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High-intensity body weight training is comparable to combined training in changes in muscle mass, physical performance, inflammatory markers and metabolic health in postmenopausal women at high risk for type 2 diabetes mellitus: A randomized controlled clinical trial

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ABSTRACT

Objective: This study compared the effects of 12 weeks of high-intensity interval body weight training (HIBWT) with combined training (COMT; aerobic and resistance exercises on body composition, a 6-minute walk test (6MWT; physical performance), insulin resistance (IR) and inflammatory markers in postmenopausal women (PW) at high risk of type 2 diabetes mellitus (TDM2).
Methods: In this randomized controlled clinical study, 16 PW at high risk of TDM2 were randomly allocated into two groups: HIBWT ($n = 8$) and COMT ($n = 8$). The HIBWT group performed a training protocol (length time ~28 min) consisting of ten sets of 60 s of high intensity exercise interspersed by a recovery period of 60 s of low intensity exercise. The COMT group performed a training protocol (length time ~60 min) consisting of a 30 min walk of moderate intensity following by five resistance exercises. All training sessions were performed in the university gym facility three days a week (no consecutive days) for 12 weeks. All outcomes (body composition, muscle function, and IR and inflammatory markers) were assessed at the baseline and at the end of the study.
Results: Both groups increased ($P < 0.05$) muscle mass index (MMI), 6MWT, and interleukin 1 receptor antagonist and decreased fasting glucose, glycated hemoglobin, Insulin, HOMA-IR, and monocyte chemoattractant protein-1 (trend, $P = 0.056$). HIBWT effects were indistinguishable ($P > 0.05$) from the effects of COMT. There was a significant ($P < 0.05$) interaction of time by the group in muscle strength, indicating that only the COMT increased the muscle strength.
Conclusions: This study suggests that changes in HOMA, IL-1ra, 6MWT, and MMI with HITBW are similar when compared to COMT in PW at high risk of TDM2.
Trial registration: The patients were part of a 12-week training study (ClinicalTrials.gov Identifier: NCT03200639).

1. Introduction

Postmenopausal period is accompanied by changes in body composition, which are characterized by an increase in body fat (obesity) and reduction in muscle mass, concomitantly with a reduction in physical performance (Kamel et al., 2002; Toth et al., 2000). In addition, such changes in body composition are related to chronically increased levels of inflammatory markers (such as C-reactive protein; CRP,

Abbreviations: 6MWT, six-minute walk test; COMT, combined training; HIBWT, high-intensity body weight training; IR, insulin resistance; MMI, muscle mass index; PW, postmenopausal women; TDM2, type 2 diabetes mellitus

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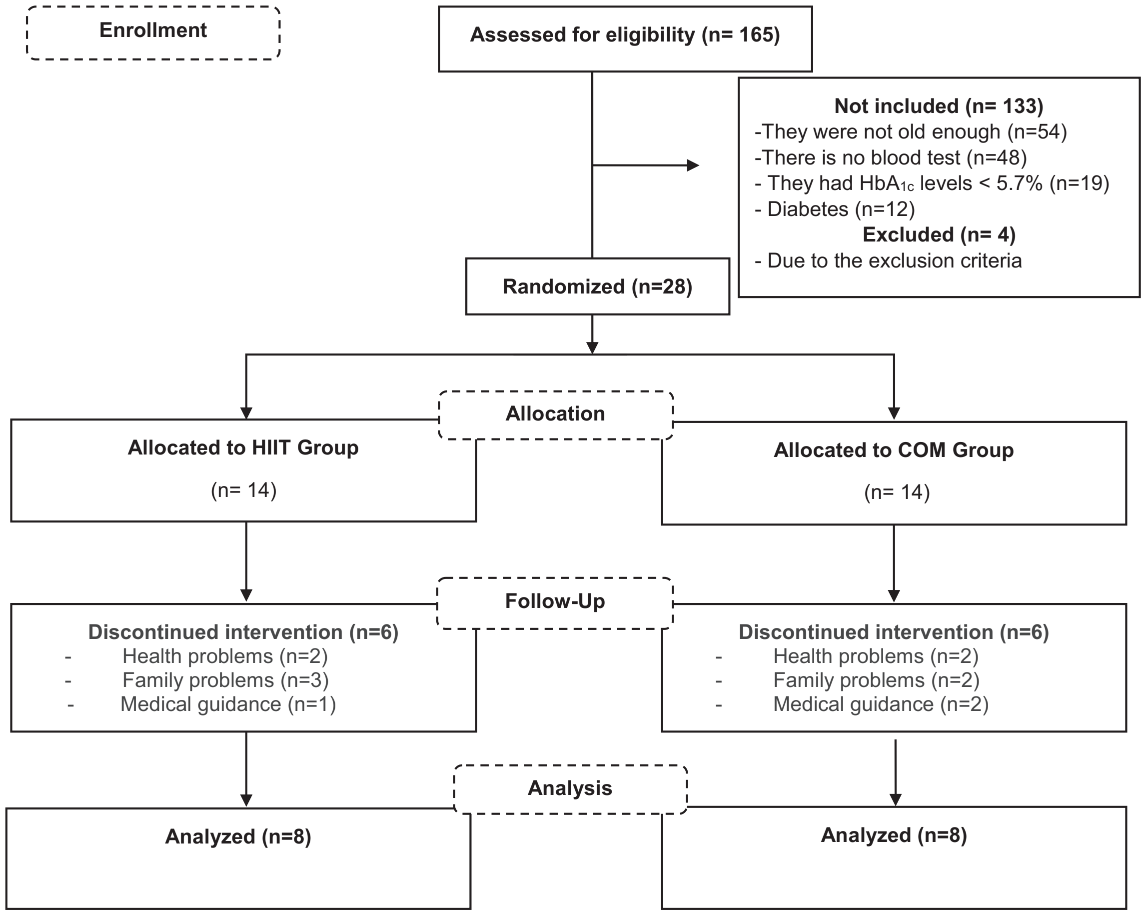

