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Effects of different order of combined training on functional capacity, blood pressure, and body composition in women from 53 to 79 years old

Efeitos de diferentes ordens do treinamento combinado sobre a capacidade funcional, pressão arterial e composição corporal em mulheres de 53 a 79 anos

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Abstract

Objective: To assess the effects of order of resistance training (RT) and high-intensity interval training (HIIT) on functional capacity, blood pressure, and body composition in middle-aged and older women. **Methods:** Twenty-two participants were randomly assigned to one of two groups: RT followed by HIIT (RT-HIIT, n = 10, mean age 64.5 ± 7.9 years) or HIIT followed by RT (HIIT-RT, n = 10, mean age 59.32 ± 4.44 years). Both groups trained twice a week for 8 weeks. RT was composed of 7 exercises for the upper and lower body. HIIT was composed of alternate pairings of high-intensity (> 85% of maximum heart rate [MHR]) and moderate-intensity (60% MHR) running. **Results:** A time effect was found for upper-body muscle endurance (HIIT-RT = +9.43%; RT-HIIT = +6.16%), agility and dynamic balance (HIIT-RT = -5.96%; RT-HIIT = -8.57%), and cardiorespiratory fitness (HIIT-RT = +5.14%; RT-HIIT = +6.13%), with no difference between groups. Body composition and blood pressure did not change throughout the investigation for either group. **Conclusion:** Eight weeks of a combined HIIT and RT exercise program improved functional capacity of middle-aged and older women without altering blood pressure and body composition, regardless of the order of exercises.
Keywords: aging; body fat distribution; body composition; resistance training; physical performance; endurance training.

Resumo

Objetivo: Avaliar os efeitos da ordem do treinamento resistido (TR) e do treinamento intervalado de alta intensidade (HIIT) sobre a capacidade funcional, pressão arterial e composição corporal em mulheres de meia-idade e idosas. **Metodologia:** Vinte e duas mulheres foram aleatoriamente designadas em dois grupos: um grupo realizou TR seguido por HIIT (TR-HIIT, n = 10, 64,5 ± 7,94 anos) e outro grupo realizou HIIT seguido por TR (HIIT-TR, n = 10, 59,32 ± 4,44 anos). Ambos os grupos treinaram duas vezes por semana durante oito semanas. O TR foi composto por sete exercícios para a parte superior e inferior do corpo. O HIIT foi composto de pares alternados de corrida de alta intensidade (> 85% da frequência cardíaca máxima [FCM]) e intensidade moderada (60% FCM). **Resultados:** Foi encontrado um efeito dos programas de exercício para a resistência muscular de membros superiores do corpo (HIIT-TR = +9.43%; TR-HIIT = +6.16%), agilidade e equilíbrio dinâmico (HIIT-TR = -5,96%; TR-HIIT = -8.57%) e aptidão cardiorrespiratória (HIIT-TR = +5.14%; TR-HIIT = +6.13%), sem diferença entre os grupos. A composição corporal e a pressão arterial não se alteraram ao longo da investigação em nenhum dos grupos. **Conclusão:** Oito semanas de um programa combinado de exercícios de HIIT e de TR proporcionaram melhora na capacidade funcional de mulheres de meia-idade e idosas, sem alterar a pressão arterial e a composição corporal, independente da ordem de execução.
Palavras-chave: envelhecimento; distribuição da gordura corporal; composição corporal; treinamento de força; desempenho físico; treino aeróbico.

INTRODUCTION

Worldwide life expectancy is increasing and, according to data from the World Health Organization, by 2050, one in five people will belong to the older population, for a total approximately 2 billion individuals over 60 years of age spread across the planet.[1] This natural process is associated with numerous changes in different biological systems, such as reduced muscle strength,[2] decreases in fat-free mass and bone mineral density, and concomitant increases in body fat,[3,4] which, altogether, can negatively affect health and functional fitness of the older adult, regardless of the presence or absence of diseases.[5] As a result of reduction in muscle strength, for example, older adults may be unable to perform basic tasks of daily living independently, compromising their health and increasing frailty and risk of falls, which will likely lead to increased risk of all-cause mortality.[6] In addition, reductions in fat-free mass and muscle mass are likely to be associated with reductions in muscle strength and mobility.[7]

In order to mitigate these losses, engaging in physical exercise programs has been recommended for older adults due to the numerous health benefits reported in the literature.[8,9] These benefits are obtained regardless of whether these programs are composed of aerobic or strength/anaerobic exercises.[10] Resistance training (RT) has been widely supported as an effective intervention,[11] since it promotes significant increases in muscle strength,[12] enhances fat-free mass,[13] reduces body fat,[14] and lowers blood pressure,[15] all of which improve health and quality of life for older adults.[16] Aerobic training, on the other hand, such as high-intensity interval training (HIIT) can elicit increases in muscle strength, aerobic capacity, functional mobility,[17] and improvements in the different components of body composition.[18]

Furthermore, to enhance the overall benefits of exercise, some studies have investigated the combined effects of these two types of physical exercise in older adults; their results have shown significant improvements in lipid profile, anthropometric measures, insulin levels, muscle strength, body composition, electromyographic activity, and mobility.[19,20] For these reasons, the American College of Sports Medicine recommends that both modalities of exercise compose a training program for older individuals.[21] However, the guidelines do not indicate whether there is a preferable order in which exercises should be performed when both modalities are included in the same session of exercise training.

