle hypertrophy during high-intensity resistance training. **Journal of Strength and Conditioning Research**, ahead print, 2020.

MALTAIS, M. L.; DESROCHES, J.; DIONNE, I. J. Changes in muscle mass and strength after menopause. **Journal of Musculoskeletal & Neuronal Interactions**, v. 9, n. 4, p. 186–197, 2009.

MANINI, T. M.; CLARK, B. C. Dynapenia and aging: an update. **The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences**, v. 67, n. 1, p. 28–40, 2012.

MARINUS, N. et al. The impact of different types of exercise training on peripheral blood brain-derived neurotrophic factor concentrations in older adults: a meta-analysis. **Sports Medicine**, v. 49, n. 10, p. 1529–1546, 2019.

MARSTON, K. J. et al. Resistance exercise-induced responses in physiological factors linked with cognitive health. **Journal of Alzheimer's Disease**, v. 68, n. 1, p. 39–64, 2019.

MAVROS, Y. et al. Mediation of cognitive function improvements by strength gains after resistance training in older adults with mild cognitive impairment: outcomes of the Study of Mental and Resistance Training. **Journal of the American Geriatrics Society**, v. 65, n. 3, p. 550–559, 2017.

MCGREGOR, R. A.; CAMERON-SMITH, D.; POPPITT, S. D. It is not just muscle mass: a review of muscle quality, composition and metabolism during ageing as determinants of muscle function and mobility in later life. **Longevity & Healthspan**, v. 3, n. 1, p. 9, 2014.

MEMÓRIA, C. M. et al. Brief screening for mild cognitive impairment: Validation of the Brazilian version of the Montreal cognitive assessment. **International Journal of Geriatric Psychiatry**, v. 28, n. 1, p. 34–40, 2013.

MILJKOVIC, N. et al. Aging of skeletal muscle fibers. **Annals of Rehabilitation Medicine**, v. 39, n. 2, p. 155–62, 2015.

MILLER, A. A.; SPENCER, S. J. Obesity and neuroinflammation: a pathway to cognitive impairment. **Brain, Behavior, and Immunity**, v. 42, p. 10–21, 2014.

MILLER, K. J. et al. Comparative effectiveness of three exercise types to treat clinical depression in older adults: A systematic review and network meta-analysis of randomised controlled trials. **Ageing Research Reviews**, v. 58, p. 100999, 2020.

MIRANDA, H. et al. Influence of exercise order on repetition performance among all possible combinations on resistance training. **Research in Sports Medicine**, v. 21, n. 4, p. 355–366, 2013.

MORTON, R. W. et al. A systematic review, meta-analysis and meta-regression of the effect of protein supplementation on resistance training-induced gains in muscle mass and strength in healthy adults. **British Journal of Sports Medicine**, v. 52, n. 6 p. 376–84, 2017.

NABUCO, H. C. G. et al. Effects of higher habitual protein intake on resistance-training-induced changes in body composition and muscular strength in untrained older women: a clinical trial study. **Nutrition and Health**, v. 25, n. 2, p. 103–112, 2019.

NASREDDINE, Z. S. et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. **Journal of the American Geriatrics Society**, v. 53, n. 4, p. 695–699, 2005.

NAZARI, M.; AZARBAYJANI, M. A.; AZIZBEIGI, K. Effect of exercise order of resistance training on strength performance and indices of muscle damage in young active girls. **Asian Journal of Sports Medicine**, v. 7, n. 3, p. e30599, 2016.

NUNES, J. P. et al. Starting the resistance-training session with lower-body exercises provides lower session perceived exertion without altering the training volume in older women. **International journal of exercise science**, v. 12, n. 4, p. 1187–1197, 2019.

NUNES, J. P. et al. The generality of strength: Relationship between different measures of muscular strength in older women. **International Journal of Exercise Science**, v. 13, n. 3, p. 1638–1649, 2020.

NUNES, J. P. et al. What influence does resistance exercise order have on muscular strength gains and muscle hypertrophy? A systematic review and meta-analysis. **European Journal of Sport Science**, v. 21, n. 2, p. 149–157, 2021a.