Fig. 1. Consort flow diagram showing numbers of patients at each stage of the trial.

monocyte chemoattractant protein-1; MCP-1, interleukin-6; IL-6 and interleukin-1 receptor antagonist; IL-1ra) (Visser et al., 2002; Piche et al., 2005; Franceschi & Campisi, 2014) termed low-grade inflammation (Franceschi & Campisi, 2014). These inflammatory markers are associated with insulin resistance (IR) and precede the onset of type 2 diabetes mellitus (TDM2) (Grossmann et al., 2015; Herder et al., 2006). Moreover, the reduction in physical performance and muscle mass elicits a synergic effect on obesity-related IR (Cleasby et al., 2016).

Conversely, previous evidence has shown that a reduced physical activity (Duval et al., 2013), rather than increased food intake (Duval et al., 2013), is the underlying mechanism of menopause-associated changes in body composition. Regular physical activity is an important non-pharmacological strategy for preventing body composition changes and TDM2 in older and middle-aged adults (Colberg et al., 2010; Garber et al., 2011). Public health guidelines recommend that healthy older adults participate in 150 min of moderate-intensity physical activity per week, combining resistance exercise with aerobic exercise (combined training; COMT) (Colberg et al., 2010; Garber et al., 2011). It has been shown that COMT improves body fat, muscle mass, IR and low-grade inflammation in older and middle-aged adults (Colberg et al., 2010; Garber et al., 2011). However, lack of time is commonly cited as a barrier for people to meet the guideline recommendations (Reichert et al., 2007; Korkiakangas et al., 2009a). In this context, high intensity interval training (HIIT), which involves repeated brief bouts of fast and intense exercise followed by periods of recovery, has been highlighted. It has been shown that HIIT provides greater reduction in body fat and IR than moderate-intensity continuous training (Maillard et al., 2016; Irving et al., 2008; Cassidy et al., 2017; Jelleyman et al., 2015). Thus, as HIIT requires less time spent on exercising, HIIT has been considered an alternative time-efficient treatment strategy to improve glycemic control in patients at high risk of TDM2. (Cassidy et al., 2017; Jelleyman et al., 2015; Batacan Jr. et al., 2016).

Although HIIT has been considered an alternative time-efficient treatment strategy, specific equipment (i.e. cycle ergometer and treadmill), commonly required by most HIIT protocols studied, are found only in physical activity facilities (i.e. gymnasiums) and they are expensive. A lack of local facilities to do physical exercises (Korkiakangas et al., 2009a) and money, especially in developing countries (Reichert et al., 2007), are important barriers for people to be able to comply with guideline recommendations. Hence, alternative HIIT protocols performed with body weight have recently been studied (Allison et al., 2017a; Gist et al., 2014a; Williams & Kraemer, 2015). For instance, Allison et al. (2017a) and Gist et al. (2014a) showed that high-intensity interval body weight training (HIBWT) promoted similar cardiorespiratory fitness adaptations to traditional HIIT on cycle ergometer in young. Thus, it would seem reasonable to assume that HIBWT is an efficient alternative strategy to traditional HIIT.

To the best of our knowledge, no previous studies have measured the HIBWT effectiveness in bringing about changes in body composition, inflammatory markers, IR and physical performance in older adults, especially in PW. The present study was designed to test whether HIBWT is a better exercise strategy when compared to COMT for PW at high risk of TDM2. To test this hypothesis, we compared the effects of an HIBWT with the effects of a COMT on body composition, physical performance and inflammatory and IR markers in PW at high risk of TDM2.

2. Methods

2.1. Study design

The number of participants required for the current randomized controlled study was calculated using G*Power software, version 3.0.1. Based on the IR marker outcomes from a study conducted by Jelleyman et al. (2015) (HIIT vs moderate-intensity continuous training), we used an alpha level of 0.05 (ANOVA: repeated measures, within-between interaction), a power of 80%, and a medium effect size of 0.30 (effect size index). A sample size of 8 subjects per group was estimated. At the beginning of the study, our sample size was increased to 14 women per group due to possible participants lost to follow-up. During the intervention, 6 women per group discontinued the study. Thus, the final sample consisted of 16 PW divided into two groups: HIBWT (n = 8) and COMT (n = 8) (Fig. 1). The randomization was performed using the MedCalc software. This study was conducted over 12 weeks. All outcomes were assessed at the baseline and at the end of the study. At the end of the study, the assessments were performed 48 h after the last session of training to avoid residual effects of the last session.

