

# Comparative effects of high-intensity interval training with combined training on physical function markers in obese postmenopausal women: a randomized controlled trial

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## Abstract

**Objectives:** This study compared the effects of high-intensity interval training (HIIT) with effects of combined training (CT) on physical function, body composition, and muscle strength in obese postmenopausal women (PW) (trial registration: NCT03200639).

**Methods:** PW were randomized to CT ( $n = 12$ ) and HIIT ( $n = 12$ ). The CT group performed 30 minutes of moderate walking at 70% of maximum heart rate (MHR) and five resistance exercises at 70% of one repetition maximum (1RM) for 12 weeks. The HIIT group performed 10 sets of vigorous exercises (30 seconds (s) of stair climbing and 30 s of body weight squats) at >80% MHR interspersed by a light walk (recovery period at 60% MHR).

**Results:** Both groups reduced body fat percentage (0.5%), chair stand (3 s) and increased leg lean mass (0.3 kg). Only the CT, however, increased muscle strength (29%) and fast walking speed (5%) compared with HIIT. The fast walking speed changes were partially explained by the muscle strength changes (36%,  $r = 0.60$ ,  $P = 0.027$ ) in the CT group.

**Conclusions:** These results suggest that HIIT is an alternative time-efficient protocol for improving chair stand and body composition when compared with CT, whereas only CT is an efficient protocol for improving muscular strength and fast walking speed in obese PW. Thus, CT must be prioritized when the increase of muscular strength and fast walking speed are the goals of training.

**Key Words:** Calisthenics – Chair stand – Gait speed – Menopause – Obesity.

**Video Summary:** Supplemental Digital Content 1, <http://links.lww.com/MENO/A443>.

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Postmenopausal women (PW) have higher adiposity levels, lower muscle mass, lower strength, and lower physical function when compared with older men.<sup>1,2</sup>

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Low muscle mass and strength (sarcopenia)<sup>3-6</sup> and high levels of body fatness (ie, obesity)<sup>2,7-10</sup> are well-known risk factors for low physical function (ie, walking, chair stand, and balance) in older women.<sup>11-14</sup> In this context, appropriate preventive strategies to improve body composition (body fat reduction and muscle mass increase) and muscle strength should be prioritized to improve physical function in PW. Different supervised-exercise modalities (aerobic and resistance training and high-intensity interval training [HIIT]) have been recommended by public health guidelines for older people.<sup>15</sup> Little evidence, however, exists on which supervised-exercise modality (ie, aerobic and resistance training or HIIT) is better for physical function in older people, particularly in PW.

Public health guidelines recommend 150 minutes of moderate-to-vigorous physical training per week, combining resistance training (ie, weight lifting for the major muscle groups at 60%-80% of one maximum repetition [1RM]) with moderate intensity aerobic training (~70% maximum heart rate [MHR] or ~5-6 rate perceived exertion [RPE]), termed as combined training (CT), to counteract sarcopenia and obesity.<sup>15-17</sup> CT decreases body fatness and increases muscle

mass, muscle strength, and physical function<sup>18-21</sup> in PW. The improvements in body composition and muscle mass and strength with the CT have been associated with improved fast walking speed,<sup>18,21</sup> chair stand,<sup>18-20</sup> and balance performance<sup>18</sup> in PW. More recently, a new exercise modality has been proposed as an alternative time-efficient intervention<sup>22</sup> because the lack of time is reported as a common barrier for people not to engage in physical activity.<sup>23,24</sup> This exercise modality is termed HIIT because it is performed with low time commitment (ie, ~60 min/wk) and with high-intensity exercises (ie, brief bouts of exercises at  $\geq 80\%$  MHR or  $\geq 7$  RPE).<sup>16,22</sup> HIIT has been shown to reduce body fatness in PW,<sup>25,26</sup> although there is some discrepancy in the literature on its hypertrophic effect.<sup>25,26</sup> To the best of our knowledge, there is, however, no evidence regarding the HIIT effects on muscle strength and physical function in PW. Thus, to consider HIIT as a time-efficient intervention in PW, studies are needed that compare the effectiveness of HIIT with the effectiveness of well-documented interventions on body composition, muscle strength, and physical function, such as CT.<sup>15-21</sup> Thus, the present clinical trial was designed to

compare the effectiveness of HIIT and CT on body composition, muscle strength, and physical function in obese PW over 12 weeks.

**METHODS**

**Study design**

This study was conducted to compare the effect of HIIT and CT on body composition, muscle strength, and physical function in obese PW. Therefore, a randomized, controlled, and parallel study (trial registration: NCT03200639) was performed over 12 weeks. Before the study began and during the follow-up, the groups were unknown to each other. All outcomes were assessed at the baseline and at the end of the training interventions. First, the secondary outcomes were assessed in the following order: nutritional, medicine intake and behavior habits (questionnaire), body composition, and muscle strength. Afterward, the primary outcome was assessed in the following order: physical function markers—short physical performance battery (SPPB) and fast walking speed (1-mile walk test). The final sample consisted of 24 PW divided into two groups: CT ( $n = 12$ ) and HIIT