In this sense, previous investigations have focused on analyzing the execution order of a combined training program, with conflicting findings. Some researchers found no influence of the execution order on maximal endurance power adaptations in older men, but superior gains for muscle quality and lower-body muscle strength gains, as well as greater changes in the neuromuscular economy, when the training was initiated with RT,[20,22] while a more recent study showed significant increases in muscle strength in post-menopausal women, with no differences between the execution orders employed.[23] To date, no studies have analyzed the possible differential effects that exercise order in combined training could promote on adaptations in functional capacity, blood pressure, and body composition components in middle-aged and older women. A study of this nature could contribute considerably to the practice of professionals and researchers who prescribe physical exercises for older women, providing more specific targeting of the most efficient order of execution for improving functional capacity, blood pressure, and body composition. Therefore, the purpose of our investigation was to analyze the effects of order of execution of RT and HIIT within a combined training program on functional capacity, blood pressure, and body composition in middle-aged and older women. Our hypothesis was that order of exercise administration would have no differential effect on improvements in functional capacity, body composition, or blood pressure of the participants.

METHODS

Participants

Participant recruitment was carried out through newspaper, radio advertisements and home delivery of flyers in the central area and residential neighborhoods of a single city. Initially, 41 women aged > 50 years volunteered to participate in this study. All interested participants completed a detailed health history and physical activity questionnaires, and were subsequently admitted to the study if they met the following inclusion criteria: no hypertension (systolic blood pressure (SBP) < 140 mmHg and diastolic blood pressure (DBP) < 90 mmHg), no diabetes, no cardiac or renal dysfunction, no smoking, no current hormone replacement therapy, and not engaging in any physical exercise more than once a week during the preceding 6 months.

After individual interviews, 9 volunteers were excluded because they did not meet the inclusion criteria. Therefore, 32 participants were included in the study and then completed a diagnostic, graded exercise stress test with 12-lead electrocardiogram (reviewed by a cardiologist). Their health professionals cleared all for participation in the study with no restrictions. Written informed consent was obtained from all participants after being provided with a detailed description of study procedures, benefits, and possible risks. This investigation was conducted in accordance with the Declaration of Helsinki and approved by the local University Ethics Committee (opinion 2.754.821). The

32 older women were randomly assigned to one of two groups: one group performed RT followed by HIIT (RT-HIIT, n = 16, 64.51 ± 7.94 years, 70.10 ± 9.12 kg, 158.01 ± 7.43 cm and 28.34 ± 3.50 kg/m^2), while the other group performed HIIT followed by RT (HIIT-RT, n = 16, 59.32 ± 4.44 years, 72.20 ± 11.61 kg, 153.91 ± 4.54 cm and 30.50 ± 5.03 kg/m^2). A blinded researcher was responsible for generating computer-based random numbers for participant allocation. The professionals responsible for the training supervision did not participate in the randomization process. However, as they monitored the older women, they were not blinded to the execution order performed by the participants. Participants engaged in both programs twice a week for 8 weeks.

After the intervention period, 12 participants dropped out of the study due to surgery, injury (not related to the training program), personal reasons, or loss of interest. Therefore, 20 participants were analyzed [HIIT-TR (n = 10, 60.30 ± 4.61 years, 71.80 ± 4.46 kg, 154.00 ± 4.46 cm, 30.40 ± 5.08 kg/m^2) TR-HIIT (n = 10, 60.00 ± 7.88 years, 69.90 ± 11.40 kg, 158.00 ± 7.38 cm, 28.20 ± 3.28 kg/m^2)]. Figure 1 presents a schematic design of participant recruitment and allocation, based on the CONSORT 2010 flow diagram.[24]

Blood pressure

SBP and DBP were measured with an automated electronic oscillometric arm blood pressure monitoring device (G-Tech Home MSP20). During measurements, participants were instructed to remain quiet, seated in a chair with back support, feet on the floor, right arm resting on a table and raised to the height of the midpoint of the sternum. Pre-training session measurements were conducted after 5 min rest. Laboratory temperature was controlled and maintained at approximately 25°C, and all procedures followed the recommendations of the American Heart Association.[25] Previous test-retest measurements resulted in an ICC of 0.99 for SBP and 0.97 for DBP.

Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Omron, Model HBF-214, Illinois, USA). Height was measured to the nearest 0.1 cm with a wall-mounted stadiometer (E120A – Tonelli), with participants standing. For both measures, participants wore light workout clothing and no shoes. Body mass index (BMI) was calculated as body mass (kg) divided by height (m) squared.