2.2. Subjects

The study was approved by the University Review Board for the Use of Human Subjects (local Ethics Committee) under number 451.081 and was written in accordance with the standards set out by the Declaration of Helsinki.

All selected volunteers met the inclusion criteria, which were: without diagnosed type 1 and 2 diabetes mellitus, however, with glycated hemoglobin (HbA1c) ≥ 5.7% (high risk for TDM2) (Association AD, 2010), not having had supervised or unsupervised exercise or other aerobic exercise for at least six months prior to the study, age 45 years or older, and spontaneous amenorrhea for at least 12 months. The exclusion criteria consisted of: alcoholics; no controlled blood pressure; presence of myopathies, arthropathies, and neuropathies; presence of muscle, thromboembolic and gastrointestinal disorders; presence of cardiovascular diseases, infection diseases and cancer. A CONSORT diagram is shown in Fig. 1.

2.3. Assessments

2.3.1. Anthropometric and body composition

The body mass index (BMI) was calculated by the body weight (kg) divided by the square of the height (m^2). Whole body and regional soft-tissue composition (percent of body fat and mineral-free lean mass) was measured using dual-energy X-ray absorptiometry (Lunar iDXA, GE Healthcare, USA) and quantified by Encore software, version 14.10. Throughout the day, before the DXA evaluation, the volunteers were instructed to ingest two liters of water to standardize the level of body hydration and were oriented to fast overnight 8–10 h before DXA evaluation. All DXA assessments were performed between 8 am and 10 am. The volunteers were instructed to urinate immediately before the DXA evaluation. Appendicular mineral-free lean mass divided by the square of the height (m^2) was used as the muscle mass index (MMI).

2.3.2. Nutritional

The food intake was quantified by a 24-hour dietary data recall. It was administered by a nutritionist, in non-consecutive days, corresponding to two weekdays and one day at the weekend. Food data analyses were performed using Dietpro software (version 5.7i) by a nutritionist. Energy, fiber and macronutrients (carbohydrates, proteins and fats) were quantified as the mean of the three days.

2.3.3. Sitting time

The self-reported International Physical Activity Questionnaire short form (IPAQ-SF) instrument was used to determine sitting time. The volunteers were instructed to think about the time they spent the total number of hours and minutes per day they spent sitting on two weekdays and one weekend day.

2.3.4. Maximum strength

The 1RM test was performed to assess the maximum muscle strength in all resistance exercises [45-degree half squat (smith machine), bench press, leg curl, rowing machine and unilateral leg extension]. However, the extension strengths of both legs were used as an indicator of muscle strength gain for both training protocols (COMT and HIBWT). The procedures were performed as described by Tomeleri et al. (2016).

2.3.5. Six-minute walk test

The six-minute walk test (6MWT) 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). A line, which indicated the beginning and end of each 114 m lap, was marked on the floor using brightly colored tape. All volunteers were advised to walk as fast as possible in the 6 min test. The distance was recorded after each volunteer completed the test.

2.3.6. Blood samples

Blood samples (16 ml; venous) were collected (dry tube with gel separator or EDTA) between 7:30 AM and 9:00 AM after an overnight fast (10 − 12h). The sample was centrifuged for 10 min (3.000 rpm) and samples were separated and stocked (-80 °C) for future analysis. The methods and the respective blood indicators were: electrochemoluminescence (E_2, LH, FSH, total testosterone, DHEA-S and T4), automated colorimetric (HbA1c%, glucose and CRP) [Cobas 6000 equipment; Kit - Roche®, USA)] and enzyme-linked immunosorbent assay (serum IL-6, IL-1ra and MCP-1) [Readwell Touch equipment - Robonik®, India; Kits - DRG®, DRG International, USA and R&D Systems®, Minneapolis, USA] methods. The homeostatic model assessment index (HOMA-IR) was also calculated (Care, 2007). The analysis was performed by an observer who was blinded to group allocation.

2.4. Training protocols

All training sessions followed the recommendation of the American College of Sports Medicine (Colberg et al., 2010; Garber et al., 2011) and were performed in the university gym facility three times per week (no consecutive days). Before and after each training session, a warm-up of 5 min of walking and a cool down of 3 min of walking was provided, respectively.