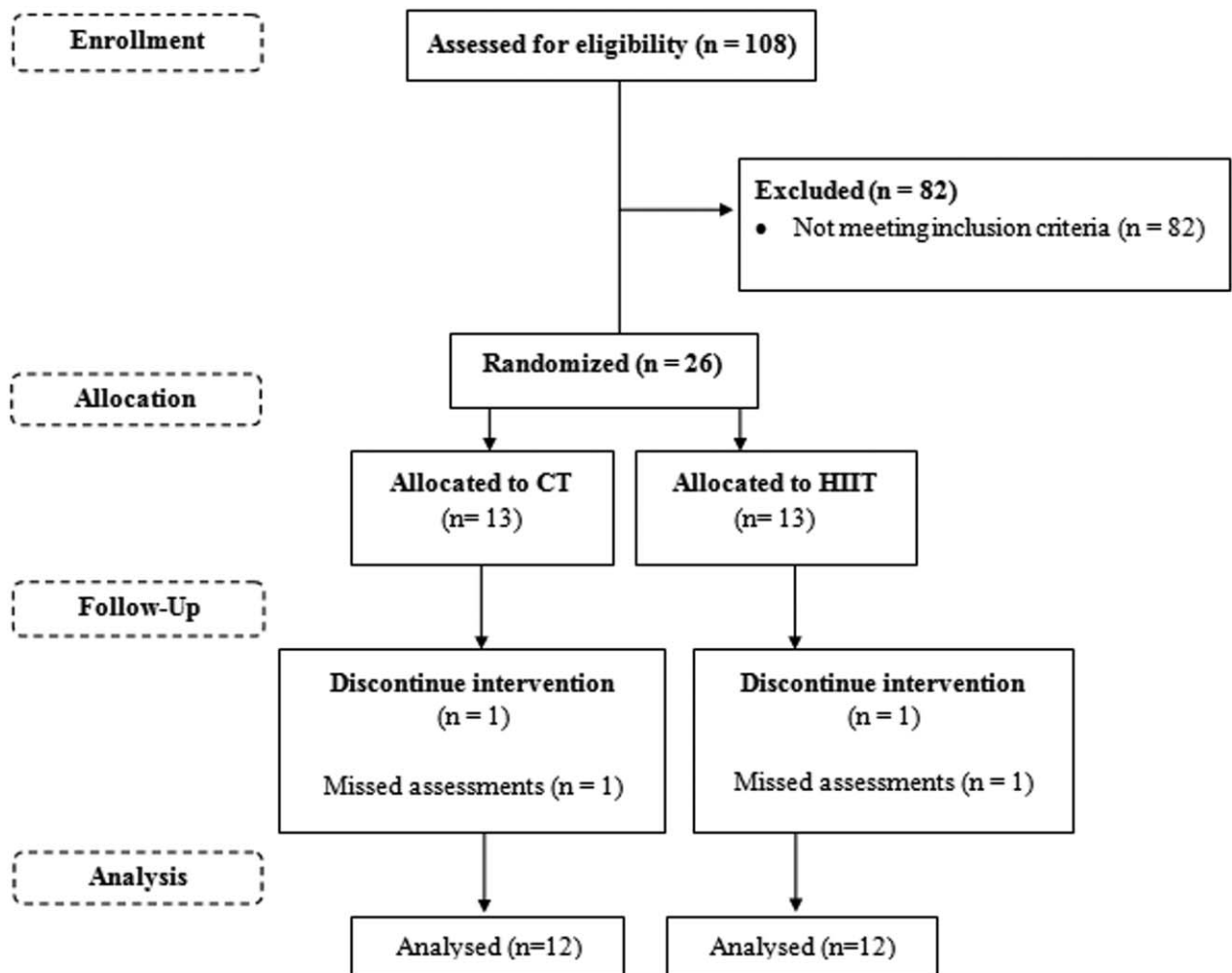


FIG. 1. Participant flow diagram. HIIT, high-intensity interval training; CT, combined training.