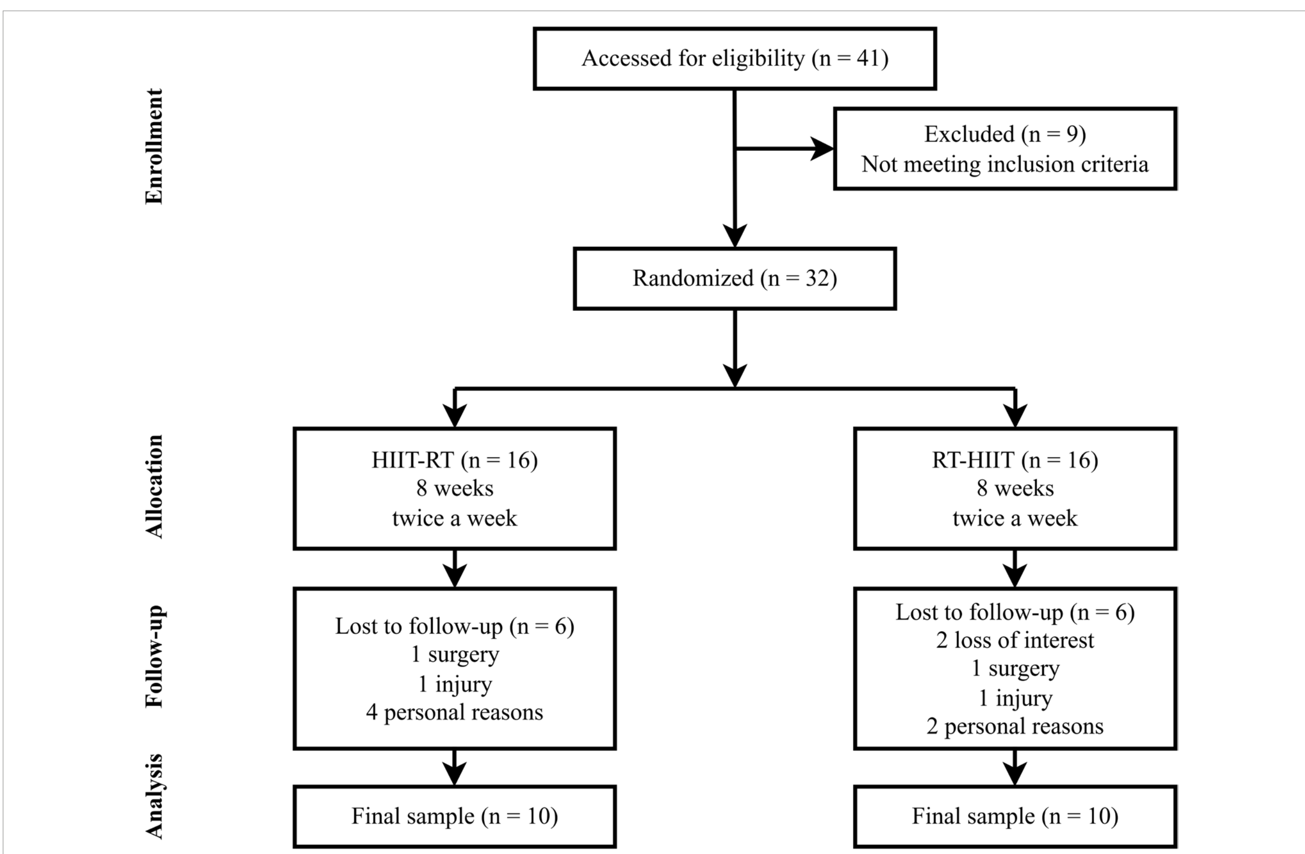


FIGURE 1. Flowchart for screening, recruitment, allocation, and intervention.

Body composition

Single-frequency bioelectrical impedance analysis (model 310e; Biodynamics Corporation, Seattle, WA, USA) was used to estimate fat-free mass (FFM) and fat mass (FM). The spectral bioelectrical impedance device was calibrated prior to testing each day according to the manufacturer's recommendations. The same professional performed all measurements on the participants between 6:00 a.m. and 9:00 a.m. Participants were instructed to void about 30 min before testing, abstain from ingesting food or drink in the 4 h prior to testing, avoid strenuous physical exercise for at least 24 h prior to testing, refrain from consuming alcoholic and caffeinated beverages for at least 48 h prior to testing, and avoid using diuretics for at least 7 days prior to testing. Prior to measurement, participants removed all metal-containing objects from their bodies. Measurements were performed on a table that was isolated from electrical conductors, with participants lying supine along the table's longitudinal centerline axis, legs abducted at a 45° angle relative to the body midline, and hands pronated. After cleaning the skin with alcohol, two electrodes were placed on the surface of the right hand and two on the right foot in accordance with previously described procedures.[26] Participants were in the supine position for 10 min prior to obtaining bioelectrical impedance measurements. Previous test-retest scans resulted in a standard error of measurement (SEM) of 0.29 kg, with an intraclass correlation coefficient (ICC) of 0.997 and SEM of 0.23 kg for FFM, and ICC 0.99 for FM.

Functional capacity

Functional capacity tests were performed in a single day at pre-training and post-training by a team of examiners, with each examiner responsible for the same test at pre-training and post-training in order to ensure quality of measurement.