2.4.1. HIIT with body weight

The high-intensity interval body weight training (HIBWT) protocol consisted of ten sets of 60 s of high (vigorous) intensity exercises at > 85% of maximum heart rate (HRmax) or Borg scale (rated perceived exertion, varying from 0 to 10 and higher scores representing higher exertion (Utter et al., 2004)) at 7–8 interspersed with a recovery period of 60 s of low intensity exercise (light walk) (Table 1). The 60 s of high intensity comprised 30s of stepping up and down on a step and 30s of squatting up and down with the body weight as fast as possible. The height of the steps was about 16 cm and the body weight squat was performed up to 90-degree knee flexion. If the volunteer did not reach the high-intensity zone (> 85% of HRmax or Borg scale 7–8), she was stimulated by the fitness professionals to increase the number of steps and squats. Moreover, if necessary, the volunteers raised the arms above head with or without a halter (0.5 or 1 kg) while performing the exercise to reach the targeted zone of training (> 85% of HRmax or Borg scale 7–8).

The HIBWT progression was planned so that in week 1 the women performed four sets of 60 s of high-intensity exercise interspersed with a recovery period of 4 min of low-intensity exercise. There was a progressive increase in sets and a progressive reduction in recovery up to

Table 1
Characterization of the training protocols.

	Progression of one session			Mean of all sessions	
	First set	Tenth set	Mean of ten sets		
	HIBWT	HIBWT	HIBWT	HIBWT	COMT
HRmax (%)	86.2 ± 2.7	91.8 ± 1.8	89.0 ± 2.1	86.7 ± 1.7	71.8 ± 4.0
Numbers of stepping up and down on a step	20.0 ± 2.4	16.6 ± 2.6	18.4 ± 2.7	17.8 ± 2.4	–
Numbers of squatting up and down	21.0 ± 4.6	18.6 ± 4.4	19.7 ± 4.1	19.8 ± 3.3	–
Borg scale	6.1 ± 0.9	8.5 ± 1.1	7.1 ± 0.7	7.0 ± 0.5	5.5 ± 0.6

Note: Data are expressed as mean (SD). Borg scale = rated perceived exertion, varying from 0 to 10, in which the higher score is the higher exertion. HIBWT = high-intensity interval body weight training. COMT = combined training. HRmax = maximum heart rate.

week 4. Thus, in weeks 4 to 12, the women perfomed ten sets of 60 s high-intensity exercise and a recovery of 60 s of low-intensity exercise.

2.4.2. Combined training (COMT)

The COMT protocol (total length time ~60 min) consisted of a 30 min walk at 70% of HRmax or Borg scale at 5–6 on a flat floor in a sports court following five total body resistance exercises at 70% of 1RM with three sets of 8–12 repetitions and 1.5 min rest interval between sets and exercises (Table 1) (Colberg et al., 2010; Garber et al., 2011). The resistance exercises (Buick Fitness®, Brazil) were: 45-degree half squat (smith machine), bench press, leg curl, rowing machine and unilateral leg extension. During the walk, the moderate intensity was measured every 10 min to ensure the relative intensity (70% of HRmax or Borg scale at 5–6). If the volunteer did not reach the moderate intensity, she was stimulated by the fitness professionals to increase the walk speed, respectively. Regarding the resistance exercises, the loads were adjusted in the 6th week to ensure a load at 70% of 1RM between 8 and 12 repetitions during the 12th week of training.

The COMT progression was planned as described. Week 1: 15 min walk at 70% of HRmax or Borg scale at 5–6 and one set of 8–12 repetitions at 70% of 1RM (five exercises). Week 2: 20 min walk and two sets, with a 1.5 min rest period between sets. Week 3: 25 min walk and two sets. Week 4 to12: 30 min walk and three sets.

2.5. Statistical analysis

Data are presented as mean ± standard deviation (SD) or percentage. An independent *t*-test and chi-squared test were used to compare the groups at baseline. Repeated measure ANOVA was used to compare the groups (HIIT and COMT) by time (Pre and Post). The Mauchley sphericity test was used to evaluate the sphericity (equality of variances of the differences between time). ANCOVA was used to confirm the ANOVA results (interaction), adjusted for hormone therapy users and smokers. Effect size to dependent sample (Cohen's *d*) and delta% (post value − baseline value/baseline value × 100) were calculated for this study. The significant level was set at $p = 0.05$.

3. Results

3.1. Baseline characteristics of the participants

The age and hormone values were within the normal range for PW. All participants showed to be overweight (BMI > 24.9 kg/m^2), to have excess body fat percentage (> 40%) and normal physical performance (6MWT > 500 m). Most PW reported hypertension and inhibitors/angiotensin II-antagonist medicine intake. All women reported not having diabetes or intake of antidiabetic agents. One woman (HbA1c value = 7.38% or 57.2 mmol/mol) from the HIBWT group and one woman (HbA1c value = 7.16% or 54.7 mmol/mol) from the COMT group were classified by HbA1c as having diabetes (HbA1c ≥ 6.5% 47.5 mmol/mol) (Table 2).

Table 2
Physical characteristics and clinical conditions of PW at baseline.