TABLE 1. Training protocols characteristics

|   | CT<br>(n = 12)            | HIIT<br>(n = 12)       | <i>P</i> <sup>a</sup><br>groups | HIIT set<br>1 week 4  | HIIT set<br>10 week 4  | <i>P</i> <sup>b</sup> | HIIT set<br>1 week 12  | HIIT set<br>10 week 12 | <i>P</i> <sup>b</sup> |
|---|---------------------------|------------------------|---------------------------------|-----------------------|------------------------|-----------------------|------------------------|------------------------|-----------------------|
| Aderence, %                             | 91.2<br>(86.3-96.0)       | 90.7<br>(85.6-95.8)    | 0.885                           |                       |                        |                       |                        |                        |                       |
| Heart rate, beats/min                   | 111.6<br>(107.4-115.8)    | 133.0<br>(125.5-140.5) | <0.001                          | 103.5<br>(83.6-123.3) | 129.5<br>(109.8-149.1) | 0.018                 | 126.5<br>(117.5-135.5) | 138.0<br>(128.0-148.1) | <0.001                |
| Heart rate zone, %                      | 71.1<br>(69.0-73.3)       | 84.6<br>(80.7-88.5)    | <0.001                          | 66.3<br>(56.9-75.7)   | 83.1<br>(72.5-93.6)    | 0.019                 | 80.3<br>(75.2-85.4)    | 87.6<br>(81.9-93.4)    | <0.001                |
| Borg scale, score                       | 5.7<br>(5.3-6.0)          | 6.7<br>(6.5-7.0)       | <0.001                          | 5.7<br>(5.0-6.4)      | 8.2<br>(7.6-8.8)       | <0.001                | 5.3<br>(4.7-5.8)       | 8.0<br>(7.4-8.5)       | <0.001                |
| Body squats, number                     | —                         | 19.2<br>(17.0-21.4)    | —                               | 18.7<br>(16.9-20.5)   | 18.7<br>(16.8-20.5)    | 1.000                 | 20.8<br>(14.0-27.7)    | 19.4<br>(16.0-22.7)    | 0.397                 |
| Steps climbs, number                    | —                         | 18.4<br>(15.7-21.2)    | —                               | 16.9<br>(15.0-18.7)   | 17.9<br>(15.2-20.5)    | 0.138                 | 17.3<br>(14.7-19.9)    | 17.4<br>(14.8-20.0)    | 0.782                 |
| Resistance training<br>total volume, kg | 6248.1<br>(5583.2-6912.9) | —                      | —                               |                       |                        |                       |                        |                        |                       |

Data are presented in means and 95% CI. Independent *t* test was performed to compare groups, *P* < 0.05.

CT, combined training; HIIT, high-intensity interval training.

<sup>a</sup>Comparison between groups.

<sup>b</sup>Comparison between sets of HIIT.

(*n* = 12) (Fig. 1). The groups were randomized (CT or HIIT) using statistical software (MedCalc, Ostend, Belgium) after all the women fulfilled the inclusion criteria (Fig. 1). The HIIT groups performed a total training protocol comprising 10 sets of 60 seconds (s) of high-intensity exercise  $\geq 80\%$  of MHR (30 s of climbing steps plus 30 s of free body weight squats) interspersed with a recovery period of 60 s of low-intensity exercise at 60% to 70% of MHR (light walk) (Table 1). The CT groups performed a total training protocol consisting of 30 minutes moderate walking at 70% MHR combined with five total body resistance exercises at 70% of 1RM with three sets of 8 to 12 repetitions at 1.5-minute rest intervals between the sets and exercises. Both groups performed a three-day-a-week (no consecutive days) routine (Table 1). After the training interventions, the assessments were performed 48 hours after the last session of training to avoid workout side effects.

## Participants

All the women were homemakers (ie, cooking and cleaning activities) and reported no history of physical training practice before the study (ie, at least 1 y). All women were aged >50 years old whose amenorrhea had occurred at least 12 months before the study and were selected at a neighborhood association near the local university. The inclusion criteria consisted of obesity (baseline body fat percentage >40%)<sup>27</sup>; controlled blood pressure; absence of myopathies, arthropathies, and neuropathies; absence of muscle, thromboembolic, and gastrointestinal disorders; absence of cardiovascular and infectious diseases; nondrinkers (no alcohol intake whatsoever in their diet); and nonuse of nutritional supplements which could affect the body composition or inflammatory serum markers.

Thus, after applying the inclusion criteria to avoid bias, all included women were apparently healthy with no functional comorbidities except for obesity. Only five women reported antihypertensive (CT = 01 and HIIT = 04), two

anti-inflammatory (CT = 0 and HIIT = 02), two antihypercholesterolemia (CT = 02 and HIIT = 0), two estradiol (E<sub>2</sub>) therapy (CT = 0 and HIIT = 02), and two tiroxin replacement therapy (CT = 01 and HIIT = 01) drugs. No supplements were reported. Only two women reported smoking habits (CT = 01 and HIIT = 01). All women were advised not to change their daily habits during the study. A CONSORT diagram is shown in Figure 1.

All PW were clear on the objectives and procedures of the study and gave us their written informed consent. The study was approved by the University Review Board for the Use of Human Subjects (local Ethics Committee) and was written in accordance with the standards set by the Declaration of Helsinki.

## Nutritional and sedentary behavior assessments

All women submitted a 3-day food record (2 d in the middle of the week and 1 on the weekend). Energy and macronutrients (carbohydrate, protein, and lipid) were quantified. Data were calculated by a trained nutritionist and using the Dietpro software (version 5.7i; Agromidia Softwares, Viçosa, Brazil) and the United States Department of Agriculture (USDA) food composition table. To quantify the sedentary behavior, we used the International Physical Activity Questionnaire (IPAQ), whose questions were about time spent on sitting time. All women submitted a 3-day sitting time record (2 d in the middle of the week and 1 on the weekend). Then, we calculated the mean of the week (7 d). The women were advised to maintain nutritional habits and the habitual physical activity until the end of the study.

## Anthropometric and body composition assessments

Throughout the day and before (24 h) the anthropometric and body composition assessments, all women were instructed to ingest 2 L of water to standardize the level of body hydration and were oriented to perform an overnight fast (10-12 h). The

assessments were collected between 7:30 and 9:00 AM. All women dressed in lightweight clothing with no shoes during the anthropometric and body composition assessments.