Agility and dynamic balance. The test started with participants sitting in a chair with heels resting on the floor. Upon a signal from the examiner, participants rose from the chair, moved to the right, circled a cone positioned 1.5 m back and 1.8 m to the side of the chair, returned to the chair, and sat down. Immediately after contacting the chair, participants stood up and moved to the left to complete the same route that had previously been performed to the right, thus completing a full circuit. The test ended as soon as the participants completed the circuit twice. Three attempts were made, with 2 min allowed for recovery between trials, and the shortest time adopted as the final test performance.[27]

Upper-body muscle endurance. The 30-s arm curl test was used to measure upper-body muscle endurance. Participants were seated on an armless chair with dominant arm fully extended holding a 2-kg dumbbell. Upon a signal from the examiner, participants performed as many flexion repetitions as possible within 30 s, with the total number of repetitions used for analysis.[21]

Cardiorespiratory fitness. The 6-min walk test was conducted as per a standardized protocol.[28] The test was performed around a rectangular area 18.0 m long by 9.2 m wide (54.4 m^2). After receiving brief instructions on the test procedure, participants positioned themselves behind a starting line. Upon a signal from the examiner, participants covered the maximum possible distance within 6 min. Participants were allowed to slow down while walking or even to end the test if any of the following symptoms were felt: dyspnea, dizziness, or pain in the chest, head, or legs. Test score was determined as the total distance (in meters) covered in the 6 min. The score was used as an indicator of mobility.

Training programs

Supervised RT and HIIT programs were carried out twice a week on Mondays and Thursdays for 8 weeks during the morning hours. All participants were personally supervised by exercise professionals with substantial RT and HIIT experience to ensure consistent and safe performance.

RT program. The protocol was based on recommendations for RT in an older population to improve muscle endurance and muscle strength.[29] It was a whole-body RT program consisting of 7 exercises performed by each training group in the following order: chest press (CP), seated row (SR), triceps pushdown (TP), preacher curl (PC) with barbell, horizontal leg press (LP), knee extension (KE), and seated calf raise (CR). Participants performed 2 sets of 10-15 repetitions for each exercise. Participants were instructed to inhale during the eccentric muscle action and exhale during the concentric muscle action, while maintaining a constant velocity of movement at a ratio of 1:2 (concentric and eccentric phases, respectively). Rest intervals between sets and exercises were 2 min and 3 min, respectively. Instructors adjusted loads of each exercise according to the participant's ability and improvements in exercise capacity throughout the study in order to ensure that exercises were performed with as much resistance as possible while maintaining proper execution technique. Progression was planned so that when 15 repetitions were completed in an exercise for two consecutive sessions, weight was increased by 2-5% for upper limb exercises and 5-10% for lower limb exercises.[29] During each training session, instructors registered the load (kg) for each of the 7 exercises for all participants. Training loads and number of repetitions were recorded to ensure training intensity for both groups during the training session.

HIIT program. Before training and at the end of the fifth week of training, participants underwent an incremental treadmill test (Imbramed, Porto Alegre, Rio Grande do Sul, Brazil) to determine initial training intensity. The test was always begun on a flat treadmill deck at a speed of 4 km/h, with increments of 0.5 km/h every minute until voluntary exhaustion. Heart rate during each test was recorded every 5 s by a heart rate monitor (Polar S810i, Polar Electro OY, Finland) to determine maximum heart rate (MHR). Both groups performed the same HIIT protocol, divided into 2 blocks of 4 weeks each. Block 1 consisted of 8 sets of 30-s sprints at a high intensity (> 85% of MHR), alternating with an active recovery of 60 s at a moderate intensity (60% of MHR), for a total of 12 min per session. Block 2 consisted of 10 sets of 30-s sprints at a high intensity (> 85% of MHR) alternating with 30 s of active recovery at a moderate intensity (60% of MHR), for a total of 10 min per session.

Statistical analysis

The assumption of normality was verified by the Shapiro-Wilk test. Data were expressed as means and standard deviations. Baseline differences between groups were explored with independent t-tests. Levene's test was used to analyze the homogeneity of variances. Two-way analysis of variance (ANOVA) for repeated measures was used for within-group comparisons. In variables where sphericity was violated as indicated by Mauchly's test, analyses were adjusted using a Greenhouse-Geisser correction. When the F-ratio was significant, Bonferroni's *post hoc* test was employed to identify mean differences. Effect size (ES) was calculated to verify magnitude of differences using Cohen's method.[30] An ES of 0.20–0.49 was considered small, 0.50–0.79 medium, and ≥ 0.80 large. For all statistical analyses, significance was accepted at $p < 0.05$. Data were stored and analyzed using STATISTICA software version 10.0 (StatSoft Inc., Tulsa, OK, USA).

RESULTS

Table 1 presents the results of body composition and hemodynamic measures of the groups at pre- and post-training. These measures did not change throughout the investigation for either group ($p > 0.05$).

