High-Intensity Interval Training as a Tool for Counteracting Dyslipidemia in Women

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Key words
high-intensity interval exercise, lipoproteins, cardiometabolic alterations, co-morbidities, type 2 diabetes mellitus

ABSTRACT
Sedentary overweight or obese adult (age < 60 years) women, allocated in type 2 diabetes mellitus (T2DM, n = 13), dyslipidemia alone (DYS, n = 12), dyslipidemia associated with hyperglycaemia (DYSHG, N = 12), or healthy control (CON, n = 10) groups, had their lipid, glucose, blood pressure, endurance performance, and anthropometry variables assessed before and after 16 weeks of a thrice-weekly high-intensity interval training (HIIT) program. Triglycerides reduced significantly (P < 0.05) in all groups, and high-density lipoprotein increased (P < 0.01) in T2DM, DYS and DYSHG; however, low-density lipoprotein reduced (P < 0.05) only in DYSHG, and total cholesterol reduced (P < 0.01) only in DYS and DYSHG. Fasting glucose reduced (P < 0.05) significantly in T2DM, DYS and DYSHG. Blood pressure, endurance performance and body composition improved (P < 0.05) in all groups. The HIIT program was effective for restoring lipid profile of DYS and DYSHG, and fasting glucose of DYSHG to levels similar to those of CON, with a weekly time commitment 25% to 56% lower than the minimum recommended in current exercise guidelines. These findings suggest that HIIT may be a time-efficient intervention for counteracting dyslipidemia.

Introduction
Type 2 diabetes mellitus (T2DM) is a highly prevalent disease and is associated with high rates of morbidity, mortality and health care expenditure [34, 40]. T2DM patients generally have several co-morbidities such as dyslipidemia (i.e., high levels of total cholesterol (TC), low-density lipoprotein (LDL-C) and triglycerides (TG), and/or low levels of high-density lipoprotein (HDL-C), hypertension, and obesity [2, 3]. Although hyperglycaemia can be controlled by traditional pharmacotherapy and/or lifestyle modifications [4, 18], dyslipidemia requires an additional dose of antilipolytic drugs in sedentary T2DM patients, which increases health care expenditure [11].

Exercise training is strongly recommended for preventing and treating T2DM and its complications [10], as well as for improving cardiovascular risk in the general population [17]. Although exercise training is also recommended (in association with pharmacotherapy) for treating dyslipidemia [35], its effects on blood lipoproteins are generally conflicting [30]. Differences in exercise type, volume and intensity, as well as in baseline blood lipid levels are some explanations for these conflicting results [30]. For example,
it has been suggested that improvements in blood lipids generally occur with higher exercise training volume (i.e., ≥ 120 min per week) [21] and intensity (60–85% of VO₂max or reserve heart rate) [36], and are more frequent [36] or of greater magnitude [21] in subjects with higher blood lipid levels at baseline. In agreement, reduced risk of incidental hypertension and cardiovascular disease in dyslipidemic subjects is associated only with physical activity levels greater than the minimum recommended in current guidelines (i.e., > 150 min per week of moderate exercise) [39].

Given that lack of time is the most frequently cited barrier to regular exercise participation [37], it is quite difficult to meet the minimum exercise recommendation for the general population [17], particularly for T2DM patients [10] who are generally sedentary or insufficiently active [28]. However, high-intensity interval training (HIIT) may be a time-efficient strategy, because it improves glycemic control [1] and other health-related markers [1, 6, 7], with a weekly time commitment (including warm-up, cool-down and rest periods) markedly lower than current guideline recommendations [10, 17].

Although previous studies suggest that HIIT may improve blood lipid levels [12, 27, 29, 31], its effects in T2DM or dyslipidemic patients are unknown. In addition, it is also unknown if exposure to hyperglycaemia (i.e., recent diagnoses of hyperglycaemia) may reduce the effects of HIIT on the lipid profile of dyslipidemic subjects. Thus, the purpose of the present study was to assess and compare the effects of HIIT on the lipid profile in women with T2DM, dyslipidemia alone (DYS) or dyslipidemia associated with hyperglycaemia (DYSHG). We hypothesized that HIIT would be effective for improving the lipid profile, and that baseline lipid levels would affect the magnitude of the HIIT-induced improvement.