For anthropometric assessment, the body weight and height were measured with a digital scale (Lider, Araçatuba, Brazil) and a stadiometer fixed to the scale, respectively. Body mass index (BMI—weight (kg)/height (m)<sup>2</sup>) was calculated according to the system used by the World Health Organization.

For body composition assessment, fat mass (total fat mass, fat percentage—F% and legs fat mass) and lean mass (total lean mass and legs lean mass) were assessed via dual-energy x-ray absorptiometry scanning (iDXA; GE Healthcare-Lunar, Madison, WI) and quantified using the standard option of software Encore version 14.10. The coefficient of variation (CV) was <1.0% for fat mass and lean mass.

### Muscle strength and muscle quality assessments

The maximal strength test (1RM) was performed in all resistance exercises (CT group): 45-degree half squat (Smith machine), bench press, leg curl, rowing machine, and unilateral leg extension. The HIIT group performed solely the unilateral leg extension 1RM. The unilateral leg extension strength was used as an indicator of the muscle strength gain for both training protocols (CT and HIIT). Both leg muscle strength values were summed and compared between groups. We decided to use the leg extension strength due to its importance in clinical practice for older adults.<sup>28</sup> Muscle quality was assessed as the muscle strength for the leg lean mass ratio to provide a muscle quality index.<sup>29</sup>

Before the 1RM test, all women attended a 1-week familiarization period with light loads to learn the exercise technique. After this week, two sessions in nonconsecutive days of the 1RM test were performed (test and retest: intraclass correlation coefficient: 0.90 [95% CI, 0.79-0.95]). In each exercise, a subjective low load (estimated as 40%-60% of the 1RM) was determined as a warm-up and 5 to 10 repetitions were performed. Afterward, the subjective load was increased (estimated as 60%-80% of 1RM) and three to five repetitions were performed. After this procedure, the women rested for 3 minutes. Then, the load was increased considerably as close as possible to the individual's maximal capacity, and the women attempted to perform the movement. If the load was overestimated or underestimated, the women rested 3 to 5 minutes before the next attempt with a lower or higher load, respectively. No more than five attempts were performed. The load used as the maximum was the load of the last exercise successfully performed (full range of motion) by the women. Three to five attempts were used to determine the maximal load.<sup>30</sup>

### Physical function assessments

The SPPB test consisted of three tests performed in the following order: balance test, 4-m walking test (usual walking speed), and five-time chair stand test. Each test score varied from 0 to 4 points, and the SPPB score varied from 0 to 12 points (sum of the scores of the three tests).<sup>31</sup> The balance test

consisted of three positions: side-by-side stand, semi tandem stand, and tandem stand. The score was based on the time hold (10 s) in each position. The usual walking speed test was evaluated by the time walking at a distance of 4 m, in which the women autoselected the velocity. Two measures were taken and the minor time was considered as the valid measure. The five-time chair stand test was evaluated by the time spent on five maximal velocity squats in a chair with their arms folded across their chest. The technique consisted of full sit and stand positions and the women started in the sitting position.

The fast walking speed was assessed with the 1-mile walking test. The 1-mile walking test was performed indoors on a flat floor in a sports court (19 m + 38 m + 19 m + 38 m of length marked every 3 m).<sup>32</sup> A line, which indicated the beginning and end of each 114 m lap, was marked on the floor using brightly colored tape. All women were stimulated (ie, verbal stimulus, “you are doing great,” “walk as fast as you can”) every two laps during the test and were advised to walk as fast as possible with no interruptions (ie, no stops during the test) at the 1-mile distance. After completing the test, the time was recorded. The walking speed test was supervised by a qualified professional.

Although we did not perform duplicate analyses for physical function tests, previous studies demonstrated high reproducibility of the tests.<sup>32,33</sup>

### Exercise training protocols

All training sessions were performed in the university gym facility with a three-day-a-week (no consecutive days) routine for 12 weeks and were supervised by fitness professionals. Before and after each training session, a warm-up of 5 minutes walking and a cool down of 3 minutes walking at 60% of MHR was provided, respectively. To ensure the relative intensity training zone of each protocol (HIIT or CT), the women were encouraged by the fitness professionals to decrease or increase the exercise intensity if they surpassed or did not reach the intensity zone.

### High-intensity interval training

The HIIT protocol followed the recommendation of previous studies<sup>22,25,26</sup> (total session length time ~28 min) and consisted of 10 sets of 60 seconds of high-intensity exercises  $\geq 80\%$  of MHR or RPE  $\geq 7$  (30 s of climbing steps plus 30 s of free body weight squats) interspersed with a recovery period of 60 seconds of low-intensity exercise at 60% to 70% of MHR or RPE at 5 (light walk). The height of the steps was about 16 cm and the free body weight squats (no help of arms) was about 90-degree knee flexion against a chair for ensuring safety. All women were advised to perform the maximal number of steps climbing and free body weight squats as possible during the high-intensity exercise phase (Table 1).