General characteristics	HIBWT (*n* = 8)	COMT (*n* = 8)
Age (years)	64.3 ± 6.7	65.0 ± 6.3
Postmenopausal time (years)	17.7 ± 9.5	19.1 ± 9.3
Hormone therapy (%)	25.0 (*n* = 2)	0.0 (*n* = 0)
Smoking (%)	25.0 (*n* = 2)	12.5 (*n* = 1)
Sitting time (min/week)	3311.0 ± 886.4	3029.8 ± 996.3
Medical treatment		
Hypertension (%)	62.5 (*n* = 5)	50.0 (*n* = 4)
Statins (%)	12.5 (*n* = 1)	12.5 (*n* = 1)
Beta-blockers (%)	0.0 (*n* = 0)	12.5 (*n* = 1)
ACE (%)	62.5 (*n* = 5)	50.0 (*n* = 4)
NSAIDs (%)	12.5 (*n* = 1)	12.5 (*n* = 1)
Body composition		
Weight (kg)	68.9 ± 18.2	64.3 ± 15.0
Height (cm^2)	153.5 ± 5.1	154.5 ± 3.9
BMI (kg/m^2)	29.2 ± 7.1	27.0 ± 6.2
Body fat (%)	41.9 ± 7.4	40.6 ± 9.5
Metabolics		
HbA1c (%)	6.2 ± 0.5	6.1 ± 0.4
HbA1c (mmol/mol)	44.4 ± 6.0	43.7 ± 5.0
Estradiol (pg/mL)	12.2 ± 7.3	11.8 ± 7.7
Testoterone (ng/dL)	21.4 ± 27.0	4.8 ± 3.3
FSH (mUI/L)	65.6 ± 26.9	90.1 ± 38.2
Luteinizing hormone (mUI/L)	28.5 ± 15.6	35.6 ± 20.7
DHEA-S (μg/dL)	44.5 ± 19.6	36.3 ± 19.4
Free-tetraiodothyronine (ng/dL)	1.0 ± 0.0	1.1 ± 0.1
Dietary intake		
Energy intake/weight (g/kg)	20.0 ± 5.0	21.7 ± 7.0
Carbohydrate/weight (g/kg)	2.7 ± 0.8	3.0 ± 0.9
Protein/weight (g/kg)	0.6 ± 0.2	0.7 ± 0.2
Lipids/weight (g/kg)	0.6 ± 0.1	0.7 ± 0.3
Carbohydrate (%)	55.2 ± 6.0	56.0 ± 7.5
Lipids (%)	30.1 ± 5.6	31.9 ± 5.1
Fiber (g)	13.2 ± 5.9	12.7 ± 5.0

Note: Data are expressed as mean (SD) or percentages (%). HIBWT = high-intensity body weight training. COMT = combined training. ACE = inhibitors/angiotensin II-antagonists. NSAIDs = nonsteroidal anti-inflammatory drugs. BMI- body mass index. HbA1c = glycated hemoglobin. FSH = follicle-stimulating hormone. DHEA-S = dehydroepiandrosterone sulfate.

3.2. Differences between groups after 12 weeks of intervention

The changes in body composition, 6MWT, and muscle strength after 12 weeks of intervention (pre vs. post) were interpreted and statistically compared (Table 3). There was significant effect for time, but not a group by time interactions (time vs. group), in MMI and 6MWT, indicating that both training protocols increased MMI and 6MWT without any differences between them. There was no significant change in body fat percentage. A significant interaction of time by groups was observed in muscle strength, indicating improvement solely in the COMT group. These results were confirmed by ANCOVA, adjusted for hormone therapy users and smokers.

The changes in IR and inflammation markers after 12 weeks of intervention (pre vs. post) were interpreted and statistically compared

Table 3
Body composition and muscular performances of PW at baseline and after 12 weeks of intervention.

	HIBWT (n = 8)		COMT (n = 8)						P group[a]	P time[a]	P interaction[a]	P adjusted[b]
	Pre	Post					Delta %	ES				
Body fat (%)	41.9 ± 7.4	41.2 ± 6.7	−1.7	0.11	40.6 ± 9.5	40.5 ± 8.7	−0.2	0.00	0.803	0.151	0.234	0.103
MMI (kg/m^2)	6.6 ± 0.7	6.8 ± 0.9	3.0	0.27	6.6 ± 1.1	6.8 ± 1.3	3.0	0.18	0.910	0.007	0.990	0.808
Legs extension (kg)	56.2 ± 17.7	56.8 ± 21.9	1.1	0.03	47.8 ± 8.5	64.0 ± 12.6	33.9	1.49	0.936	0.002	0.003	0.008
6MWT (m)	577.4 ± 82.8	599.7 ± 91.7	3.9	0.27	614.4 ± 88.5	669.1 ± 104.8	8.9	0.62	0.239	0.031	0.331	0.386

Note: Data are expressed as mean (SD). HIBWT = high-intensity interval body weight training. COMT = combined training. MMI = muscle mass index. 6MWT = six-minute walk test. ES = effect size. Interaction = interaction of time by group.
[a] Repeated measure ANOVA.
[b] ANCOVA adjusted for smoking and hormone therapy.