NUNES, J. P. et al. Responsiveness to muscle mass gain following 12 and 24 weeks of resistance training in older women. **Aging Clinical and Experimental Research**, v. 33, n. 4, p. 1071–1078, 2021b.

NUNES, P. R. P. et al. Effect of resistance training on muscular strength and indicators of abdominal adiposity, metabolic risk, and inflammation in postmenopausal women: controlled and randomized clinical trial of efficacy of training volume. **AGE**, v. 38, n. 2, p. 40, 2016.

PADILHA, C. S. et al. Effect of resistance training with different frequencies and detraining on muscular strength and oxidative stress biomarkers in older women. **AGE**, v. 37, n. 5, p. 104, 2015.

PEDERSEN, B. K.; FEBBRAIO, M. A. Muscle as an endocrine organ: focus on muscle-derived interleukin-6. **Physiological Reviews**, v. 88, n. 4, p. 1379–406, 2008.

PHILLIPS, S. M.; WINETT, R. a. Uncomplicated resistance training and health-related outcomes: evidence for a public health mandate. **Current Sports Medicine Reports**, v. 9, n. 4, p. 208–213, 2010.

PINA, F. L. C. et al. Influence of resistance exercises order on body composition in older men. **Journal of Physical Education**, v. 24, n. 3, p. 443–451, 2013.

REITAN, R. M. Validity of the Trail Making Test as an indicator of organic brain damage. **Perceptual and Motor Skills**, v. 8, n. 3, p. 271–276, 1958.

REPETTO, M. et al. Oxidative stress in blood of HIV infected patients. **Clinica Chimica Acta**, v. 255, n. 2, p. 107–117, 1996.

RIBEIRO, A. S. et al. Effects of traditional and pyramidal resistance training systems on muscular strength, muscle mass, and hormonal responses in older women. **Journal of Strength and Conditioning Research**, v. 31, n. 7, p. 1888–1896, 2017.

RIBEIRO, A. S. et al. The potential role of pre-exhaustion training in maximizing muscle hypertrophy: a review of the literature. **Strength and Conditioning Journal**, v. 41, n. 1, p. 75–80, 2019.

RIBEIRO, A. S.; NUNES, J. P.; SCHOENFELD, B. J. Selection of resistance exercises for older individuals: the forgotten variable. **Sports Medicine**, v. 50, n. 6, p. 1051–1057, 2020.

RIBEIRO, A. S.; SCHOENFELD, B. J.; NUNES, J. P. Large and small muscles in resistance training: Is it time for a better definition? **Strength and Conditioning Journal**, v. 39, n. 5, p. 33–35, 2017.

RIKLI, R.; JONES, C. J. Senior fitness test manual. 2nd. ed. **Champaign: Human Kinetics**, 2013.

ROBERTS, B. M.; NUCKOLS, G.; KRIEGER, J. W. Sex differences in resistance training. **Journal of Strength and Conditioning Research**, n. c, p. 1, 2020.

ROMANO, N. et al. Effects of resistance exercise order on the number of repetitions performed to failure and perceived exertion in untrained young males. **Journal of Human Kinetics**, v. 39, n. 1, p. 177–183, 2013.

ROSSI, F. E. et al. Influence of skeletal muscle mass and fat mass on the metabolic and inflammatory profile in sarcopenic and non-sarcopenic overfat elderly. **Ageing Clinical and Experimental Research**, v. 31, n. 5, p. 629-635, 2019.

RUIZ, J. R. et al. Association between muscular strength and mortality in men: prospective cohort study. **BMJ**, v. 337, n. 7, p. a439–a439, 2008.

SANTOS, L. et al. The improvement in walking speed induced by resistance training is associated with increased muscular strength but not skeletal muscle mass in older women. **European Journal of Sport Science**, v. 17, n. 4, p. 488–494, 2017.

SARAIVA, A. et al. Influence of exercise order on strength in Judo athletes. **Gazzetta Medica Italiana**, v. 173, n. 5, p. 251–257, 2014.