The HIIT progression was separated as described: week 1—four sets of high-intensity exercise (1 min) interspersed with four sets of low-intensity exercise (4 min). Week 2—six sets of high-intensity exercise (1 min) interspersed with five

**TABLE 2.** Baseline characteristics of the both groups

|                            | CT (n = 12)            | HIIT (n = 12)          | P Pre |
|----------------------------|------------------------|------------------------|-------|
| Age, y                     | 63.0 (57.1-68.8)       | 62.9 (58.5-67.3)       | 0.980 |
| Menopause time, y          | 18.7 (12.3-25.1)       | 15.8 (9.1-22.4)        | 0.495 |
| Week sitting time, minutes | 3002.8 (2378.9-3626.7) | 2948.4 (2244.5-3652.2) | 0.899 |
| E <sub>2</sub> , pg/mL     | 7.9 (4.4-11.5)         | 14.8 (3.4-26.3)        | 0.254 |
| FSH, mIU/mL                | 77.7 (51.0-104.3)      | 58.8 (42.5-75.2)       | 0.175 |
| SPPB, score                | 12.0 (10.1-12.0)       | 11 (10.0-12.0)         | 0.214 |

Continuous data are presented in means and 95% CI. Independent *t* test was performed to compare groups, *P* < 0.05. Categorical data are presented in median and 95% CI; Mann–Whitney *U* test was performed to compare groups, *P* < 0.05.

CI, confidence interval; CT, combined training; E<sub>2</sub>, estradiol; FSH, follicle-stimulating hormone; HIIT, high-intensity interval training; SPPB, short physical performance battery.

sets of low-intensity exercise (3 min). Week 3—eight sets of high-intensity exercise (1 min) interspersed with eight sets of low-intensity exercise (2 min). Weeks 4 to 12—10 sets of high-intensity exercise (1 min) interspersed with 10 sets of low-intensity exercise (1 min).

**Combined training**

The CT protocol followed the recommendation of the American College of Sports Medicine Guidelines.<sup>15,16</sup> The CT protocol (total length time ~60 min) consisted of a 30-min moderate walk at 70% of MHR or RPE at 5 to 6 along a long flat floor around a sports court plus five total body resistance exercises at 70% of 1RM with three sets of 8 to 12 repetitions with a 1.5-minute rest interval between sets and exercises. The resistance exercises were performed using muscle-building machines (Buick Fitness, Taquara, BR) in the following order: 45-degree half squat (Smith machine), bench press, leg curl, rowing machine, and unilateral leg extension. In the sixth week of training, if the women could perform more than 12 repetitions in a respective exercise, the load was increased between 5% and 15% to maintain the zone between 8 and 12 repetitions to ensure the 70% of 1RM in all exercises. The resistance training total volume was calculated by multiplying the exercise load (in 45-degree half squat the body weight was summed to the load lifted to calculate the total volume) times the number of repetitions times the number of sets (Table 1).

The CT progression was separated as described: week 1—walking 15 minutes plus one set of the five total body resistance exercises. Week 2—walking 20 minutes plus two sets of the five total body resistance exercises. Week 3—walking 25 minutes plus two sets of the five total body

resistance exercises. Weeks 4 to 12—walking 30 minutes plus three sets of the five total body resistance exercises.

**Statistical analysis**

Data are presented as mean or median and 95% CI. The independent *t* test and Mann–Whitney *U* test were used to compare the training variables and the baseline characteristics (Tables 1 and 2) between groups. Mixed-model ANOVA (time vs group) was used to compare the groups during the follow-up (Tables 3-5). The effect size (partial eta squared =  $\eta_p^2$ ) and observed power was measured in this study. Cohen (1988) provided benchmarks to define small ( $\eta_p^2 = 0.01$ ), medium ( $\eta_p^2 = 0.06$ ), and large ( $\eta_p^2 = 0.14$ ) effects.<sup>34</sup> Pre- to postchanges ( $\Delta$ ) were calculated as the final value minus baseline. To determine whether a change in body composition and muscle strength across the intervention (pre and post) within the individual was associated with improvements in physical function across the intervention, we used multiple regression as recommended by Bland and Altman.<sup>35</sup> We made the fast walking speed the outcome variable and muscle strength, muscle quality and the women were made the predictor variables. The subject was treated as a categorical factor. We removed the variation due to the women, and expressed the variation at a fast walking speed due to muscle strength and muscle quality as a proportion of what is left:

$$\sqrt{\frac{\text{sum of square for muscle strength markers}}{\text{sum of square for muscle strength markers} + \text{residual sum of square}}}$$

The observed power was calculated for this study. The significant level was set at *P* < 0.05.