(Table 4). There were significant ($P < 0.05$) effects for time, but not a group by time interactions, in HbA1c, insulin, HOMA-IR, glucose and IL-1ra, indicating that both training protocols improved these markers without any differences between them. There was a trend ($P = 0.056$) toward a reduction in MCP-1, but there were also no significant interactions for these variables. A trend toward interaction was observed solely in IL-6. There was no significant change in CRP. These results were confirmed by ANCOVA, adjusted for hormone therapy users and smokers.

After 12 weeks of intervention, training frequencies were: HIBWT = 93.7% ± 9.4% and COMT = 92.3% ± 7.9%. One woman was reclassified from diabetic to pre-diabetic and two women were reclassified from pre-diabetic to non-diabetic patients in the HIBWT group. In the COMT group, one woman was reclassified from diabetic to pre-diabetic and two women were reclassified from pre-diabetic to non-diabetic patients.

4. Discussion

Public health guidelines recommend that healthy older adults do 150 min of moderate-intensity physical activity per week (Colberg et al., 2010; Garber et al., 2011). However, it has been reported that a very low proportion (< 10%) of adults and older adults meet the 150 min of physical activity (Tucker et al., 2011; Troiano et al., 2008) required. Common reasons for people not to do exercise are a lack of time (Godin et al., 1994; Trost et al., 2002), mainly among adults at high risk or diagnosed with TDM2 (Korkiakangas et al., 2009b). As HIIT only requires 20 min per session and are only performed 3 times per week, and improves glycemic control in patients at high risk of TDM2 (Gibala et al., 2014; Gillen et al., 2012), HIIT has been considered an alternative time-efficient treatment strategy (Cassidy et al., 2017; Jelleyman et al., 2015). However, a need for expensive specific equipment (i.e. a treadmill or bike), high motor skill level (i.e. running at high speed) required for the majority of HIIT protocols are common barriers concerning regular physical activity especially in developing countries (Reichert et al., 2007; Trost et al., 2002; Korkiakangas et al., 2009b; Berg et al., 1997). HIBWT has been a viable alternative to traditional HIIT because it does not incur high costs (i.e. expensive specific equipment), it does not require a specific place to be performed (Gist et al., 2014b; Sperlich et al., 2017; Allison et al., 2017b) and may be configured for a lower motor skill level (i.e. callisthenic exercise), allowing people with lower motor skill levels to perform HIIT. Although other studies have shown that HIBWT improves fat mass, cardiorespiratory capacity and IR in young adults overweight or not (Gist et al., 2014b; Sperlich et al., 2017; Allison et al., 2017b), our study is the first to measure the HIBWT effectiveness in bringing about changes in body composition, inflammatory markers, IR and physical performance in older women. The results of the current study showed that changes in HOMA, IL-1ra, 6MWT and MMI with HITBW are similar when compared to COMT in PW at high risk of TDM2. Thus, HIBWT is comparable to COMT in changes in muscle mass, physical performance, inflammatory markers and metabolic health in PW.

Our results revealed that the HIBWT increased MMI similarly to the COMT (Table 3). Although it is widely accepted that high-load (i.e., ≥70% of one repetition maximum) resistance training is necessary to induce significant increases in muscle size (such as resistance training) (Garber et al., 2011; American College of Sports M et al., 2009), recent studies have supported that exercises performed with low-load (< 50%

Table 4
Insulin resistance and inflammatory makers of PW at baseline and after 12 weeks of intervention.

	HIBWT (n = 8)				COMT (n = 8)				P group[a]	P time[a]	P interaction[a]	P adjusted[b]
	Pre	Post	Delta %	ES	Pre	Post	Delta %	ES				
Biochemical												
Glucose (mg/dL)	109.7 ± 23.1	101.5 ± 14.1	−7.5	0.43	95.1 ± 14.9	92.6 ± 17.1	−2.6	0.16	0.187	0.045	0.263	0.210
HbA_{1c} (%)	6.2 ± 0.5	5.9 ± 0.3	−4.8	0.49	6.1 ± 0.4	5.9 ± 0.2	−3.3	0.67	0.694	0.021	0.946	0.939
HbA1c (mmol/mol)	44.4 ± 6.0	41.9 ± 4.1	−5.6	0.49	43.7 ± 5.0	41.0 ± 2.4	−6.1	0.67	0.694	0.021	0.946	0.939
Insulin (mU/mL)	13.6 ± 6.1	11.1 ± 4.2	−18.3	0.47	9.9 ± 5.8	8.6 ± 4.7	−13.1	0.26	0.244	0.022	0.432	0.239
HOMA-IR	3.8 ± 2.2	2.8 ± 1.1	−26.3	0.58	2.4 ± 1.7	2.1 ± 1.5	−12.5	0.21	0.214	0.025	0.233	0.112
Inflammatory												
CRP (mg/mL)	0.5 ± 0.5	0.7 ± 0.6	40.0	0.10	0.1 ± 0.1	0.1 ± 0.1	0.0	0.00	0.064	0.244	0.244	0.179
MCP-1 (pg/mL)	425.0 ± 68.0	375.0 ± 121.5	−11.8	0.51	445.9 ± 149.1	342.1 ± 121.3	−23.3	0.76	0.899	0.056	0.478	0.191
IL-6 (pg/mL)	1.4 ± 1.1	2.6 ± 2.2	85.7	0.70	1.3 ± 1.8	1.2 ± 1.1	−7.7	0.03	0.339	0.125	0.097	0.080
IL1ra (pg/mL)	482.5 ± 258.3	741.0 ± 428.6	53.5	0.73	303.6 ± 121.1	588.9 ± 265.0	94.0	1.38	0.251	< 0.001	0.758	0.422

