COMBINING DIFFERENT CONCURRENT TRAINING METHODS IN OLDER ADULTS WITH METABOLIC SYNDROME

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COMBINAÇÃO DE DIFERENTES MÉTODOS DE TREINO CONCORRENTES EM IDOSOS COM SÍNDROME METABÓLICA

COMBINACIÓN DE DIFERENTES MÉTODOS DE ENTRENAMIENTO CONCURRENTES EN ANCIANOS CON SÍNDROME METABÓLICO

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ABSTRACT

Introduction: There are no studies comparing the effects of different concurrent training routines [i.e., a resistance training plus high-intensity interval training (RT+HIIT) program compared to an RT plus moderate-intensity continuous training (RT+MICT) program] on cardiorespiratory fitness (CRF) and physical performance in older adults with metabolic syndrome (MetS). Objectives: This study aimed to compare the effects of two concurrent training routines, RT+HIIT versus RT+MICT, on CRF and physical fitness in adults and older adults with MetS. Methods: Thirty-nine participants (67.0±6.7 years of age) were randomly assigned into three groups: RT+ MICT, RT+ HIIT and the control group (CON, no exercise). The 12-week physical training program consisted of 3 sessions/week (~50 minutes/session). The aerobic training component was customized for iso-caloric energy expenditure (P≥0.217) and iso-load distribution (TRIMP, P≥0.893), however the MICT component had a longer aerobic training time (P≤0.01). We evaluated pre- and post-evaluation CRF (VO_2peak), physical capacity [power of lower limbs (PLL), running velocity, and running time to exhaustion], plasma lactate, rate of perceived exertion (RPE), resting heart rate (HR_{rest}), and peak heart rate (HR_{peak}). Results: At the end of the intervention, a significant increase in the VO_2peak was observed only in the RT+HIIT group (P=0.01), but compared to the CON group both RT+HIIT and RT+MICT groups had significant improvement in the VO_{2peak} (P≤0.02). Only the RT+HIIT group had lower HR_{rest} as compared to the baseline and the CON group. Also, both RT+HIIT and RT+MICT groups, but not CON, significantly improved running speed, time to exhaustion, and PLL (P<0.05). There were no significant changes in HR_{peak}, RPE, and lactate for any of the groups. Conclusion: Our results suggest that 12 weeks of RT+MICT or RT+HIIT improve lower-limb physical performance. Also, our results suggest that RT+HIIT provides additional CRF benefits in older adults with MetS. ***Level of evidence II; Randomized Experimental Study.***

Keywords: High-intensity interval training; Resistance training; Endurance training; Aged.

RESUMO

Introdução: Não há estudos que comparem diferentes rotinas de treinamentos concorrentes [isto é, programa de treinamento resistido mais treinamento intervalado de alta intensidade (TR+HIIT) ao TR mais treinamento contínuo de intensidade moderada (TR+MICT)] na aptidão cardiorrespiratória (ACR) e desempenho físico em idosos com síndrome metabólica (SM). Objetivos: O objetivo deste estudo foi comparar os efeitos de duas rotinas de treinamentos concorrentes (TR+HIIT vs. TR+MICT) na ACR e aptidão física em adultos e idosos com SM. Métodos: Trinta e nove participantes (67,0 ± 6,7 anos) foram divididos randomicamente em três grupos: TR+MICT, TR+HIIT e grupo controle (CON, sem exercício). O programa de treinamento físico de 12 semanas consistiu em 3 sessões/semana (~ 50 minutos/sessão). O componente de treinamento aeróbico (HIIT ou MICT) foi adaptado para gasto energético isocalórico (P ≥ 0,217) e distribuição de isocarga (TRIMP; P ≥ 0,893), porém, o componente MICT teve tempo de treinamento aeróbico maior (P ≤ 0,01). Avaliamos a ACR pré e pós-intervenção (VO_{2pico}), capacidade física (potência de membros inferiores [PMI], velocidade de corrida e tempo de corrida até a exaustão), lactato plasmático, percepção subjetiva de esforço (PSE), frequência cardíaca de repouso ($FC_{repouso}$) e máxima (FC_{pico}). Resultados: No final da intervenção, somente o grupo TR+HIIT teve aumento significativo do VO_{2pico} (P = 0,01), mas em comparação com o grupo CON, ambos os grupos TR+HIIT e TR+MICT tiveram melhora significativa do VO_{2pico} (P ≤ 0,02). Somente o grupo TR+HIIT mostrou $FC_{repouso}$ menor em comparação com o basal e com o grupo CON. Além disso, os grupos TR+HIIT e TR+MICT, mas não o grupo CON, tiveram melhora significativa da velocidade de corrida, do tempo até a exaustão e da PMI (P < 0,05). Não houve alterações significativas em FC_{pico}, PSE e lactato em nenhum dos grupos. Conclusão: Nossos resultados sugerem que 12 semanas de TR+MICT ou TR+HIIT melhoram o desempenho físico dos membros inferiores. Além disso, nossos resultados sugerem que TR+HIIT fornece benefícios adicionais de ACR em idosos com SM. ***Nível de evidência II; Estudo Experimental Randomizado.***