Figure 2 shows the changes in functional capacity during 8 weeks of training submitted in two exercise orders (HIIT-RT and RT-HIIT). A significant main effect of time was noted for upper-body muscle endurance (HIIT-RT = +9.43%; RT-HIIT = +6.16%, small to medium ES), agility and dynamic balance (HIIT-RT = -5,96%; RT-HIIT = -8.57%, medium to large ES), and cardiorespiratory fitness (HIIT-RT = +5.14%; RT-HIIT = +6.13%, medium to large ES), with no difference between groups.

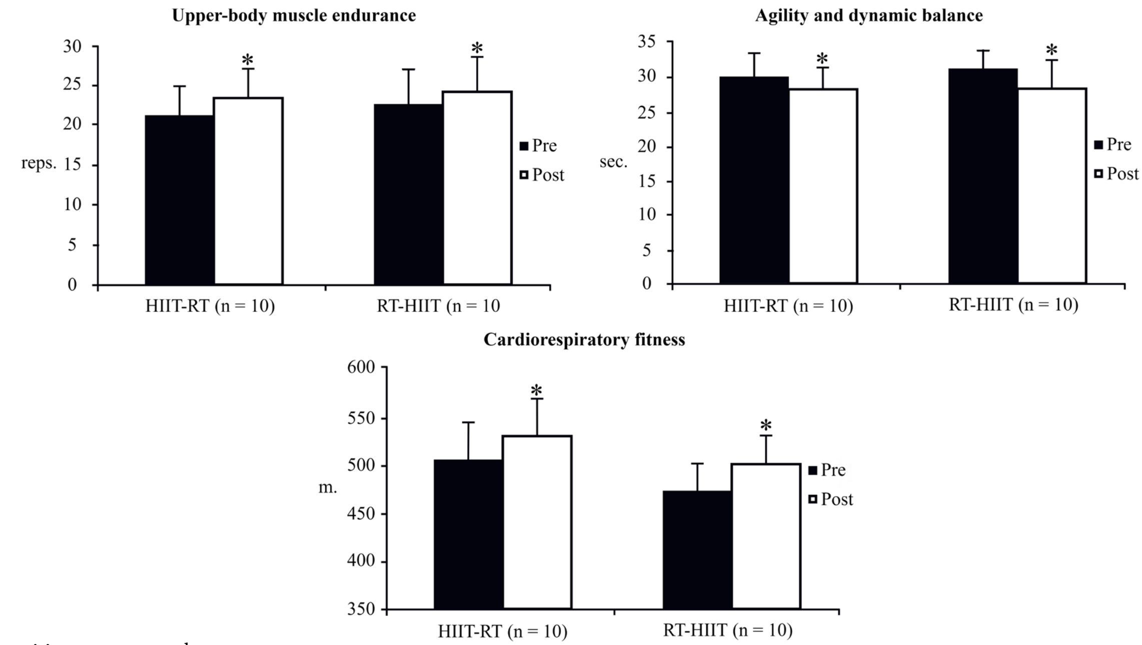
DISCUSSION

The main finding of our study is that both orders of exercise (HIIT followed by RT and RT followed by HIIT) elicited significant changes in functional capacity of middle-aged and older women, with no differences between the two sequences. Blood pressure and body composition did not change significantly following the intervention for either group. Thus, our initial hypothesis was confirmed. These findings are similar to those of Buckinx et al.[31] who observed significant changes in functional capacity of older men and women (timed up and go test: -10%, 6-min walk test: +15%, standing chair test: -19%), with no alterations in body composition (muscle mass,

TABLE 1. Blood pressure and body composition response during 8 weeks of combined training, stratified by order of modalities (HIIT-RT and RT-HIIT). Values are expressed as mean ± standard deviation.

Variable	Group	Pre	Post	ANOVA	p-value	ES
SBP (mmHg)	HIIT-RT	119.60 ± 15.64	114.50 ± 10.95	Group	0.50	-0.33
	RT-HIIT	113.90 ± 22.22	110.30 ± 18.17	Time	0.11	-0.16
				Interaction	0.77	
DBP (mmHg)	HIIT-RT	80.60 ± 10.15	75.90 ± 07.23	Group	0.31	-0.46
	RT-HIIT	74.40 ± 08.51	74.10 ± 10.35	Time	0.11	-0.04
				Interaction	0.15	
Fat-free mass (kg)	HIIT-RT	44.90 ± 4.31	44.40 ± 4.15	Group	0.77	-0.12
	RT-HIIT	45.70 ± 6.59	46.10 ± 6.48	Time	0.45	0.06
				Interaction	0.23	
Fat mass (kg)	HIIT-RT	28.90 ± 9.79	26.80 ± 8.26	Group	0.18	-0.21
	RT-HIIT	23.80 ± 4.62	23.90 ± 3.99	Time	0.25	0.02
				Interaction	0.46	

HIIT-RT: high-intensity interval training followed by resistance exercises; RT-HIIT: resistance exercises followed by high-intensity interval training; SBP: systolic blood pressure; DBP: diastolic blood pressure; ES: effect size.



reps.: repetitions, sec.: seconds, m.: meters.