**TABLE 3.** Nutritional characteristics of both groups at baseline and after 12 weeks of training

|         | CT (n = 12)               |                           | $\Delta$                | HIIT (n = 12)             |                           | $\Delta$                  | <i>P</i> group | <i>P</i> time | <i>P</i> time vs group |
|---------|---------------------------|---------------------------|-------------------------|---------------------------|---------------------------|---------------------------|----------------|---------------|------------------------|
|         | Pre                       | Post                      |                         | Pre                       | Post                      |                           |                |               |                        |
| E, kcal | 1492.6<br>(1249.1-1736.0) | 1571.2<br>(1238.3-1904.1) | 78.6<br>(-230.1-387.4)  | 1287.8<br>(1188.9-1386.7) | 1300.2<br>(1064.7-1535.6) | 12.3<br>(-240.9 to 265.7) | 0.074          | 0.621         | 0.718                  |
| CHO, g  | 194.8<br>(162.2-227.4)    | 186.2<br>(143.5-228.9)    | -8.5<br>(-42.0 to 24.8) | 166.3<br>(149.4-183.3)    | 172.1<br>(146.1-198.1)    | 5.7<br>(-23.2 to 34.8)    | 0.230          | 0.891         | 0.483                  |
| PTN, g  | 55.0<br>(45.0-64.9)       | 65.6<br>(49.0-82.2)       | 10.6<br>(-8.1 to 29.5)  | 47.9<br>(40.4-55.4)       | 52.5<br>(40.1-65.0)       | 4.6<br>(-8.9 to 18.2)     | 0.091          | 0.161         | 0.574                  |
| LPD, g  | 52.3<br>(42.7-61.9)       | 61.7<br>(46.6-76.9)       | 9.4<br>(-6.2 to 25.2)   | 47.4<br>(37.9-56.8)       | 44.8<br>(33.8-55.7)       | -2.5<br>(-18.5 to 13.3)   | 0.053          | 0.507         | 0.249                  |

Data are presented in means and 95% CI. Repeated measures ANOVA was used to compare groups, *P* < 0.05.

CHO, carbohydrate intake; CI, confidence interval; CT, combined training; E, energy intake; HIIT, high-intensity interval training; LPD, lipid intake; PTN, protein intake.

**TABLE 4.** Body composition characteristics of both groups at baseline and after 12 weeks of training

|                                    | CT (n = 12)         |                     |                       | HIIT (n = 12)       |                     |                         | P group | P time | $\eta_p^2$ | Power | P time vs group | $\eta_p^2$ | Power |
|------------------------------------|---------------------|---------------------|-----------------------|---------------------|---------------------|-------------------------|---------|--------|------------|-------|-----------------|------------|-------|
|                                    | Pre                 | Post                | $\Delta$              | Pre                 | Post                | $\Delta$                |         |        |            |       |                 |            |       |
| <i>Anthropometric assessments</i>  |                     |                     |                       |                     |                     |                         |         |        |            |       |                 |            |       |
| Weight, kg                         | 69.1<br>(62.1-76.1) | 67.9<br>(59.9-76.0) | -1.1<br>(-3.6 to 1.4) | 75.5<br>(64.2-86.7) | 74.1<br>(62.9-85.3) | -1.3<br>(-2.7 to -0.02) | 0.315   | 0.069  | 0.14       | 0.45  | 0.855           | 0.00       | 0.05  |
| BMI, kg/m <sup>2</sup>             | 29.9<br>(27.9-32.0) | 29.4<br>(27.0-31.8) | -0.5<br>(-1.7 to 0.5) | 31.1<br>(26.8-35.4) | 30.6<br>(26.4-34.8) | -0.4<br>(-1.1 to 0.2)   | 0.592   | 0.108  | 0.11       | 0.36  | 0.873           | 0.00       | 0.05  |
| <i>Fat mass assessments</i>        |                     |                     |                       |                     |                     |                         |         |        |            |       |                 |            |       |
| F %                                | 44.3<br>(42.3-46.2) | 44.0<br>(41.9-46.0) | -0.3<br>(-0.8 to 0.2) | 45.8<br>(42.4-49.3) | 45.1<br>(41.7-48.5) | -0.7<br>(-1.5 to 0.1)   | 0.451   | 0.047  | 0.16       | 0.52  | 0.404           | 0.03       | 0.13  |
| Total FM, kg                       | 30.4<br>(26.4-34.3) | 30.3<br>(26.1-34.4) | -0.1<br>(-0.8 to 0.6) | 34.8<br>(27.1-42.4) | 33.9<br>(26.3-41.5) | -0.8<br>(-1.9 to 0.2)   | 0.314   | 0.121  | 0.10       | 0.34  | 0.236           | 0.06       | 0.21  |
| Legs FM, kg                        | 9.9<br>(7.8-12.1)   | 9.8<br>(7.6-11.9)   | -0.1<br>(-0.3 to 0.0) | 11.0<br>(8.8-13.3)  | 10.8<br>(8.5-13.0)  | -0.2<br>(-0.6 to 0.1)   | 0.465   | 0.058  | 0.15       | 0.48  | 0.491           | 0.02       | 0.10  |
| <i>Lean mass assessments</i>       |                     |                     |                       |                     |                     |                         |         |        |            |       |                 |            |       |
| Total LM, kg                       | 36.0<br>(32.7-39.2) | 36.3<br>(32.8-39.8) | 0.3<br>(-0.1 to 0.7)  | 37.5<br>(33.9-41.0) | 37.5<br>(33.8-41.2) | 0.05<br>(-0.5 to 0.6)   | 0.548   | 0.306  | 0.04       | 0.17  | 0.470           | 0.02       | 0.11  |
| Legs LM, kg                        | 12.3<br>(10.8-13.8) | 12.7<br>(11.1-14.4) | 0.4<br>(0.2-0.6)      | 12.7<br>(11.1-14.2) | 12.9<br>(11.3-14.6) | 0.2<br>(-0.0 to 0.5)    | 0.790   | <0.001 | 0.47       | 0.99  | 0.276           | 0.05       | 0.19  |
| <i>Muscle strength assessments</i> |                     |                     |                       |                     |                     |                         |         |        |            |       |                 |            |       |
| MS, kg                             | 50.7<br>(41.1-60.3) | 65.4<br>(54.8-75.9) | 14.6<br>(8.6-20.6)    | 57.9<br>(47.6-68.1) | 61.5<br>(45.7-77.2) | 3.5<br>(-4.8 to 12.0)   | 0.824   | 0.001  | 0.40       | 0.96  | 0.028           | 0.20       | 0.62  |
| MQ                                 | 4.0<br>(3.5-4.6)    | 5.0<br>(4.6-5.5)    | 1.0<br>(0.5-1.5)      | 4.5<br>(3.9-5.0)    | 4.7<br>(3.6-5.7)    | 0.1<br>(-0.5 to 0.8)    | 0.927   | 0.006  | 0.29       | 0.83  | 0.042           | 0.17       | 0.54  |