Descritores: *Treinamento intervalado de alta intensidade; Treinamento de força; Treinamento de endurance; Idosos.*

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RESUMEN

Introducción: No hay estudios que comparen diferentes rutinas de entrenamientos concurrentes [es decir, programa del entrenamiento de resistencia (ER) más entrenamiento de intervalos de alta intensidad (ER+HIIT) con el ER más entrenamiento continuo de intensidad moderada (ER+ECIM) en la aptitud cardiorrespiratoria (ACR) y desempeño físico en ancianos con síndrome metabólico (SM). Objetivos: El objetivo de este estudio fue comparar los efectos de dos rutinas de entrenamientos concurrentes (ER+HIIT sobre ER+ECIM) sobre la ACR y aptitud física en ancianos con SM. Métodos: Treinta y nueve participantes (67,0±6,7 años) fueron divididos aleatoriamente en 3 grupos: ER+ECIM, ER+HIIT y grupo de control (CON, sin ejercicio). El programa de entrenamiento físico de 12 semanas consistió en 3 sesiones semanales (50 minutos/sesión). En componente de entrenamiento aeróbico HIIT o ECIM se igualó en cuanto al gasto energético isocalórico (P≥0,217) y la distribución de isocarga (TRIMP; P≥0,893), sin embargo, el componente ECIM tuvo un mayor tiempo de entrenamiento aeróbico (P≤0,01). Se evaluó la ACR antes y después de la intervención (VO_2pico), la capacidad física (potencia de las extremidades inferiores [PEI], la velocidad, y el tiempo hasta el agotamiento), el lactato plasmático y percepción subjetiva del esfuerzo (RPE), la frecuencia cardíaca en reposo HRest) y máxima (FC_{pico}). Resultados: Al final de la intervención, solo el grupo ER+HIIT presentó un aumento significativo del VO_2pico (P=0,01), pero en comparación con el grupo CON, tanto el grupo ER+HIIT como el ER+ECIM presentaron una mejora significativa l del VO2pico (P ≤ 0,02).. Sólo el grupo ER+HIIT demostró una HRest menor en comparación con el nivel de referencia y el grupo CON. Además, los grupos ER+HIIT y ER+ECIM, pero no el grupo CON, tuvieron una mejora significativa en la velocidad de carrera, el tiempo hasta el agotamiento y la PEI (P<0,05). No hubo cambios significativos en FC_{pico}, RPE y lactato para ninguno de los grupos. Conclusión: Nuestros resultados sugieren que 12 semanas de ER+ECIM o ER+HIIT mejoran el rendimiento físico de las extremidades inferiores. Además, sugieren que ER+HIIT proporciona beneficios adicionales en la ACR en ancianos con SM. ***Nivel de evidencia II; Estudio experimental aleatorio***

Descriptores: *Entrenamiento de intervalos de alta intensidad; Entrenamiento de fuerza; Entrenamiento de resistencia; Anciano.*

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INTRODUCTION

It is well established that physical activity (PA) provides cardiovascular health benefits, reducing the risk of developing hypertension and diabetes.[1, 2] In contrast, low cardiorespiratory fitness (CRF) is associated with higher cardiovascular risk and premature death, which can be counterbalanced by the increase on CRF.[3,4] Still, more than a quarter of the adult population does not reach the recommended international guidelines for PA and have low CRF.[5] Thus, more than 1.4 billion adults worldwide are at a higher risk of cardiovascular disease (CVD) and related effects.[1]