SARDELI, A. V. et al. Effect of resistance training on inflammatory markers of older adults: A meta-analysis. **Experimental Gerontology**, v. 111, n. 3, p. 188–196, 2018.

SCHOENFELD, B. J. et al. Strength and hypertrophy adaptations between low- vs. High-load resistance training: A systematic review and meta-analysis. **Journal of Strength and Conditioning Research**, v. 31, n. 12, p. 3508–3523, 2017.

SCHOENFELD, B. J. et al. Resistance training volume enhances muscle hypertrophy but not strength in trained men. **Medicine and Science in Sports and Exercise**, v. 51 n. 1, p. 94-103, 2019.

SCHOENFELD, B. J.; OGBORN, D.; KRIEGER, J. W. Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. **Journal of Sports Sciences**, v. 35, n. 11, p. 1073–1082, 2017.

SCHUCH, F. B. et al. Exercise for depression in older adults: a meta-analysis of randomized controlled trials adjusting for publication bias. **Revista Brasileira de Psiquiatria**, v. 38, n. 3, p. 247–254, 2016.

SFORZO, G. A.; TOUEY, P. R. Manipulating exercise order affects muscular performance during a resistance exercise training session. **Journal of Strength and Conditioning Research**, v. 10, n. 1, p. 20–24, 1996.

SILVA, D. et al. Comparison of four verbal memory tests for the diagnosis and predictive value of mild cognitive impairment. **Dementia and Geriatric Cognitive Disorders Extra**, v. 2, n. 1, p. 120–31, 2012.

SIMÃO, R. et al. Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercise in women. **Journal of Strength and Conditioning Research**, v. 21, n. 1, p. 23–28, 2007.

SIMÃO, R. et al. Exercise order in resistance training. **Sports Medicine**, v. 42, n. 3, p. 251–265, 2012a.

SIMÃO, R. et al. Influence of exercise order on repetition performance during low-intensity resistance exercise. **Research in Sports Medicine**, v. 20, n. 3–4, p. 263–273, 2012b.

SINGH-MANOUX, A. et al. Obesity trajectories and risk of dementia: 28 years of follow-up in the Whitehall II Study. **Alzheimer's & Dementia**, v. 14, n. 2, p. 178–186, 2018.

SMOLAREK, A. et al. The effects of strength training on cognitive performance in elderly women. **Clinical Interventions in Aging**, v. 1, n. 11, p. 749–753, 2016.

SPREUWENBERG, L. P. B. et al. Influence of exercise order in a resistance-training exercise session. **Journal of Strength and Conditioning Research**, v. 20, n. 1, p. 141–144, 2006.

STEIB, S.; SCHOENE, D.; PFEIFER, K. Dose-response relationship of resistance training in older adults. **Medicine & Science in Sports & Exercise**, v. 42, n. 5, p. 902–914, 2010.

STENHOLM, S. et al. Sarcopenic obesity-definition, etiology and consequences. **Current Opinion Clinical Nutrition and Metabolism Care**, v. 11, n. 6, p. 693–700, 2008.

STUART, C. et al. Fatigue and perceptual responses of heavier- and lighter-load isolated lumbar extension resistance exercise in males and females. **PeerJ**, v. 6, n. 3, p. e4523, 2018.

STUNKARD, A. J.; FAITH, M. S.; ALLISON, K. C. Depression and obesity. **Biological Psychiatry**, v. 54, n. 3, p. 330–337, 2003.

SUCHOMEL, T. J. et al. The importance of muscular strength: training considerations. **Sports Medicine**, v. 48, n. 4, p. 765–785, 2018.

TOMELERI, C. M. et al. Resistance training improves inflammatory level, lipid and glycemic profiles in obese older women: A randomized controlled trial. **Experimental Gerontology**, v. 84, p. 80–87, 2016.

TOMELERI, C. M. et al. Resistance exercise order does not affect the magnitude and duration of post-exercise blood pressure in older women. **Journal of Strength and Conditioning Research**, v. 34, n. 4, p. 1062-1070, 2020a.