Data are presented in means and 95% CI. Repeated measures ANOVA was used to compare groups,  $P < 0.05$ . BMI, body mass index; CI, confidence interval; CT, combined training; FM, fat mass; F %, body fat percentage; HIIT, high-intensity interval training; LM, lean mass; MQ, muscle quality; MS, muscle strength.

**RESULTS**

The baseline characteristics of both groups are shown in Table 2. Both groups showed normal values (on average) in follicle-stimulating hormone, E<sub>2</sub>, and SPPB score (a marker of physical function) for PW. At baseline, the nutritional, body composition, muscle strength, and physical function characteristics are shown in Tables 3 to 5, respectively. No differences between the groups were observed for the baseline values.

The pre- and postintervention values of the nutritional indicators, body composition, muscle strength, and muscle quality were statistically compared between the groups (CT and HIIT) and interpreted. No time and interaction effects were observed in the nutritional indicators (Table 3). For body composition assessments, both groups reduced F% and increased leg lean mass (time effect;  $P < 0.05$ ). Only the CT group increased the muscle strength and muscle quality when compared with the HIIT group (time vs group effect;  $P < 0.05$ ) (Table 4).

For physical function assessments, both groups reduced chair stand time (time effect;  $P < 0.05$ ) (Table 5). Only the CT group increased fast walking speed (time vs group effect;  $P < 0.05$ ) when compared with the HIIT group (Table 5). The fast walking speed increase was explained by muscle strength increases (36%,  $r = 0.60$ ,  $P = 0.027$ ) in the CT.

**DISCUSSION**

To the best of knowledge, this is the first study which compared HIIT effectiveness (because HIIT is performed in less time) with CT effectiveness on body composition, muscle strength, and physical function markers in obese PW. The main findings of the present study demonstrated that both training protocols improved body composition and chair stand (a good physical function marker). Only the CT group, however, increased muscle strength, muscle quality, and fast walking speed when compared with HIIT. Moreover, the fast walking speed change was explained by an increase in muscle strength (36%) only in the CT group. These data are important

**TABLE 5.** Physical function characteristics of both groups at baseline and after 12 weeks of training

|                          | CT (n = 12)        |                  |                         | HIIT (n = 12)       |                   |                         | P group | P time | $\eta_p^2$ | Power | P time vs. group | $\eta_p^2$ | Power |
|--------------------------|--------------------|------------------|-------------------------|---------------------|-------------------|-------------------------|---------|--------|------------|-------|------------------|------------|-------|
|                          | Pre                | Post             | $\Delta$                | Pre                 | Post              | $\Delta$                |         |        |            |       |                  |            |       |
| Fast walking speed, m/s  | 1.6<br>(1.5-1.7)   | 1.7<br>(1.6-1.8) | 0.08<br>(0.04-0.1)      | 1.6<br>(1.4-1.7)    | 1.6<br>(1.5-1.6)  | -0.01<br>(-0.1 to 0.07) | 0.126   | 0.185  | 0.07       | 0.26  | 0.045            | 0.17       | 0.53  |
| Usual walking speed, m/s | 1.1<br>(1.0-1.2)   | 1.1<br>(1.0-1.2) | -0.03<br>(-0.1 to 0.06) | 1.0<br>(0.8-1.1)    | 1.0<br>(0.9-1.1)  | -0.0<br>(-0.1 to 0.1)   | 0.204   | 0.579  | 0.01       | 0.08  | 0.649            | 0.00       | 0.07  |
| Chair stand, s           | 11.0<br>(9.7-12.4) | 7.8<br>(6.8-8.8) | -3.2<br>(-4.4 to -1.9)  | 12.3<br>(10.2-14.5) | 9.3<br>(7.5-11.1) | -3.0<br>(-4.8 to -1.2)  | 0.149   | <0.001 | 0.64       | 0.99  | 0.856            | 0.00       | 0.05  |

Data are presented in means and CI of 95%. Repeated measures ANOVA was used to compare groups,  $P < 0.05$ . CI, confidence interval; CT, combined training; HIIT, high-intensity interval training.

because a low proportion of the population achieves the recommendations of physical training<sup>36,37</sup> because of a lack of time and access to physical training facilities.<sup>23,24</sup> Thus, as HIIT is performed with a very low time commitment and no equipment, our results suggest that HIIT is an alternative time-efficient protocol for improving physical function and body composition when compared with CT in PW. CT must, however, be prioritized when the increase in muscular strength and fast walking speed are the training goals.