Physical training (PT) has been used as an optimal strategy to reduce sedentariness and inactivity and its deleterious effects.[6, 7] Particularly, moderate-intensity continuous aerobic training (MICT) has been recommended by the current ACSM's guideline as the only aerobic component in the fitness programs for older adults.[5] In contrast, to date, there are no recommended guidelines on how to prescribe high-intensity interval training (HIIT) in older adults.[5] However, among the different types of PT, concurrent training [CT; i.e. resistance training (RT) combined with MICT] has been shown interesting results on metabolic syndrome (MetS) outcomes and on CVD risk factors in adults and older adults.[8-11] Despite the well-known cardiometabolic benefits of CT as a viable tool to increase CRF and reduce the prevalence of inactivity in high-risk populations, there are several knowledge gaps on how to properly prescribe this type of training in people with advanced age. In addition, it is still unclear what is the optimal intensity or volume of the aerobic component.[12, 13]

Previous studies have shown that HIIT[14, 15] and MICT[13] have both successfully improved neuromuscular and CRF in healthy and frail older adults. However, there is no scientific-based evidence to confirm which modality (HIIT vs MICT) improves CRF and neuromuscular functions when combined with RT. Therefore, this study aims to analyze the response of different CT volume and intensities (RT+HIIT *versus* RT+MICT) in adults and older adults with MetS.

METHODS

Participants

This study included sedentary older adult and elderly participants (67.0±6.7 years old) with MetS, according to IDF, 2006.[16] All participants had at least 3 of the 5 MetS attributes. Participants' baseline descriptions are shown in Table 1, and further detailed description can be found elsewhere.[17,18]

The project was developed in accordance with the Declaration of Helsinki[19] and approved by the Research Ethics Committee (No. Reference: CE/FCDEF-UC/00202016). Eligible participants were informed of all study procedures and signed a consent form.

Overall design

This study is a randomized trial designed to evaluate the effects of two CT modes [12-week PT program (3 sessions/week; 50 minutes/session)] on CRF in participants with MetS.[16]

Table 1. Baseline characteristics of functional fitness and comparison between groups, calculated with MANCOVA, controlling for the effect of sex and age.

Variables	MICT group (N = 13)	HIIT group (N = 13)	CON group (N = 13)	P value
Woman, N (%)	11 (85%)	9 (69%)	9 (69%)	0.584†
Age, years	71 (5)	63 (7) *	68 (4)	0.001
BMI, $kg.m^{-2}$	29.3 (5.5)	31.1 (5.5)	29.5 (3.2)	0.633
VO_2peak, $mL.kg^{-1}.min^{-1}$	19.7 (3.9)	21.4 (4.0)	20.5 (3.3)	0.577
Lactate, mmol/L	2.9 (1.4)	3.5 (2.1)	3.7 (1.9)	0.751
Borg scale, CR-10	6 (2)	6 (2)	5 (1)	0.496
PLL, watt	451 (41)	552 (50)	505 (28)	0.334
HR_{rest}, $bat.min^{-1}$	69 (12)	75 (12)	68 (6)	0.154
HR_{peak}, $bat.min^{-1}$	127 (13)	131 (15)	116 (22)	0.206

Data are expressed as mean and standard deviations; * $P \leq 0.01$, when compared to the MICT group. †, chi-square test. ‡, independent T-test; §, Mann-Whitney test. BMI, body mass index; HR_{rest}, resting heart rate; HR_{peak}, heart rate at the end of the test; PLL, power strength of lower limb muscles; WC, waist circumference.

Participants were randomly assigned to three groups as follow: 1) RT+MICT program, 2) RT+HIIT program or 3) control group (CON). Participants of the CON group did not engage in a formal PT program during the intervention period. Also, PT levels were self-reported by questionnaire at baseline and at the end of the intervention. Similarly, a self-reported dietary questionnaire was used to assess the food intake at baseline and after the intervention. All groups were instructed to maintain the same nutritional pattern throughout the trial, and no changes in energy intake or in macronutrients were reported.

Exercise Programs intervention

The training sessions were performed three times a week ($3 \cdot week^{-1}$) in a closed gymnastic pavilion and were organized in the following order: warm-up, RT, aerobic training (MICT or HIIT), and flexibility training. The RT+MICT program followed ACSM recommendations for sedentary older adults.[5] The HIIT training followed the recommendations for older adults, proposed in a previous meta-analysis.[20]

Strength training lasted ~20 minutes/session and consisted of five exercises: deadlift, barbell bent-over row, stiff-leg deadlift, bench press and crunches. Each exercise was performed in two sets of 8-15 repetitions, with a rest interval of 1-2 minutes.[21] The RT exercise intensity progressively increased, ranging between 2-5 of the rating perceived exertion (RPE) CR-10 Borg scale[22] as described in Table 2. All the training sessions were supervised by a physical education teacher who conducted the exercise sessions, motivated the participants and assured movement execution correction and safety.