TOMELERI, C. M. et al. Resistance training reduces metabolic syndrome and inflammatory markers in older women: a randomized controlled trial. **Journal of Diabetes**, v. 10, n. 4, p. 328–337, 2018.

TOMELERI, C. M. et al. Influence of resistance training exercise order on muscle strength, hypertrophy, and anabolic hormones in older women: a randomized controlled trial. **Journal of Strength and Conditioning Research**, v. 34, n. 11, p. 3103–3109, 2020b.

TROLLOR, J. N. et al. The association between systemic inflammation and cognitive performance in the elderly: The Sydney Memory and Ageing Study. **Age**, v. 34, n. 5, p. 1295–1308, 2012.

TUCSEK, Z. et al. Obesity in aging exacerbates blood-brain barrier disruption, neuroinflammation, and oxidative stress in the mouse hippocampus: effects on expression of genes involved in beta-amyloid generation and Alzheimer's disease. **The journals of gerontology. Series A, Biological sciences and medical sciences**, v. 69, n. 10, p. 1212–26, 2014.

VAN DAM, R. et al. Lower cognitive function in older patients with lower muscle strength and muscle mass. **Dementia and Geriatric Cognitive Disorders**, v. 45, n. 3–4, p. 243–250, 2018.

WESTCOTT, W. L. Resistance training is medicine: effects of strength training on health. **Current Sports Medicine Reports**, v. 11, n. 4, p. 209–216, 2012.

WILLIAMS, M. A.; STEWART, K. J. Impact of strength and resistance training on cardiovascular disease risk factors and outcomes in older adults. **Clinics in Geriatric Medicine**, v. 25, n. 4, p. 703–714, 2009.

WITKO-SARSAT, V. et al. Advanced oxidation protein products as a novel marker of oxidative stress in uremia. In: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (Ed.). **Climate Change 2013 - The Physical Science Basis**. Cambridge: Cambridge University Press, 1996. 49p. 1–30.

YESAVAGE, J. A. et al. Development and validation of a geriatric depression screening scale: A preliminary report. **Journal of Psychiatric Research**, v. 17, n. 1, p. 37–49, 1982.

ZAMBONI, M. et al. Adipose tissue, diet and aging. **Mechanisms of Ageing and Development**, v. 136–137, p. 129–137, 2014.

## APÊNDICES

### Apêndice A: Termo de consentimento

#### TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Título da pesquisa:

*"Efeito de quatro ordens de execução dos exercícios em programa de treinamento resistido em mulheres idosas treinadas"*



Prezada Senhora,

Gostaríamos de convidá-la a participar da pesquisa **"Efeito de quatro ordens de execução dos exercícios em programa de treinamento resistido em mulheres idosas treinadas"** a ser realizada no município de Londrina/PR. O objetivo desta pesquisa será analisar o efeito de um programa de treinamento com pesos sobre parâmetros morfológicos, metabólicos, cognitivos e de desempenho de mulheres idosas.

Todas as avaliações serão realizadas por profissionais previamente treinados para tal finalidade. A assinatura deste termo permitirá que você participe das seguintes atividades:

(1) Programa de treinamento com pesos com duração de 50 semanas; (2) Preenchimento de questionários sobre prática de atividades físicas, hábitos alimentares e fumo; (3) Medidas de peso, estatura e pressão arterial/frequência cardíaca em repouso; (4) Avaliação da composição corporal pelos métodos de impedância bioelétrica (teste com duração de 30s: deitado em um colchonete, dois pequenos eletrodos serão colocados na mão e pé direito e transmitirão uma pequena corrente elétrica que indicará a quantidade de água [procedimento indolor e sem qualquer tipo de risco]), DEXA (teste com duração de aproximadamente sete minutos: deitado em uma mesa no próprio equipamento, sem portar qualquer tipo de objeto metálico, vestindo apenas roupas). O equipamento fará um escaneamento do corpo todo para determinação da massa livre de gordura (procedimento indolor e sem qualquer tipo de risco); (5) Coleta de sangue venoso em jejum de 12 h feito por um técnico capacitado e habilitado para a avaliação de indicadores metabólicos; (7) Avaliação da aptidão neuromuscular pelos testes isométrico e isocinético (no dinamômetro Biodex), e de uma repetição máxima (teste realizado em três exercícios para os segmentos de membros superiores, inferiores e tronco, que consiste na realização de três tentativas com o objetivo de levantar a maior quantidade de peso possível em apenas uma repetição para determinação da força muscular máxima); (8) Avaliação de funções cognitivas. (9) Avaliação biomecânica da marcha. (10) Eletroencefalografia.