Note: Data are expressed as mean (SD). HIBWT = high-intensity interval body weight training. COMT = combined training. HbA1c = glycated hemoglobin. HOMA-IR = homeostatic model assessment index. CRP = C-reactive protein. MCP1 = monocyte chemoattractant protein-1. IL-6 = interleukin-6. IL-1ra = interleukin-1 receptor antagonist. ES = effect size. Interaction = interaction of time by group.
[a] Repeated measure ANOVA.
[b] ANCOVA adjusted for smoking and hormone therapy.

of strength maximum or body weight) induce significant increases in muscle size and hypertrophic signaling (Gillen et al., 2013; Agergaard et al., 2017). Agergaard et al. (2017) have shown that 10 sets of 36 repetitions (i.e. resistance exercise) at 16% of one repetition maximum is sufficient to increase muscle protein synthesis and hypertrophic signaling in elderly individuals. Lifting a load of 16% of one repetition maximum may require a much smaller effort than lifting body weight. In the current study, the volunteer performed 10 blocks of HIBWT (i.e. 30s of stepping up and down on a step and 30s of squatting up and down) as fast as possible. On average, the volunteer performed 17.8 stepping up and down exercises on a step and 19.8 squatting up and down exercises with body weight, performing ~38 repetitions (movement) in each block. Our results corroborate with two studies which have shown that HIIT can improve muscle mass in young overweight/obese women (Sperlich et al., 2017; Gillen et al., 2013). Sperlich et al. (2017) showed that circuit-like functional high-intensity training (exercises performed with body weight) increase fat-free mass of overweight women. Moreover, Bell et al. (2015) showed that HIIT (10×1 min intervals on a bicycle ergometer cycling at ~95% HRmax) significantly increases the myofibrillar and sarcoplasmic fractional synthetic rate in sedentary older men. Therefore, the HIBWT proposed here seems to be sufficient to induce changes in MMI similarly to COMT in PW at high risk of TDM2.

Physical performance is measured via a number of performance-based assessments, such as 6MWT (McGinn et al., 2008; Mutikainen et al., 2011). Low 6MWT performance is strongly associated with falls, hospitalizations, cardio and cerebrovascular diseases and mortality in older adults (McGinn et al., 2008; Mutikainen et al., 2011). It has been shown that resistance training and COMT increase physical performance (Garber et al., 2011). Our results revealed that the HIBWT increased 6MWT similarly to the COMT in PW at high risk of TDM2 (Table 3), although the HIBWT showed a small effect (ES = 0.27) whereas the COMT showed a medium effect (ES = 0.62). Maximum muscle strength and power have been established as early determinants of physical performance in older adults (Reid & Fielding, 2012). In the current study, the COMT group increased muscle strength when compared to HITWB, suggesting that other muscle adaptation (e.g. muscle power) contributed to changes in physical performance with HIBWT. In the current study, HIBWT was performed by repeated brief bouts of a fast exercise (stepping up and down on a step and squatting up and down) as fast as possible. Indeed, evidence suggests that exercise involving fast-type muscle contractions is an efficient training modality for inducing gains in muscle power, regardless of the training load used (Tiggemann et al., 2016). However, we may only speculate this, and future research is necessary to clarify this issue.

Reduction in glycemia markers prevents deaths related to diabetes and myocardial infarction in patients with TDM2 (Stratton et al., 2000). It has been shown that COMT improves glycemia markers in older and middle-aged adults (Colberg et al., 2010; Garber et al., 2011). Our results showed that HIBWT reduced HbA1c similarly to COMT in PW at high risk of TDM2 (Table 4). The HIBWT showed reductions in HbA1c of 0.30%. This is in agreement with a meta-analysis that has found a similar reduction of 0.25% in HbA1c after traditional HIIT in people with metabolic syndrome/TDM2 (Jelleyman et al., 2015). Our results also showed that HIBWT reduces fasting glucose similarly to the COMT (Table 4). The HIBWT and COMT showed a reduction in fast glucose of ~7.5% and 2.6%, respectively. Our results are in line with previous studies that have showed small (of ≤14%) or no reduction in fasting glucose after different types of exercises (Cassidy et al., 2017; Jelleyman et al., 2015; Batacan Jr. et al., 2016). As fasting glucose is associated with hepatic insulin sensitivity, small reductions following exercise have been attributed to small energy deficits elicited by exercise and, consequently, small reductions in liver fat content (Cassidy et al., 2017; Lim et al., 2011). For instance, whereas one week of a diet low in energy (600 kcal) reduces 30% of liver fat content and 35% of fasting glucose (Lim et al., 2011), eight months of aerobic training or COMT reduces 6% or 4%, respectively (Slentz et al., 2011) and reduces fasting glucose in ≤14% (Cassidy et al., 2017; Jelleyman et al., 2015; Batacan Jr. et al., 2016). Thus, the HIBWT seems to be sufficient to induce changes in glycemia markers similarly to COMT in PW at high risk of TDM2.