The MICT session lasted ~25 minutes/session of continuous brisk walking. The intensity was established at moderate to a vigorous intensity between 60-70% HR_{max} [estimated using Tanaka *et al.*[23] equation (i.e. (208 – age* 0.7)] and was controlled by a cardiac-telemetry device (ONRHYTHM 110 KALENJI®, Villeneuve, France) and by the RPE progressing from 3-5 points. As previously outlined,[20] the HIIT sessions lasted 15 minutes/session, combining 3-minute running bouts (80-90% HR_{max}) intercepted by 3-minutes of active recovery periods at 55-65% HR_{max}. The intensity was also controlled by a cardiac-telemetry device and by RPE progressing from 5 to 7 points on the running phase and from 2 to 3 points on the active recovery period.

The training of flexibility was performed at the end of each session (5 minutes) to promote calm down and included static stretches of the major muscles' groups lasting between 10-15 seconds for each movement and 1 to 2 repetitions.

Table 2. Periodization of resistance training.

Weeks	Intensity (Borg scale CR-10)	Repetitions
1 and 2	2	15
3 to 5	3	12-15
6 to 10	4	10-12
11 to 12	5	8-10

Training load and energy expenditure control

As aerobic training had different volumes (MICT= 25 min; HIIT= 15 min) and different intensities (MICT= 60-70% $HR_{max;}$ HIIT= 80-90% and 55-65% HR_{max}), we estimated the TRIMP (training impulse) of both aerobic workouts (MICT and HIIT), as proposed by Banister [24] TRIMP comparison between groups is presented in Table 3.

We estimated the exercise energy expenditure (ExEE) that would have occurred during both aerobic exercises by VO_2 (assuming 5kcal/LO_2) from individual rates of energy expenditure across each target of heart rate training zone (Table 3). The O_2 consumption (to estimate ExEE) were calculated from the graded exercise test (performed at baseline training) through indirect calorimetry (gas exchange O_2 and CO_2, using ergospirometry).

Table 3. Training characteristics.

Variables	MICT group (N = 13)	HIIT group (N = 13)	P value
Training sessions	29.5 (1.2)	28.(9 2.4)	0.486§
Training adherence (%)	82.1 (5.5)	80.3 (6.9)	0.486§
12-weeks of AT (min)	738 (5)	433.8 (37)	0.000§
12-week RT + AT (min)	1624.6 (104)	1156.9 (99)	0.000§
$TRIMP_{Banister}$ session	14.34 (5.07)	14.10 (3.91)	0.893‡
$TRIMP_{Banister}$ 12-wks	418.15 (124.93)	415.79 (115.14)	0.967‡
ExEE (kcal) session	142.71 (32.26)	126.66 (13.55)	0.217§
ExEE (kcal) 12-wks	4151.97 (1071.49)	3698.68 (442.32)	0.217§

Data are expressed as mean and standard deviations. ‡, independent T-test; §, Mann-Whitney test;AT, aerobic training; ExEE, exercise energy expenditure (session: from one session; 12wks: multiplied by individual training frequency); RT, resistance training; TRIMP, training impulse (session: from one session; 12wks: multiplied by individual time accumulated).

The ExEE was calculated by the following formula:[25] ExEE = (TrEE × 0.15) + [TrEE – training duration × (REE × 1.2)]. Where TrEE is the Kcal expended during training and REE is the resting energy expenditure. The REE was obtained after 5 min of rest before the graded exercise test. Also, REE was divided by the fat-free mass obtained by dual-energy x-ray absorptiometry (Lunar iDXA GE®. Diegem, Belgium).

Outcomes

Cardiorespiratory fitness assessment

For CRF assessment, participants were submitted to a Modified Bruce treadmill test[26] (HP Cosmos® treadmill, model Pulsar®). VO_{2peak} was assessed by gas analysis using a Quark CPET COSMED® (Roma, Italy). VO_{2peak} was defined as the mean value from the last 30 seconds of the test.

The RPE (measured by the CR-10 scale[22]), the maximum speed test ($km.h^{-1}$) and the total test duration were recorded at the end of the Bruce test. After the test, 0.3 µl of blood from the ring finger was also collected for lactate analysis (Lactate Pro2 LT-1730, Arkray® Portable Lactometer. Kyoto, Japan).