Methods

Population and study design

Overweight or obese (body mass index between 25 and 35 kg/m²) adult women were allocated to T2DM, DYS, DYSHG and healthy control (CON) groups, according to their glycaemic and lipid profile at baseline. Eligibility criteria common to all participants included sedentary or insufficiently active lifestyle (according to the International Physical Activity Questionnaire previously validated in the Chilean population) [32], non-involvement in regular physical activity or exercise program during the previous 6 months, no use of any antilipolytic medication, and age between 18 and 59 years. T2DM women should have an established diagnosis of T2DM for at least 12 months (fasting hyperglycaemia > 126 mg·dL⁻¹ and glycated hemoglobin (HbA₁c) ≥ 6.5%) [10], unchanged drug therapy during the previous 6 months, a family history of T2DM (mother and/or father), and no history of long-term diabetic complications (foot injury, retinopathy, nephropathy, or diabetic peripheral neuropathy). DYS women should have at least one of the following lipid abnormality (TC > 200 mg·dL⁻¹, LDL-C > 144 mg·dL⁻¹, or HDL-C < 30 mg·dL⁻¹) [35]. Similarly, DYSHG should have at least one of the following lipid abnormalities (TC > 200 mg·dL⁻¹, LDL-C > 144 mg·dL⁻¹, or HDL-C < 30 mg·dL⁻¹) [35], hyperglycaemia (fasting glycaemia between 100 and 126 mg·dL⁻¹), and be under no hypoglycemic drug therapy. CON women should have none of the above-cited lipid and glycemic abnormalities at baseline. Women with musculoskeletal disorders, cardiovascular contraindications to exercise, a history of stroke, asthma and chronic obstructive pulmonary disease, or smokers were not included in the study. A minimum of 70% of exercise program compliance was required in order to be included in the final statistical analyses.

One-hundred and ninety-four T2DM, DYS, DYSHG, or CON women, patients of the Family Healthcare Centre Tomas Rojas from Los Lagos (Chile) answered a telephone call explaining the study protocol and agreed to participate in the present investigation. The participants underwent a structured history, medical record review, and physical examination by a physician to assess eligibility criteria. Ninety-six participants (T2DM, n = 20; DYS, n = 19; DYSHG, n = 25; CON, n = 32) who met all of the inclusion criteria were included in the present study (Fig. 1). Participants then underwent a thrice-weekly HIIT program (jogging/running intervals interspersed with recovery periods of low-intensity walking) for 16 weeks [1]. Lipid (fasting TC, LDL-C, HDL-C and TG) and fasting glucose profile, resting blood pressure, endurance performance, and physical examination by a physician to assess eligibility criteria. Ninety-six participants (T2DM, n = 20; DYS, n = 19; DYSHG, n = 25; CON, n = 32) who met all of the inclusion criteria were included in the present study (Fig. 1). Participants then underwent a thrice-weekly HIIT program (jogging/running intervals interspersed with recovery periods of low-intensity walking) for 16 weeks [1]. Lipid (fasting TC, LDL-C, HDL-C and TG) and fasting glucose profile, resting blood pressure, endurance performance, and physical examination by a physician to assess eligibility criteria. Ninety-six participants (T2DM, n = 20; DYS, n = 19; DYSHG, n = 25; CON, n = 32) who met all of the inclusion criteria were included in the present study (Fig. 1). Participants then underwent a thrice-weekly HIIT program (jogging/running intervals interspersed with recovery periods of low-intensity walking) for 16 weeks [1].

Blood analyses

Blood samples (nearly 3.5 ml) were collected before and after 16 weeks of HIIT (at least 48 h after the last exercise session to avoid an acute effect of exercise), in the morning and after a 10 h overnight fast, as previously described [1]. In brief, samples were immediately placed in ice and centrifuged at 1,789 x g for 5 min at −4°C, and plasma samples were then immediately transferred to pre-chilled microtubes and stored at −20°C for later analysis of HbA₁c (high-performance liquid chromatography [Variant™ II Turbo Hemoglobin Testing System, Bio-Rad Inc., Hercules, CA, USA]), glucose, TC and TG (enzymatic methods using standard kits [Wiener Lab Inc., Rosario, Argentina] on an automatic analyzer [Metrolab 2300 Plus™, Metrolab Biomed Inc., Buenos Aires, Argentina]), HDL-C (enzymatic method after phosphotungstate precipitation), and LDL-C (calculated using the Friedewald formula) [14].