FIGURE 2. Functional capacity response during 8 weeks of training submitted to two exercise orders (HIIT-RT and RT-HIIT). Values are expressed as mean ± standard deviation. *Difference between the moments of the experiment ($p < 0.05$).

fat mass, fat-free mass), after 12 weeks of HIIT (3 sessions per week). Another investigation conducted with older men and women also showed that a HIIT-RT program (12 weeks, 3 times/week) did not induce significant changes in body composition components.

Guadalupe-Grau et al.[32] subjected octogenarian men with COPD to 9 weeks of a low-volume HIIT-RT program and observed significant improvements in functional capacity (arm curl: +82%, 6-min walk test: +38%), but no alterations in muscle mass, fat mass, or blood pressure (SBP, DBP). Another investigation conducted with older men and women showed that 12 weeks of concurrent training (HIIT + RT) did not elicit significant changes in SBP and DBP.[33] On the other hand, other researchers, after applying a similar exercise design but with a longer intervention (4 to 8 months), observed significant alterations in SBP and DBP in older adults.[34] The authors of these studies attribute the absence of changes in body composition and blood pressure to the relatively short-term intervention employed. In this sense, it would be plausible to assume the same rationale would apply to our results, considering our participants trained for only 8 weeks.

Our findings regarding cardiorespiratory fitness estimated through the 6-min walk test showed significant increases, ranging from 7 to 77 m, for both training sequences. A recent systematic review with meta-analysis showed that HIIT has the potential to increase 6-min walk test performance by an average of 66 m after training.[35] Again, our results were slightly less, probably due to the short duration of the intervention. Furthermore, inconsistencies among results from different studies are probably due to the multiple HIIT protocols employed and use of hybrid interventions that combine different exercise modalities with HIIT.[36]

Regarding the execution order of the two modes of physical exercise, in a previous study, 26 older men performed a combined training regimen (HIIT and RT, 12 weeks, 3 times a week) after random allocation to one of two groups: one performed RT and then HIIT, while the other group started the training sessions with HIIT, followed by RT. After the intervention period, there were significant increases in maximal endurance power and muscle thickness, with no difference between the execution orders, except for muscle quality, lower-body muscle strength, and neuromuscular economy, in which the group that performed RT prior to HIIT exhibited greater increases.[20,22] Another study, conducted with healthy postmenopausal women (> 50 years old) who were engaged for 12 weeks, twice a week, in a water-based combined training program, with one group performing RT prior to aerobic training and another group performing the opposite order, reported that both exercise sequences significantly improved cardiorespiratory fitness (average between groups ~9.3%), muscle thickness (average between groups ~5%), and upper body muscle strength (average between groups ~10%), with no differences between the orders; however, for lower-body muscle strength, the increases were greater for the group that started the training session with RT prior to aerobic exercises (34% for RT before aerobic vs. 14% for aerobic before RT).[23] In fact, a recent systematic review with meta-analysis pointed that there was no support for a given exercise order for the training outcomes of lower-body muscle strength, muscle hypertrophy, maximal aerobic capacity, and relative body fat, while for lower-body dynamic strength, the execution order played an important role (favoring RT prior to endurance exercise).[37]

Regardless of the absence of significant differences between training modality sequences in our study, is it crucial to highlight that the combination of two modes of physical exercises was effective in promoting significant changes in functional capacity, especially in tests involving muscle strength (i.e., arm curl) and cardiorespiratory capacity (i.e., 6-min walk test). This might be due to the fact that RT may reverse age-related declines in muscle strength, while aerobic exercises (HIIT) are related to changes in aerobic capacity.

Some limitations of our study need to be addressed. First, our study sample was relatively small and composed of middle-aged and older women, which may limit extrapolation of the results to other groups (i.e., older men and women, persons with diabetes, institutionalized individuals). In addition, the lack of monitoring of participants' food consumption did not allow a more consistent isolation of analysis of training effects on body composition. Lack of systematic control of dietary intake may have at least partially compromised the adaptive responses caused by these protocols. Individuals engaged in physical exercise programs tend to be careless with daily dietary quality and energy intake,[33] which could have influenced our results.

On the other hand, it is important to point out the strengths of our investigation. All training sessions were supervised by professionals with RT and HIIT experience to ensure participant safety, quality of execution, and effectiveness of the exercises. Several studies have shown the relevance of a supervised physical exercise program for older adults.[21] Moreover, load adjustments were continuously applied based on participants' individual progression over the course of the training sessions, which ensured maintenance of proper intensity throughout the intervention. There were no adverse events for participants in any of the training sessions, reinforcing the safety and feasibility of exercise (especially when considering HIIT) for older adults.

CONCLUSION

We conclude that both RT followed by HIIT and HIIT followed by RT promote significant changes in functional capacity of middle-aged and older women, without differences between the two orders. The lack of alterations in blood pressure and body composition may have been due to the brevity of the intervention, a point worthy of consideration for future studies. Additional studies using longer program duration may allow changes in body composition to manifest, especially if dietary intake is observed or regulated.

Conflict of interest

The authors declare no conflicts of interest.