Heart rate assessment

Resting heart rate (HR_{rest}) was measured using a digital sphygmomanometer (Tavolo LCD display 4, DM460. Arezzo, Italy). Initially, participants rested for 5-minutes in the sitting position and, afterwards, two measurements were performed with a 1-minute interval. HR_{rest} was calculated by the average of both evaluations. In the last 30 seconds of the Modified Bruce test, the heart rate peak (HR_{peak}) was determined.

Power assessment

To measure the lower limbs' muscle power (PLL), participants performed the sit-up test,[27] which represents the number of repetitions that a participant can stand up and sit back in a chair repeatedly for 30 seconds. The number of repetitions was inserted into Smith *et al.*[28] formula to obtain PLL in watt.

Statistical analysis

Data are described as means and standard deviations (SD), or when signalized, standard error (SE). Normality of the data was analyzed through the Shapiro-Wilks hypothesis. ANOVA two-way followed by Bonferroni post-hoc tested the differences within groups. Differences between groups from pre- to post-intervention were evaluated through multivariate analysis of covariance (MANCOVA) followed by LSD post-hoc. The magnitude of the effect (pre- to post-intervention) was calculated using the statistical calculation of Cohen's d.[29] Eta squared (η^2) was used as the magnitude of the effect of ANOVA repeated measures. Data were analyzed using IBM-SPSS (Inc., Chicago, IL, USA, v.24), assuming a 95% significance level.

RESULTS

There were no differences between groups at baseline, except in age, being HIIT participants younger than the MICT group (*P*=0.001) – Table 1.

Participants reported no adverse event due to intervention. Also, all participants completed follow-up.

After CT interventions, a moderate main effect of time was observed for RPE (P=0.02, η^2=0.139), but not for HR_{peak} and blood lactate concentration for any group (P>0.77) – Table 4 and Figures 1 to 3, respectively. There was no significant group-by-time interaction effect for these variables. The HR_{rest} present a significant and moderate effect of time (P=0.043, η^2=0.121), with a significant decrease only in the HIIT group (P=0.030) and a significant and large group interaction (P=0.04, η^2=0.161), although there was no difference between groups after the intervention (see Table 4 and Figure 4).

There was a large main effect of time for maximum test speed (P=0.000, η^2=0.335), maximum test duration (P=0.000, η^2=0.369) and PLL (P=0.001, η^2=0.277) with a significant improvement in these variables on both RT+MICT and RT+HIIT groups, while the CON group did not change (P>0.05) – Table 4 and Figures 5 to 7, respectively. There was a large group-by-time interaction effect for maximum test duration (P=0.015, η^2=0.207) and PLL (P=0.028, η^2=0.180), but not for maximum test speed. Post-hoc revealed a significant difference in delta change (pre- to post-test) in maximum test duration (P<0.02) for booth RT+HIIT and RT+MICT comparing to CON group; also, there is a significant increase (P=0.02) in PLL for RT+MICT comparing to CON group.

Finally, there was a trend to the main effect of time (P=0.07, η^2=0.085) and a significant and large group interaction (P=0.01, η^2=0.214) for VO_{2peak}. Post-hoc revealed a significant increase (pre- to post-test) only in the HIIT group (P=0.007), being this value greater than the CON group at post-intervention (RT+HIIT *vs* CON: P=0.019, ES=1.39, mean difference 3.5 ml/kg^{-1}/min^{-1} 95%IC 0.6 to 6.5; RT+MICT *vs* CON: P=0.025, ES= 0.8, mean difference 3.3 ml/kg^{-1}/min^{-1} 95%IC 0.4 to 6.2) – Table 4 and Figure 8.

DISCUSSION

The results of this intervention showed that participants submitted to a CT for 12-weeks had significant improvements in VO_{2peak} and lower limb performance. More specifically, both RT+MICT and RT+HIIT groups showed a significant increase in PLL, the maximum test speed and maximum test duration. The significant group-by-time interaction presented in VO_{2peak}, in the maximum test duration, PLL and HR_{rest} revealed a change toward a better physical performance while the control group did not. Currently, there are no recommendations to include HIIT in the fitness programs proposed by the ACSM for older adults.[5] The present study's data suggest that including HIIT into a CT program is a time-efficient strategy (~28% less time) to improve CRF when compared to MICT. In addition, based on previously published data from this same experiment,[17] HIIT should be incorporated as part of the PT program for MetS treatment. We demonstrated that there was an improvement in several markers of the MetS (decreased plasma