Blood pressure and anthropometric measurements

Blood pressure measurements were performed one week before and after 16 weeks of HIIT, on three non-consecutive days, in triplicate (2-min interval between each measurement), at the same time of day (between 8 and 11 a.m.), with an automatic monitor (Omron HEM 7114™, Omron Healthcare Inc., Lake Forest, IL, USA), as previously described [1]. The mean of the 9 blood pressure measurements, performed both before and after the follow-up, were registered and used for inter- and intra-group analyses [5].

Body mass (Omron HBF-INT™, Omron Healthcare Inc., Lake Forest, IL, USA), height (Health-o-meter™ Professional, Sunbeam Prod-
Enrollment → Assessed for eligibility (n = 194)

Not included (n = 98)
- Not included T2DM:
  ♦ Without T2DM family history (n = 17)
  ♦ Address in rural areas (n = 5)
  ♦ Foot injury or history of foot injury (n = 19)
  ♦ Altered electrocardiography (n = 4)
  ♦ Musculoskeletal disorders (n = 13)
  ♦ Nephropathy (n = 6)
  ♦ Age ≥ 60 years (n = 10)
- Not included DYS:
  ♦ Address in rural areas (n = 3)
  ♦ Asthma (n = 1)
- Not included DYSHG:
  ♦ History of stroke (n = 2)
  ♦ Asthma (n = 3)
  ♦ Altered electrocardiography (n = 2)
- Not included CON:
  ♦ Asthma (n = 5)
  ♦ Altered electrocardiography (n = 2)
  ♦ Regular physical activity (n = 3)
  ♦ Age ≥ 60 years (n = 3)

Assigned to (n = 96)

Not included T2DM:
- Without T2DM family history (n = 17)
- Address in rural areas (n = 5)
- Foot injury or history of foot injury (n = 19)
- Altered electrocardiography (n = 4)
- Musculoskeletal disorders (n = 13)
- Nephropathy (n = 6)
- Age ≥ 60 years (n = 10)

T2DM (n = 20)

DYS (n = 19)

DYSHG (n = 25)

CON (n = 32)

Allocation → Follow-Up

Lost to follow-up (n = 7)
- Seasonal flu (n = 2)
- Change of physical activity program (n = 2)
- Exercise compliance < 70% (n = 3)

Lost to follow-up (n = 5)
- Seasonal flu (n = 2)
- Change of address (n = 2)
- Change of physical activity program (n = 1)
- Exercise compliance < 70% (n = 2)

Lost to follow-up (n = 13)
- Seasonal flu (n = 2)
- Seasonal asthma (n = 2)
- Back pain due to home accident (n = 1)
- Exercise compliance < 70% (n = 8)

Lost to follow-up (n = 20)
- Seasonal flu (n = 4)
- Did not perform all assessments (n = 5)
- Voluntary withdraw (n = 1)
- Exercise compliance < 70% (n = 10)

Analysis

Analyzed (n = 13)

Analyzed (n = 12)

Analyzed (n = 12)

Analyzed (n = 12)

▶ Fig. 1 Study design.
Endurance performance assessment

Endurance performance was assessed one week before and after 16 weeks of HIIT by the 2 km walking test (2KWT) [22]. In brief, the test was performed in an indoor sports court (100 m track), after a 10 min warm-up (low-intensity walking and slow movements involving the knee and ankle joints). Participants were then instructed to walk as fast as possible at a steady pace. Heart rate was continuously monitored (ProTrainer™, Polar Electro Inc., Kempele, Finland). In order to ensure an accurate test [22], participants were encouraged to walk faster if their heart rate was lower than 75 % of the age-predicted maximum heart rate. The time spent in walking the 2 km was measured and used for analysis. All tests were carried out between 8:00 and 10:00 a.m.