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Authors' contribution

AG: Conceptualization, data curation, funding acquisition, investigation, methodology, project administration, writing – original draft. HSF: Conceptualization, data curation, investigation, methodology, writing – review & editing. FLCP: Investigation, writing – original draft. RGF: Data curation, investigation, writing – original draft. JLM: Methodology, validation, writing – review & editing. AMG: Formal analysis, software, writing – original draft. DVO: Formal analysis, investigation, software, writing – review & editing. MAN: Data curation, formal analysis, funding acquisition, investigation, methodology, resources, software, supervision, validation, visualization, writing – review & editing.

REFERENCES

1. World Health Organization. Global strategy and action plan on ageing and health. Available from: https://www.who.int/ageing/WHO-GSAP-2017.pdf. Accessed in Jul 12, 2021.
2. Manini TM, Clark BC. Dynapenia and aging: an update. J Gerontol A Biol Sci Med Sci. 2012;67(1):28-40. https://doi.org/10.1093/gerona/glr010.
3. He X, Li Z, Tang X, Zhang L, Wang L, He Y, et al. Age- and sex-related differences in body composition in healthy subjects aged 18 to 82 years. Medicine (Baltimore). 2018;97(25):e11152. https://doi.org/10.1097/MD.0000000000011152.
4. Novotny SA, Warren GL, Hamrick MW. Aging and the muscle-bone relationship. Physiology (Bethesda). 2015;30(1):8-16. https://doi.org/10.1152/physiol.00033.201.

5. Tieland M, Trouwborst I, Clark BC. Skeletal muscle performance and ageing. J Cachexia Sarcopenia Muscle. 2018;9(1):3-19. https://doi.org/10.1002/jcsm.12238.

6. Wilkinson DJ, Piasecki M, Atherton PJ. The age-related loss of skeletal muscle mass and function: measurement and physiology of muscle fibre atrophy and muscle fibre loss in humans. Ageing Res Rev. 2018;47:123-32. https://doi.org/10.1016/j.arr.2018.07.005.

7. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(4):601. https://doi.org/10.1093/ageing/afz046.

8. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2019;1(1):CD012424. https://doi.org/10.1002/14651858.CD012424.pub2.

9. Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, et al. International Exercise Recommendations in Older Adults (ICFSR): Expert Consensus Guidelines. J Nutr Health Aging. 2021;25(7):824-53. https://doi.org/10.1007/s12603-021-1665-8.

10. Guedes JM, Bortoluzzi MG, Matte LP, Andrade CM, Zulpo NC, Sebben V, et al. Efeitos do treinamento combinado sobre a força, resistência e potência aeróbica em idosas. Rev Bras Med Esporte. 2016;22(6):480-84. https://doi.org/10.1590/1517-869220162206124834.

11. Borde R, Hortobágyi T, Granacher U. Dose-response relationships of resistance training in healthy old adults: a systematic review and meta-analysis. Sports Med. 2015;45(12):1693-720. https://doi.org/10.1007/s40279-015-0385-9.

12. Grgic J, Schoenfeld BJ, Davies TB, Lazinica B, Krieger JW, Pedisic Z. Effect of resistance training frequency on gains in muscular strength: a systematic review and meta-analysis. Sports Med. 2018;48(5):1207-20. https://doi.org/10.1007/s40279-018-0872-x.

13. Ribeiro AS, Aguiar AF, Schoenfeld BJ, Nunes JP, Cavalcante EF, Cadore EL, et al. Effects of different resistance training systems on muscular strength and hypertrophy in resistance-trained older women. J Strength Cond Res. 2018;32(2):545-53. https://doi.org/10.1519/JSC.0000000000002326.

14. Thomas E, Gentile A, Lakicevic N, Moro T, Bellafiore M, Paoli A, et al. The effect of resistance training programs on lean body mass in postmenopausal and elderly women: a meta-analysis of observational studies. Aging Clin Exp Res. 2021;33(11):2941-52. https://doi.org/10.1007/s40520-021-01853-8.

15. Gerage AM, Ritti-Dias RM, Nascimento MA, Pina FLC, Gonçalves CGS, Sardinha LB, et al. Chronic resistance training does not affect post-exercise blood pressure in normotensive older women: a randomized controlled trial. Age (Dordr). 2015;37(3):63. https://doi.org/10.1007/s11357-015-9801-1.

16. Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, et al. Resistance training for older adults: position statement from the national strength and conditioning association. J Strength Cond Res. 2019;33(8):2019-52. https://doi.org/10.1519/JSC.0000000000003230.

17. Coetsee C, Terblanche E. The effect of three different exercise training modalities on cognitive and physical function in a healthy older population. Eur Rev Aging Phys Act. 2017;14:13. https://doi.org/10.1186/s11556-017-0183-5.

18. Buckinx F, Gouspillou G, Carvalho LP, Marcangeli V, Boutros GEH, Dulac M, et al. Effect of high-intensity interval training combined with L-citrulline supplementation on functional capacities and muscle function in dynapenic-obese older adults. J Clin Med. 2018;7(12):561. https://doi.org/10.3390/jcm7120561.

19. García-Pinillos F, Laredo-Aguilera JA, Muñoz-Jiménez M, Latorre-Román PA. Effects of 12-week concurrent high-intensity interval strength and endurance training program on physical performance in healthy older people. J Strength Cond Res. 2019;33(5):1445-52. https://doi.org/10.1519/JSC.0000000000001895.