Gostaríamos de esclarecer que a participação é totalmente **voluntária**. O participante pode recusar-se a participar/desistir a qualquer momento sem sofrer prejuízo algum. As informações serão utilizadas somente para fins de pesquisa e todos os documentos e amostras utilizados serão identificados por um código numérico sem identificação nominal para preservar a identidade do participante. Lembramos que não será cobrada taxa alguma por estas avaliações. Da mesma forma, não será paga quantia alguma aos participantes.

Ao final do estudo, comprometemo-nos a retomar com os resultados de todas as avaliações, que serão entregues aos participantes. Espera-se, com essa pesquisa, proporcionar informações que possam favorecer a melhoria da saúde e qualidade de vida de indivíduos adultos idosos por meio da prática de treinamento e associação com aspectos nutricionais, além de possibilitar a melhoria de parâmetros morfológicos, neuromusculares e metabólicos dos participantes. Apesar de considerados mínimos, os possíveis riscos são: desconfortos na coleta sanguínea e cansaço durante os testes físicos. É possível também que alguns grupamentos musculares exigidos nos testes de esforço fiquem doloridos entre 24 e 48 horas após a realização dos mesmos.

Caso você tenha dúvidas ou necessite de maiores esclarecimentos pode contatar o coordenador do grupo de pesquisa, Prof. Dr. Edilson Serpeloni Cyrino, no Laboratório de Metabolismo, Nutrição e Exercício, localizado no Centro de Educação Física e Esporte, da Universidade Estadual de Londrina, pelo telefone (43) 3371-4772 / 99139-4509 ou procurar o Comitê de Ética em Pesquisa Envolvendo Seres Humanos da Universidade Estadual de Londrina, na Rodovia Celso Garcia Cid, km 380 – Campus Universitário, telefone (43) 3371-4000. Este termo deverá ser preenchido em duas vias de igual teor, sendo uma delas, devidamente preenchida, assinada e entregue a você.

  
 \_\_\_\_\_  
 Edilson Serpeloni Cyrino

Londrina, \_\_\_ de \_\_\_\_\_ de 2019.

Eu, \_\_\_\_\_ (nome por extenso do  
 sujeito de pesquisa), portadora do RG: \_\_\_\_\_ tendo sido devidamente  
 esclarecido sobre os procedimentos da pesquisa, concordo em participar **voluntariamente** da pesquisa descrita  
 acima.  
 Assinatura (ou impressão dactiloscópica): \_\_\_\_\_ Data: \_\_/\_\_/2019

### Apêndice B: Recordatório Alimentar

Nome: _____		Data: ____/____/____	
Dia da semana do Recordatório: _____		Avaliador: _____	
<b>REFEIÇÃO E O HORARIO</b>	<b>Alimentos, bebidas e/ou preparações</b>	<b>Quantidades (gramas ou medida caseira)</b>	
<b>Café da manhã</b> Horário: _____			
<b>Lanche manhã</b> Horário: _____			
<b>Almoço</b> Horário: _____			
<b>Lanche tarde</b> Horário: _____			
<b>Jantar</b> Horário: _____			
<b>Ceia</b> Horário: _____			