Poor physical function performances have been strongly associated with a high risk of mortality in older adults,<sup>11,13,14</sup> particularly the chair stand test.<sup>14</sup> The chair stand test provides a valid measure of physical function.<sup>11,13,14,31</sup> In the present study, both groups showed similar improvement in the chair stand test. Thus, as CT has been demonstrated to be an efficient protocol to improve chair stand,<sup>18-20</sup> our results demonstrated that HIIT is an alternative time-effective training strategy to improve the chair stand when compared with CT in obese PW.

Fast walking speed is a simple and reliable test of physical function.<sup>6,38</sup> Low fast walking speed (<0.8-1.0 m/s) is a strong predictor of all-cause mortality in older adults.<sup>12</sup> In women, fast walking speed slightly decreases ~2% per decade and after the sixth decade of age there is a dramatic reduction of ~12% per decade.<sup>39</sup> Meaningful changes in fast walking speed have been reported between ~0.05 and 0.14 m/s of increase.<sup>40,41</sup> In the present study, only CT increased fast walking speed and this increase was ~0.08 m/s (Table 5). Low muscle strength is a well-known factor which is associated with low fast walking speed.<sup>3-6</sup> We observed that the increase in fast walking speed was associated with the increase in muscle strength (36%,  $r = 0.60$ ,  $P = 0.027$ )—only in the CT group. Thus, it seems that muscle strength gains may be important for improvements in fast walking speed in PW. Collectively, based on public health recommendations,<sup>15-17</sup> CT is a gold standard training exercise protocol for older adults to improve fast walking speed, particularly obese PW.

In the present study, the HIIT did not increase muscle strength, only the CT did (Table 4). It has been well demonstrated that both low load (20%-50% 1RM) and high load (70%-80% 1RM) increase muscle strength; however, greater increases were observed when higher loads were used.<sup>42-44</sup> The mechanisms which may explain the superiority in muscle strength gains with higher loads may be due to higher neural adaptations (ie, muscle activation) when compared with lower loads.<sup>45-47</sup> In the CT group, resistance training was performed with 70% of 1RM, whereas HIIT was performed with body weight. Data from previous studies have demonstrated that body weight accounts for 35% to 45% of 1RM in squat exercises for young adults and PW.<sup>30,48</sup> Furthermore, previous data have reported that when low loads are used, muscle failure (exhaustion) must occur to increase muscle strength.<sup>45-47,49</sup> The HIIT group only achieved slight muscle fatigue, but not muscle failure (Table 1) because no reduction in the number of stepping up and down on a step and squatting was observed between the 1st and 10th set of HIIT (Table 1).

This may explain the absence of an increase in muscle strength in the HIIT group. In addition, the adaptations promoted by the leg extensor exercise in the CT training routine seems to be highly specific to the movement involved in the stimulus of the 1RM test (leg extensor exercise).<sup>50</sup> As only the CT group performed leg extension exercises, specific adaptations related to movement (speed, range of motion, and muscle groups) may have favored the CT group in the 1RM.

Muscle mass gain (muscle hypertrophy) is a result of an accumulation of muscle proteins due to a high protein synthesis and a low protein breakdown.<sup>49</sup> Interestingly, a study carried out by Bell et al demonstrated that HIIT performed on a cycle ergometer increased protein synthesis similarly to resistance training (a well-known model for muscle hypertrophy).<sup>49-51</sup> Moreover, a study carried out by Mandrup et al showed that 12 weeks of HIIT performed on a cycle ergometer for ~35 minutes increased total lean body mass (~0.5 kg or 1%) in PW.<sup>26</sup> Similarly, in the present study, the HIIT group increased lean mass similarly to CT (resistance exercises) (leg lean mass, CT: 0.4 kg or 3% and HIIT: 0.2 kg or 1.5%; Table 4). Thus, these data suggest that HIIT is an alternative time-effective training strategy to increase muscle mass in obese PW when compared with CT.

## CONCLUSIONS

The findings of the present RCT study involving obese PW indicate that HIIT is an alternative time-efficient protocol for improving chair stand (a good marker of physical function) and body composition when compared with CT in obese PW. Only CT, however, increases muscle strength, muscle quality, and fast walking speed when compared with HIIT. Moreover, these findings further support the importance of exercise training-induced improvement in muscle strength on fast walking speed in obese PW. Thus, in obese PW who need to improve physical function and body composition and have little time to exercise or difficult access to physical facilities, HIIT is an alternative time-efficient treatment strategy. CT, however, must be prioritized when increase in muscle strength, muscle quality, and fast walking speed are the training goals.

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