20. Cadore EL, Izquierdo M, Alberton CL, Pinto RS, Conceição M, Cunha G, et al. Strength prior to endurance intra-session exercise sequence optimizes neuromuscular and cardiovascular gains in elderly men. Exp Gerontol. 2012;47(2):164-9. https://doi.org/10.1016/j.exger.2011.11.013.

21. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc. 2011;43(7):1334-59. https://doi.org/10.1249/MSS.0b013e318213fefb.

22. Cadore EL, Izquierdo M, Pinto SS, Alberton CL, Pinto RS, Baroni BM, et al. Neuromuscular adaptations to concurrent training in the elderly: effects of intrasession exercise sequence. Age (Dordr). 2013;35(3):891-903. https://doi.org/10.1007/s11357-012-9405-y.

23. Pinto SS, Alberton CL, Bagatini NC, et al. Neuromuscular adaptations to water-based concurrent training in postmenopausal women: effects of intrasession exercise sequence. Age (Dordr). 2015;37(1):9751. https://doi.org/10.1007/s11357-015-9751-7.

24. Moher D, Schulz KF, Altman DG. The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomised trials. Lancet. 2001;357(9263):1191-4. PMID: 11323066.

25. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves JW, Hill MN, et al. Recommendations for blood pressure measurement in humans: an AHA scientific statement from the council on high blood pressure research professional and public education subcommittee. J Clin Hypertens (Greenwich). 2005;7(2):102-9. https://doi.org/10.1111/j.1524-6175.2005.04377.x.

26. Sardinha LB, Lohman TG, Teixeira PJ, Guedes DP, Going SB. Comparison of air displacement plethysmography with dual-energy X-ray absorptiometry and 3 field methods for estimating body composition in middle-aged men. Am J Clin Nutr. 1998;68(4):786-93. https://doi.org/10.1093/ajcn/68.4.786.

27. Andreotti RA, Okuma SS. Validating a test battery of activities of daily living for physically independent elderly. Rev Paul Educ Fís. 1999;13(1):46-66. https://doi.org/10.11606/issn.2594-5904.rpef.1999.137759.

28. Rikli RE, Jones CJ. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. Gerontologist. 2013;53(2):255-67. https://doi.org/10.1093/geront/gns071.

29. Chodzko-Zajko WJ, Proctor DN, Singh MAF, Minson CT, Nigg CR, Salem GJ, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc. 2009;41(7):1510-30. https://doi.org/10.1249/MSS.0b013e3181a0c95c.

30. Saul LK, Weinberger KQ, Sha F, Ham J, Lee DD. Spectral methods for dimensionality reduction. Semi-supervised Learn [Internet] 2006 [Accessed in 2021 Jul 31];3:1-18. Available in: https://cseweb.ucsd.edu/~saul/papers/smdr_ssl05.pdf

31. Buckinx F, Gaudreau P, Marcangeli V, Boutros GEH, Dulac MC, Morais JA, et al. Muscle adaptation in response to a high-intensity interval training in obese older adults: effect of daily protein intake distribution. Aging Clin Exp Res. 2019;31(6):863-74. https://doi.org/10.1007/s40520-019-01149-y.

32. Guadalupe-Grau A, Aznar-Laín S, Mañas A, Castellanos J, Alcázar J, Ara I, et al. Short- and long-term effects of concurrent strength and HIIT training in octogenarians with COPD. J Aging Phys Act. 2017;25(1):105-15. https://doi.org/10.1123/japa.2015-0307.

33. Silva MAR, Baptista LC, Neves RS, França E, Loureiro H, Lira FS, et al. The effects of concurrent training combining both resistance exercise and high-intensity interval training or moderate-intensity continuous training on metabolic syndrome. Front Physiol. 2020;11:572. https://doi.org/10.3389/fphys.2020.00572.

34. Schroeder EC, Franke WD, Sharp RL, Lee DC. Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: a randomized controlled trial. PLoS One. 2019;14(1):e0210292. . https://doi.org/10.1371/journal.pone.0210292.

35. Wu ZJ, Wang ZY, Gao HE, Zhou XF, Li FH. Impact of high-intensity interval training on cardiorespiratory fitness, body composition, physical fitness, and metabolic parameters in older adults: a meta-analysis of randomized controlled trials. Exp Gerontol. 2021;150:111345. https://doi.org/10.1016/j.exger.2021.111345.

36. Tavoian D, Russ DW, Law TD, Simon JE, Chase PJ, Guseman EH, et al. A randomized clinical trial comparing three different exercise strategies for optimizing aerobic capacity and skeletal muscle performance in older adults: protocol for the DART study. Front Med (Lausanne). 2019;6:236. https://doi.org/10.3389/fmed.2019.00236.

37. Eddens L, van Someren K, Howatson G. The role of intra-session exercise sequence in the interference effect: a systematic review with meta-analysis. Sports Med. 2018;48(1):177-88. https://doi.org/10.1007/s40279-017-0784-1.