## ANEXOS

## Anexo A: Comitê de ética



UNIVERSIDADE  
ESTADUAL DE LONDRINA



HOSPITAL UNIVERSITÁRIO  
DIRETORIA SUPERINTENDENTE

PARECER Nº429  
PROCESSO 9544.2019.84



PARANÁ  
GOVERNO DO ESTADO

Ao Pesquisador

João Pedro Alves Nunes

Considerando o Projeto de Pesquisa com o título: **"EFEITO DE QUATRO ORDENS DE EXECUÇÃO DOS EXERCÍCIOS EM PROGRAMA DE TREINAMENTO RESISTIDO SOBRE A COMPOSIÇÃO CORPORAL, FORÇA MUSCULAR, CAPACIDADE FUNCIONAL, BIOMARCADORES SANGUÍNEOS E COGNIÇÃO EM MULHERES IDOSAS TREINADAS"** apresentado a esse Hospital Universitário, estando vinculado ao Programa de Pós-graduação em Educação Física do Centro de Educação Física e Esporte da Universidade Estadual de Londrina;

Considerando o parecer favorável apresentado nas instâncias administrativas que envolvem a realização do estudo.

Informamos que o nosso **parecer é favorável** à realização do projeto acima nominado, resguardando-se o atendimento da legislação vigente.

Atendendo a Resolução 466/12 do Conselho Nacional de Saúde o projeto deverá ser analisado pelo Comitê de Ética em Pesquisa da UEL (CEP/UEL) para posterior operacionalização.

Conforme **Ofício Circular da Diretoria Superintendente do HU nº 214/2015**, a cópia do parecer de aprovação do CEP/UEL deverá ser apresentado à Chefia e/ou Gerente das unidades envolvidas antes do início da coleta de dados.

Solicitamos que, tão logo o Comitê de Ética emita parecer, essa Diretoria Superintendente seja notificada, para os procedimentos cabíveis relacionados à documentação da pesquisa.

Solicitamos também que, uma vez realizado o estudo, uma cópia seja apresentada a esta Diretoria, para ciência e divulgação.

Em 01/08/2019

Erfa. Ma. Viviani Blazon El Reda Feijó  
Diretora Superintendente

Comissão de Avaliação de Projetos de Pesquisa Científica (CAPPC) do HU  
Fone: (43)3371-2301

## Anexo B: Montreal Cognitive Assessment (MoCA)

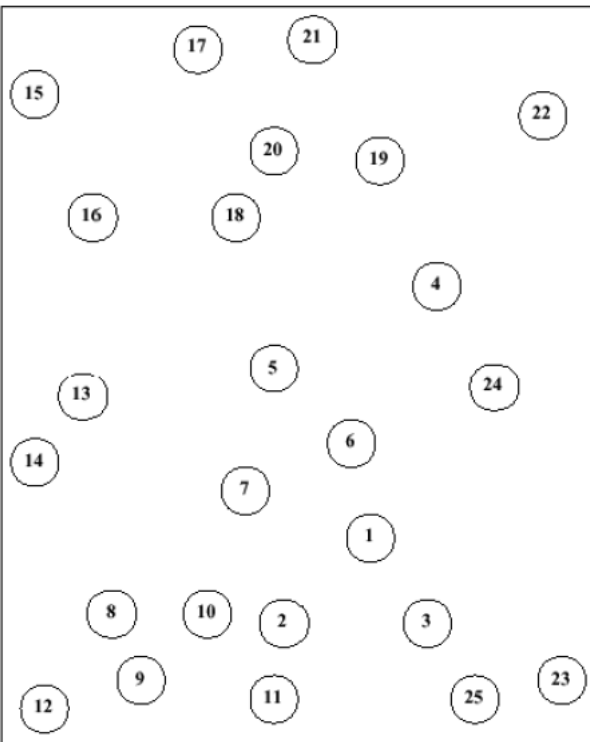
**MONTREAL COGNITIVE ASSESSMENT (MOCA)** Versão Experimental Brasileira

Nome: \_\_\_\_\_ Data de nascimento: \_\_\_/\_\_\_/\_\_\_  
 Escolaridade: \_\_\_\_\_ Data de avaliação: \_\_\_/\_\_\_/\_\_\_  
 Sexo: \_\_\_\_\_ Idade: \_\_\_\_\_