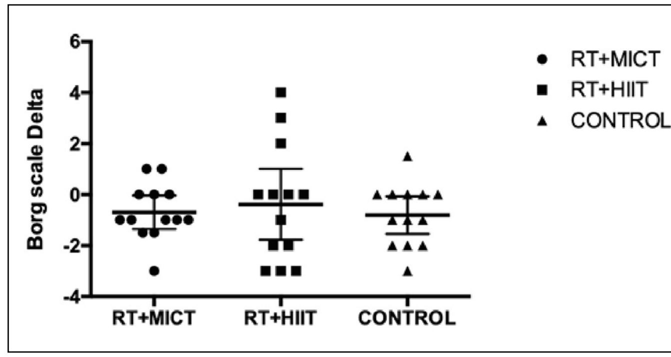

Figure 1. Delta change in Borg scale (CR-10) after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

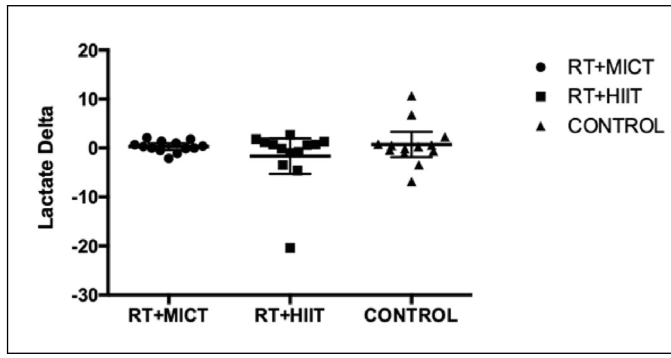

Figure 2. Delta change in Lactate (mmol/L) after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

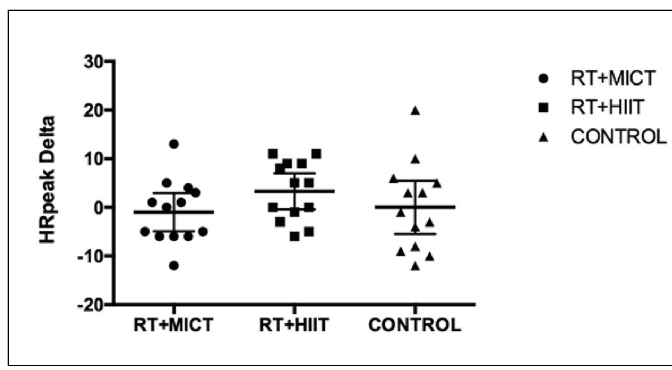

Figure 3. Delta change in heart rate at the end of the test (HRpeak, beats per minute) after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

Table 4. Differences (delta change) between evaluations after the training programs. Delta change was compared with MANCOVA (with sex and age as covariates). The main effect of time (within-group) and group interaction was compared with two-way repeated-measures ANOVA.

Variables	RT plus MICT (N = 13)			RT plus HIIT (N = 13)			CON (N = 13)			
	Δ (SE)	P within group	ES	Δ (SE)	P within group	ES	Δ (SE)	P within group	ES	P group interaction
VO_2 peak, mL.kg^{-1}.min^{-1}	1.6 (1.1) *	0.100	-0.424	2.7 (0.7) *	0.007	-0.566	-1.3 (0.9)	0.167	0.441	0.013
Maximum test speed, km.h^{-1}	0.5 (0.2) *	0.012	-0.783	0.7 (0.2) *	0.001	-0.547	0.2 (0.1)	0.332	-0.124	0.186
Test time, min	1.5 (0.5)	0.003	-0.612	2.1 (0.4) *	0.000	-0.582	0.1 (0.4)	0.785	-0.057	0.015
Lactate, mmol/L	0.3 (0.8)	0.781	-0.205	-0.1 (0.8)	0.898	0.052	0.7 (0.8)	0.351	-0.229	0.336
Borg scale, CR-10	-0.6 (0.3)	0.133	0.375	-0.3 (0.6)	0.399	0.171	-0.8 (0.3)	0.082	0.624	0.792
PLL, watt	47.1 (11.5) *	0.000	-0.318	25.6 (11.8)	0.032	-0.147	1.3 (11.1)	0.909	-0.014	0.028
HR_{rest}, bat.min^{-1}	-0.6 (3.5)	0.984	0.056	-7.3 (2.9) #	0.030	0.611	-0.3 (2.0)	0.881	0.057	0.043
HR_{peak}, bat.min^{-1}	-1.0 (1.8)	0.850	0.084	3.1 (2.9)	0.534	-0.217	7.6 (3.0)	0.157	-0.315	0.518

Data are expressed as mean and standard error; * p< 0.01, when compared to the CON group; # p< 0.07, when compared to the CON group MICT, continuous moderate training group; CON, control group; DM – differences on means; ES – effect size; HIIT, high-intensity interval training; PLL - power strength of lower limb muscles; HR_{rest} – resting heart rate; HR_{peak}– heart rate at the end of the test; SE – standard error; RT: resistance training.