Exercise training intervention

Participants performed a thrice-weekly HIIT program for 16 weeks. All exercise sessions were performed on a flat surface (indoor sports court), and supervised by an exercise specialist. The HIIT program consisted of high-intensity exercise intervals (jogging/running) interspersed with low-intensity active recovery (walking). Participants had their heart rate continuously monitored (ProTrainer™, Polar Electro Inc., Kempele, Finland) and were oriented to maintain their jogging/running and walking pace at 90–100 % and below 70 % of their reserve heart rate [20], respectively. The HIIT program started (week 1 to 2) with 8 jogging/running intervals of ~30 s interspersed with ~120 s of low-intensity walking. To promote a sufficient workload to elicit improvements throughout the follow-up, there was a 7 to 10 % increase in the high-intensity interval time and a 4 % decrease in the recovery interval time every 2 weeks [1]. There was also an increase of 2 exercise intervals every 4 weeks of follow-up. With the exercise intensity/volume progression, total working time ranged from 4 to 7 min (week 1 to 16), total recovery time ranged from 12 to 16 min (week 1 to 16) and the number of intervals ranged from 8 to 14 (week 1 to 16). Thus, the exercise session duration ranged from 22 min to 36.5 min (week 1 to 16), totaling 66 min/wk (week 1) to 109 min/wk (week 16) of exercise. A detailed description of the HIIT volume and intensity progression during follow-up is shown in Table 1.

Statistical analyses

Data are presented as mean ± standard deviation (SD) or median and inter-quartile interval. Statistical analyses were performed using SPSS™ statistical software version 18.0 (SPSS Inc., Chicago, IL, USA). Normality and homoscedasticity of variables were determined using the Shapiro-Wilk and Levene’s test, respectively. Two-way ANOVA with repeated measures (group vs. time) was used to indicate inter- and intra-intervention differences in the data presenting a Gaussian distribution. Bonferroni’s post hoc test was performed to identify significance as indicated by ANOVA. The Kruskal-Wallis test was used to indicate inter- and intra-intervention differences in nonparametric variables (body mass, waist circumference), and Dunn’s post hoc test was used to identify significant data indicated by Kruskal-Wallis. Delta changes (Δpre-post) in each biological unit, as well as in percentage, were calculated for plasma lipoprotein and glucose.

Results

Twenty-four participants (T2DM, n = 4; DYS, n = 5; DYSHG, n = 5; CON, n = 10) were lost to follow-up due to reasons not related to the study (Fig. 1). Twenty-three participants (T2DM, n = 3; DYS, n = 2; DYSHG, n = 8; CON, n = 10) were excluded from final analysis because they did not have the minimal exercise training compliance of 70 % (Fig. 1). Thus, forty-nine overweight or obese women completed 16 weeks of HIIT and were included in the final analysis. Participants’ age, height and blood pressure were not significantly different between groups at baseline (Table 2). Anthropometric variables were not significantly different between T2DM, DYS and DYSHG at baseline; however, body mass was slightly higher in T2DM and DYSHG than CON (p < 0.05), and BMI was higher in T2DM than CON (p < 0.05). Only T2DM women were taking medi-
> Table 2  Subjects’ characteristics before and after the experimental protocols.