VISUOESPACIAL / EXECUTIVA		Copiar o cubo		Desenhar um RELÓGIO (onze horas e dez minutos) (3 pontos)		Pontos		
				<input type="checkbox"/> Contorno <input type="checkbox"/> Números <input type="checkbox"/> Ponteiros		___/5		
NOMEAÇÃO								
						___/3		
MEMÓRIA								
Leia a lista de palavras. O sujeito deve repeti-las, faça duas tentativas. Evocar após 5 minutos.			Rosto	Veludo	Igreja	Margarida	Vermelho	Sem Pontuação
		1ª tentativa						
		2ª tentativa						
ATENÇÃO								
Leia a seqüência de números (1 número por segundo)		O sujeito deve repetir a seqüência em ordem direta		<input type="checkbox"/> 2 1 8 5 4		___/2		
		O sujeito deve repetir a seqüência em ordem indireta		<input type="checkbox"/> 7 4 2				
Leia a série de letras. O sujeito deve bater com a mão (na mesa) cada vez que ouvir a letra "A". Não se atribuem pontos se ≥ 2 erros.		<input type="checkbox"/> FBACMNAAJKLBAFAKDEAAAJAMOFAB				___/1		
Subtração de 7 começando pelo 100		<input type="checkbox"/> 93	<input type="checkbox"/> 86	<input type="checkbox"/> 79	<input type="checkbox"/> 72	<input type="checkbox"/> 65	___/3	
4 ou 5 subtrações corretas: 3 pontos; 2 ou 3 corretas 2 pontos; 1 correta 1 ponto; 0 correta 0 ponto								
LINGUAGEM								
Repetir: Eu somente sei que é João quem será ajudado hoje.		<input type="checkbox"/>		O gato sempre se esconde embaixo do sofá quando o cachorro está na sala.		___/2		
<input type="checkbox"/>								
Fluência verbal: dizer o maior número possível de palavras que comecem pela letra F (1 minuto).		<input type="checkbox"/> _____ (N ≥ 11 palavras)				___/1		
ABSTRAÇÃO								
Semelhança p. ex. entre banana e laranja = fruta		<input type="checkbox"/> trem - bicicleta		<input type="checkbox"/> relógio - régua		___/2		
EVOCAÇÃO TARDIA								
Deve recordar as palavras SEM PISTAS		Rosto	Veludo	Igreja	Margarida	Vermelho	Pontuação apenas para evocação SEM PISTAS	
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
OPCIONAL								
Pista de categoria								
Pista de múltipla escolha								
ORIENTAÇÃO								
<input type="checkbox"/> Dia do mês		<input type="checkbox"/> Mês	<input type="checkbox"/> Ano	<input type="checkbox"/> Dia da semana	<input type="checkbox"/> Lugar	<input type="checkbox"/> Cidade	___/6	
© Z. Nasreddine MD www.mocatest.org Versão experimental Brasileira: Ana Luisa Rosas Sarmiento Paulo Henrique Ferreira Bertolucci - José Roberto Wajman (UNIFESP-SP 2007)						<b>TOTAL</b> Adicionar 1 pt se ≤ 12 anos de escolaridade		
						___/30		