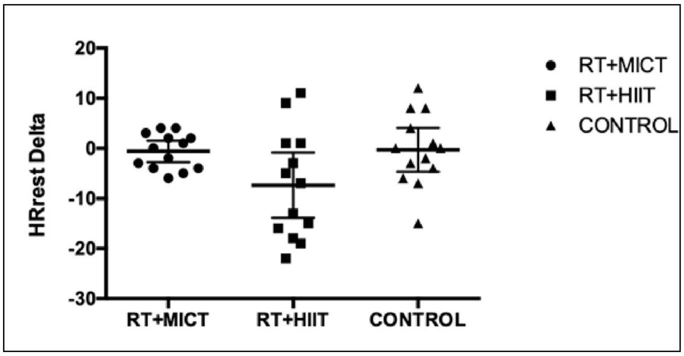

Figure 4. Delta change in heart rate at rest (HRrest, beats per minute) after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

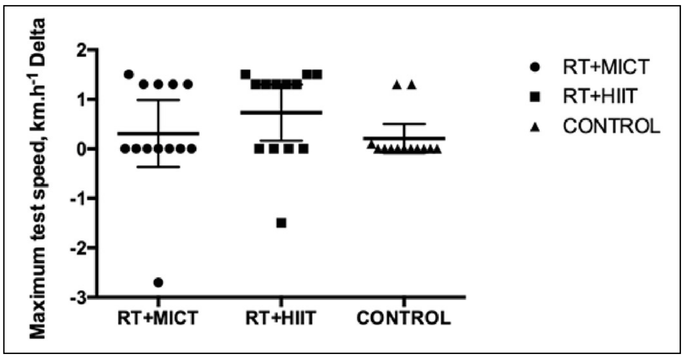

Figure 5. Delta change in Maximum test speed, km.h-1 after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

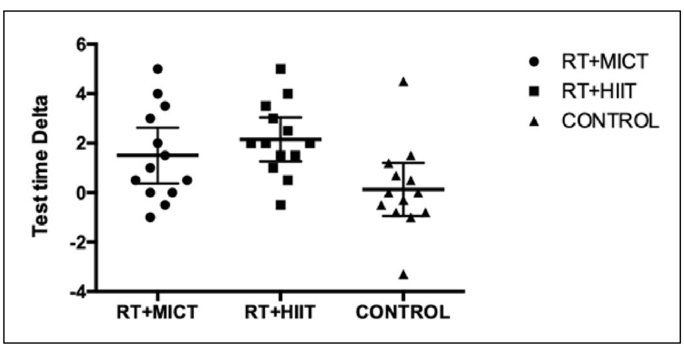

Figure 6. Delta change in test time (minutes) after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

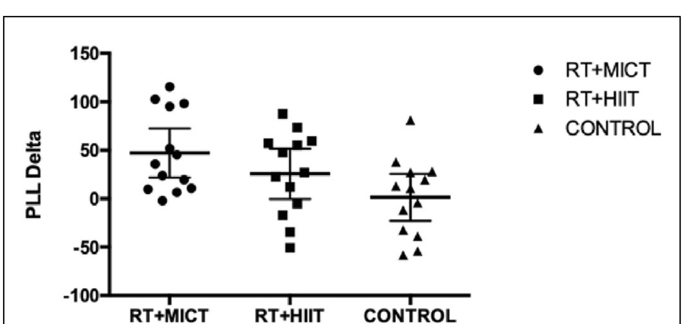

Figure 7. Delta change on the power of lower limb muscle (PLL), in watts, after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