Our results revealed that HIBWT increased insulin and HOMA-IR similarly to the COMT in PW at high risk of TDM2 (Table 4). However, although there was no statistical interaction, the HIBWT showed a medium effect (ES = 0.58) whereas the COMT showed a small effect (ES = 0.21) on HOMA-IR. In a meta-analysis, Jelleyman et al. (2015) also observed a reduction in HOMA-IR after traditional HIIT. However, Jelleyman et al. observed a reduction in HOMA-IR of 0.55, whereas in our study there was a reduction of 1.0 (26.3%). This discrepancy finding is not clear, but may be related to high initial HOMA-IR levels in the HIBWT group (HOMA-IR baseline = 3.8). Using a regression equation, Jelleyman et al. showed that to achieve a reduction in HOMA-IR of 0.5 or greater after HIIT, the baseline HOMA-IR value needs to be at least 3.18 (Jelleyman et al., 2015). This could explain the small effect of HOMA-IR in the COMT group (HOMA-IR baseline = 2.4) when compared to the HIIT group. Overall, these findings suggest that HIBWT may improve insulin sensitivity in those who are IR. Therefore, HIBWT seems to be an alternative time-efficient treatment strategy to improve IR makers in PW at high risk of TDM2.

The progression from pre-diabetes to TDM2 occurs when the pancreatic β-cells fail to compensate for IR (Donath & Shoelson, 2011). Adipose and pancreatic islet infiltration by immune cells has been related to insulin deficiency and a development of T2DM (Donath & Shoelson, 2011). MCP-1 has been reported as a possible way to this pathological condition, recruiting monocyte to target tissue (Donath & Shoelson, 2011). Indeed, it has been reported that high circulating MCP-1 level is an independent risk factor for the development of TDM2 (Herder et al., 2006). MCP-1 can be induced by IL-1β (pro-inflammatory cytokine). Evidence shows that IL-1β induces the production of MCP-1 in islets and, therefore IL-1β is involved in pancreatic beta-cell inflammation and damage (Donath & Shoelson, 2011). IL-1ra is a well-known anti-inflammatory cytokine that limits IL-1β signaling (Donath & Shoelson, 2011; Karstoft & Pedersen, 2015; Larsen et al., 2007). Moreover, inhibition of IL-1β by anakinra (a recombinant human IL-1ra) improves beta-cell dysfunction and glucose homeostasis in individuals with TDM2 (Larsen et al., 2007). Our results revealed that the HIBWT increased IL-1ra similarly to the COMT in PW at high risk of TDM2 (Table 4). Moreover, the HIBWT and COMT demonstrated a trend ($P = 0.056$) to reduce MCP-1, without any differences between them (Table 4). Although studies on the chronic effect of exercise on circulating IL-1ra and MCP-1 are very scarce, it has been reported that aerobic and high-intensity resistance training increase IL-1ra (Karstoft & Pedersen, 2015; Forti et al., 2016) and aerobic training reduced MCP-1 (Franca-Pinto et al., 2015). To the best of our knowledge, the current study is the first to show that 12 weeks of HIBWT exert effects similarly to COMT on IL-1ra and MCP-1 in PW.

Our results revealed that there was no change in IL-6 after interventions (Table 4). Our study corroborates with the Batacan et al.'s study (Batacan Jr. et al., 2016). Batacan et al. observed that traditional HIIT does not change CRP and IL-6 in overweight/obese populations (Batacan Jr. et al., 2016). Contrary to our results, some investigations have noted a reduction in CRP and IL-6 after exercise training (Tomeleri et al., 2016; Mavros et al., 2014) in older women. The mechanisms by which exercise training reduces IL-6 and CRP have yet to be fully elucidated. However, some studies have shown that a reduction in CRP and IL-6 in older adults with type 2 diabetes and obesity are related to improvements in fat body following training (Tomeleri et al., 2016; Mavros et al., 2014). Body fat is the site for macrophage-derived IL-6 production and may disproportionately contribute to the circulating levels of inflammatory markers (Donath & Shoelson, 2011). In the current study, body fat did not significantly change after both training sessions, which may explain the discrepancy between our work and other studies.

5. Conclusion

The results of the present study suggest that HIBWT is comparable to COMT in changes in muscle mass, physical performance, inflammatory markers and metabolic health in PW. These results provide further evidence that HIBWT can be an alternative time-efficient treatment strategy (accessible and safe) to COMT in PW at high risk of TDM2.

Disclosure

Nothing to disclose.

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