<table>
<thead>
<tr>
<th></th>
<th>T2DM (n = 13)</th>
<th>DYS (n = 12)</th>
<th>DYSHG (n = 12)</th>
<th>CON (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre Post</td>
<td>Pre Post</td>
<td>Pre Post</td>
<td>Pre Post</td>
</tr>
<tr>
<td>Age (y)</td>
<td>45.6 ± 11</td>
<td>42.2 ± 9</td>
<td>42.3 ± 10</td>
<td>41.4 ± 9</td>
</tr>
<tr>
<td>Time elapsed from diagnosis (months)</td>
<td>42.5</td>
<td>2.6</td>
<td>1.6</td>
<td></td>
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<tr>
<td>Height (cm)</td>
<td>1.56 ± 0.06</td>
<td>1.56 ± 0.06</td>
<td>1.59 ± 0.06</td>
<td>1.57 ± 0.06</td>
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<tr>
<td><strong>Body composition</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Body mass (kg)</td>
<td>73.8 ± 7†</td>
<td>72.2 ± 7†</td>
<td>69.5 ± 6</td>
<td>69.6 ± 12</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>30.6 ± 4†</td>
<td>29.9 ± 4†</td>
<td>28.5 ± 2</td>
<td>29.0 ± 3</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>101.1 ± 9</td>
<td>97.0 ± 8 **</td>
<td>99 ± 4</td>
<td>99.1 ± 7</td>
</tr>
<tr>
<td>∑ 4 Skinfold (mm)</td>
<td>147 ± 21</td>
<td>119 ± 14 **</td>
<td>127 ± 9</td>
<td>128 ± 38</td>
</tr>
<tr>
<td>Endurance performance (min) *</td>
<td>23.2 ± 1.8</td>
<td>21.0 ± 1.2 **</td>
<td>22.5 ± 1.4</td>
<td>23.0 ± 1.1</td>
</tr>
<tr>
<td><strong>Blood pressure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP (mm/Hg)</td>
<td>132 ± 4</td>
<td>128 ± 3 *</td>
<td>129 ± 4</td>
<td>127 ± 7</td>
</tr>
<tr>
<td>Diastolic BP (mm/Hg)</td>
<td>77 ± 4</td>
<td>77 ± 3</td>
<td>75 ± 6</td>
<td>76 ± 5</td>
</tr>
<tr>
<td><strong>Medication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metformin (N) (mg/day)</td>
<td>13 (1700 ± 0)</td>
<td>7 (850)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glibenclamide (N) (mg/day)</td>
<td>8 (5 ± 0)</td>
<td>4 (5 ± 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enalapril (N) (mg/day)</td>
<td>3 (10 ± 0)</td>
<td>0 (0±0)</td>
<td></td>
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</tr>
</tbody>
</table>

Data are presented as mean ± SD. T2DM: type 2 diabetes mellitus group; DYS: dyslipidemic group; DYSHG: dyslipidemic plus hyperglycemic group; CON: healthy control group. * Endurance performance was assessed by the 2-kilometer walking test. Asterisks denote significant difference from pre follow-up in the same group (* = P<0.05; ** = P<0.01). Daggers denote significant difference from CON group during the same period († = P<0.05).
There were no significant differences in baseline characteristics between participants who completed the follow-up and those who did not (data not shown). As expected, fasting lipid (Fig. 2) and glucose (Table 3) profiles were significantly different between groups at baseline. DYS and DYSHG women showed higher (P < 0.01) TC and LDL-C than both T2DM and CON women (Fig. 2). HDL-C was lower (P < 0.001) in T2DM, DYS and DYSHG women than in CON women (Fig. 2). T2DM and DYSHG women showed higher (P < 0.001) fasting glucose than both DYS and CON women, which were higher (P < 0.001) in T2DM than DYSHG women (Table 3). TG was not significantly different between groups at baseline (Fig. 2).

The exercise program was well tolerated by all participants, and there were no injuries during the training program. Exercise compliance of the four groups averaged 86 ± 1 % during 16 weeks of HIIT (there was no significant difference between groups in exercise compliance). Six participants of the T2DM group reduced their daily dosage of metformin and four patients reduced their glibenclamide dosage during follow-up (Table 2). First, the dosage was reduced only on the exercise training days (thrice weekly) due to episodes of postexercise hypoglycemia starting 1 h after the exercise session (from the 1st week of follow-up). Then, the dosage was reduced on all days of week (from the 11th week of follow-up) due to increasing episodes of hypoglycemia in the non-exercise days. The three T2DM participants under antihypertensive drug therapy before follow-up stopped taking the medication after physician recommendation at a routine medical consultation (from the 11th week of follow-up).