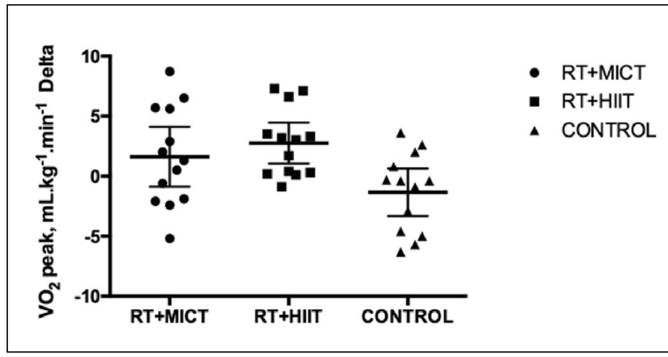

Figure 8. Delta change in VO2 peak, mL.kg-1.min-1 after 12 weeks of resistance training plus high-intensity interval training (RT+HIIT) or resistance training plus moderate-intensity continuous training (RT+MICT). The cross are means and ± standard error. The dots with filled circles, squares and triangles are individual participant values.

concentrations of insulin and fasting glucose, LDL cholesterol, hip circumference and improvement in HOMA-IR) in the RT+HIIT group.[17] In contrast, the RT+MICT group only improved hip circumference and fasting triglycerides. Taking together, our results suggest that HIIT can be used in clinical practice to improve physical fitness and metabolic health in older adults with MetS.

According to our result, low volume (15-min) and high-intensity aerobic training (80-90% HR_{max}) sessions are enough to elicit a significant cardiorespiratory adaptation in older adults (~3.5 ml/kg^{-1}/min^{-1} or ~16% increase of O_2 consumption, comparing to CON group). These data are consistent with a previous meta-analysis that addressed this topic, i.e., which analyzed the optimal dosage of HIIT in the elderly population to significantly improve CRF.[20] Improvements in VO_{2peak} have been found in other studies after 12-week of CT (RT+MICT *or* MICT+RT)[30,31] or even after 8-week of RT+MICT.[8,13] These studies showed superior gains in VO_{2peak} comparing to our RT+MICT intervention. Such differences may be related to exercise protocol design, e.g., session intensity and volume.[32] On the other hand, our HIIT protocol showed improved results in VO_{2peak}, when compared to a recent study in elderly individuals,[33] with a lower session volume and program duration (six bouts of 1-min run at 90% HR_{max}, interspersed by 2 min of active recovery at 40% HR_{max}, 3·week^{-1} for 8-week).

After the 12-week intervention, participants of both RT+MICT and RT+HIIT groups increased PLL and speed velocity and the test time duration, i.e., they walk/run longer before voluntarily discontinuing the test or before reaching 85% HR_{max}. Similar results have been reported by other studies[11, 13,15,31,34] with protocols similar to our study. Gains in muscular power have been associated with increased functional capacity,[12] which is associated with a decreased risk of sarcopenia, falls, fractures and disability.[35]

Another interesting result found in our study was the reduction in the HR_{rest} observed in the RT+HIIT group after this 12-week intervention, an outcome that did not change on the RT+MICT group. It is essential to highlight that HR_{rest} is a significant risk factor for premature death. Notably, these results are consistent with those found by others studies after 8-week of the HIIT program (performed 3·week^{-1})[36] and after 24-weeks of MICT+RT (performed 2·week^{-1}) in patients with CVD[9]. The decrease of HR_{rest} after aerobic training is an expected response. However, the underlying mechanisms are still a source of debate within the literature. The HR_{rest} decrease effect seen in short- term PT is due to the increase in vagal activity and reductions in norepinephrine response, while long-term PT promotes structural heart changes and increasing systolic volume. Apparently, both mechanisms can decrease intrinsic HR and contribute to improved heart activity.[37, 38]

Collectively, these results seem to suggest a higher efficacy (as a time-efficient strategy) of the RT+HIIT program compared to the RT+MICT protocol to decrease HR_{rest}.

This investigation has two important limitations. First, according to previous study,[20] our groups needed 17 participants to identify a change in VO_{2peak} between MICT and HIIT groups using a two-sided significance level of α=0.05 and β=0.8, but our study achieves only 13 participants in each group. However, based on the same study, a total of 10 participants are required to identify pre- to post-change in VO_{2peak}. Thus, our study has statistical power to identify pre- to post-change in CRF, even considering it has no statistical power to identify the between-group difference. Secondly, all groups were instructed to maintain the same nutritional pattern during the trial, and we used self-reported dietary questionnaires to assess the food intake before and after the intervention, although there were no changes in macronutrients in these 2-time points. Nonetheless, the lack of nutritional control throughout the intervention is a study limitation, and it can affect the performance outcomes in the volunteers from this study.

CONCLUSION

In conclusion, short-term MICT and HIIT exercise associated with RT were both effective in improving lower limb physical performance, even though the HIIT+RT may be more time-effective than MICT+RT to improve CRF in older adults with MetS.

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