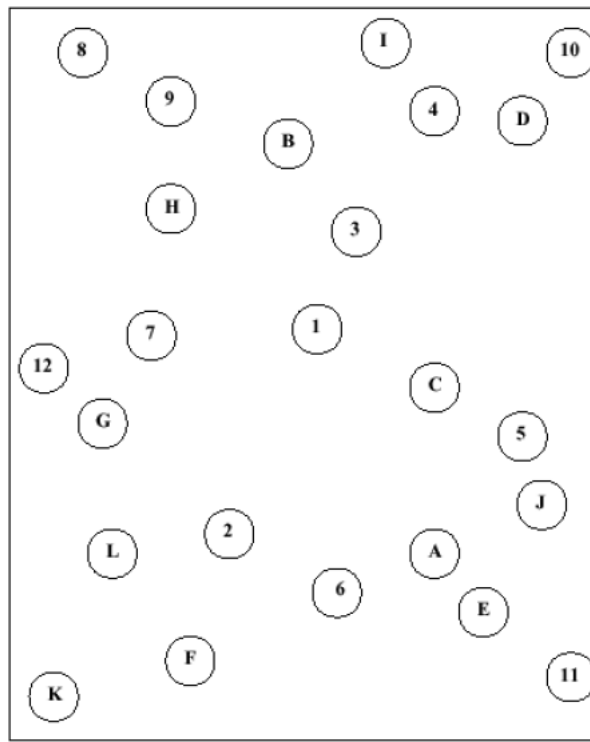
**Anexo C: Trail Making Test A e B**

Patient's Name: \_\_\_\_\_ Date: \_\_\_\_\_



A square grid containing 25 numbered circles (1-25) scattered across the area. The numbers are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25.

Patient's Name: \_\_\_\_\_ Date: \_\_\_\_\_



A square grid containing 12 numbered circles (1-12) and 12 lettered circles (A-L) scattered across the area. The numbers are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. The letters are: A, B, C, D, E, F, G, H, I, J, K, L.

## Anexo D: Escala de Depressão Geriátrica - GDS

### ESCALA DE DEPRESSÃO GERIÁTRICA - GDS

1. Está satisfeito (a) com sua vida? (não =1) (sim = 0)
2. Diminuiu a maior parte de suas atividades e interesses? (sim = 1) (não = 0)
3. Sente que a vida está vazia? (sim=1) (não = 0)
4. Aborrece-se com frequência? (sim=1) (não = 0)
5. Sente-se de bem com a vida na maior parte do tempo? (não=1) (sim = 0)
6. Teme que algo ruim possa lhe acontecer? (sim=1) (não = 0)
7. Sente-se feliz a maior parte do tempo? (não=1) (sim = 0)
8. Sente-se frequentemente desamparado (a)? (sim=1) (não = 0)
9. Prefere ficar em casa a sair e fazer coisas novas? (sim=1) (não = 0)
10. Acha que tem mais problemas de memória que a maioria? (sim=1) (não = 0)
11. Acha que é maravilhoso estar vivo agora? (não=1) (sim = 0)
12. Vale a pena viver como vive agora? (não=1) (sim = 0)
13. Sente-se cheio(a) de energia? (não=1) (sim = 0)
14. Acha que sua situação tem solução? (não=1) (sim = 0)
15. Acha que tem muita gente em situação melhor? (sim=1) (não = 0)

#### Avaliação:

0 = Quando a resposta for diferente do exemplo entre parênteses.
--

1= Quando a resposta for igual ao exemplo entre parênteses.
---

Total > 5 = suspeita de depressão
-----------------------------------

### Anexo E: Inventário de Ansiedade de Beck - BAI

Nome: \_\_\_\_\_ Idade: \_\_\_\_\_ Data: \_\_\_\_ / \_\_\_\_ / \_\_\_\_

Abaixo está uma lista de sintomas comuns de ansiedade. Por favor, leia cuidadosamente cada item da lista. Identifique o quanto você tem sido incomodado por cada sintoma durante a **última semana, incluindo hoje**, colocando um "x" no espaço correspondente, na mesma linha de cada sintoma.

	Absolutamente não	Levemente Não me incomodou muito	Moderadamente Foi muito desagradável mas pode suportar	Gravemente Difícilmente pode suportar
1. Dormência ou formigamento				
2. Sensação de calor				
3. Tremores nas pernas				
4. Incapaz de relaxar				
5. Medo que aconteça o pior				
6. Atordoado ou tonto				
7. Palpitação ou aceleração do coração				
8. Sem equilíbrio				
9. Aterrorizado				
10. Nervoso				
11. Sensação de sufocação				
12. Tremores nas mãos				
13. Trêmulo				
14. Medo de perder o controle				
15. Dificuldade de respirar				
16. Medo de morrer				
17. Assustado				
18. Indigestão ou desconforto no abdômen				
19. Sensação de desmaio				
20. Rosto afoqueado				
21. Suor (não devido ao calor)				