There were significant improvements in the lipid and glucose profile after HIIT (Fig. 2, 3, and Table 3). TC was significantly lower (P < 0.001) in T2DM, DYS and DYSHG women than in CON women (Fig. 2). T2DM and DYSHG women showed higher (P < 0.001) fasting glucose than both DYS and CON women, which were higher (P < 0.001) in T2DM than DYSHG women (Table 3). TG was not significantly different between groups at baseline (Fig. 2).
reduced (P < 0.01) in DYS and DYSHG women (Fig. 2a), while LDL-C was significantly reduced (P < 0.05) only in DYSHG (Fig. 2b). HDL-C increased significantly (P < 0.01) in T2DM, DYS and DYSHG women, but not in CON women (Fig. 2c). All groups reduced TG (P < 0.05) after HIIT (Fig. 2d). Finally, fasting glucose was significantly reduced (P < 0.05) in T2DM, DYS and DYSHG women, but not in CON women after HIIT (Table 3).

It is important to note that delta analysis (pre vs. post absolute (mg/dL) and relative (%) changes) did not show significant differences in TC and LDL-C reduction between DYS and DYSHG women, in HDL-C increase between T2DM, DYS and DYSHG women, as well as in TG reduction between all groups (Fig. 3). However, the absolute and relative reduction in fasting glucose was higher (P < 0.05) in T2DM and DYSHG than in DYS and CON women, with higher reductions (P < 0.05) in T2DM than DYSHG women (Fig. 3). With these improvements, the groups with altered lipid profiles at baseline showed TC, LDL-C and HDL-C levels similar to those of the CON group after 16 weeks of HIIT (Fig. 3). Moreover, DYSHG women also showed fasting glucose levels similar to those of CON women after 16 weeks of HIIT (Table 3).

HIIT was effective for reducing systolic blood pressure (P < 0.05), but not diastolic blood pressure, in all groups (T2DM = −3.7 ± 1.7 mmHg; DYS = −2.4 ± 0.9 mmHg; DYSHG = −2.8 ± 1.1 mmHg; CON = −2.4 ± 1.1 mmHg) (Table 2). HIIT also reduced (P < 0.05) weight (T2DM = −2.2 ± 1.0 kg; DYS = −2.1 ± 1.7 kg; DYSHG = −3.0 ± 1.4 kg; CON = −2.0 ± 1.1 kg), BMI (T2DM = −0.64 ± 0.33 kg/m²; DYS = −0.59 ± 0.49 kg/m²; DYSHG = −0.88 ± 0.40 kg/m²; CON = −0.58 ± 0.36 kg/m²), waist circumference (T2DM = −4.0 ± 1.8 cm; DYS = −2.9 ± 1.6 cm; DYSHG = −4.4 ± 1.4 cm; CON = −3.1 ± 1.9 cm) and skinfold thickness (T2DM = −28.0 ± 10.6 mm; DYS = −15.8 ± 5.3 mm; DYSHG = −24.0 ± 9.8 mm; CON = −16.5 ± 8.6 mm) in all groups (Table 2). Finally, HIIT improved endurance performance as shown by a reduced time (P < 0.01) to complete 2KWT in all groups (T2DM = 2.3 ± 0.8 min; DYS = 2.8 ± 1.0 min; DYSHG = 2.1 ± 0.7 min; CON = 2.1 ± 0.8 min) (Table 2).

Discussion

The main findings of the present study were that despite the effectiveness of HIIT for improving TG in all participants and HDL-C in women with metabolic diseases (T2DM, DYS and DYSHG), TC and LDL-C improved only in women with altered lipid profiles at baseline (DYS and DYSHG). Additionally, the HIIT program was effective for improving fasting glucose in women with metabolic diseases (T2DM, DYS and DYSHG), with greater improvements in women with altered fasting glucose at baseline (T2DM and DYSHG). Finally, the HIIT program was also effective for improving blood pressure, endurance performance and body composition in women independently of their baseline health status. To the best of our knowledge, this is the first study that evaluated and compared the effects of a long-term (>12 weeks) HIIT program on lipid profile in women with T2DM, DYS or DYSHG.

Previous findings suggest that there may exist both a minimum exercise volume (i.e., ≥120 min per week) [21] and intensity (60–85% of VO2max or reserve heart rate) [36] for improving blood lipids, which would occur mainly in subjects with elevated baseline levels [21, 36]. On the other hand, recent studies have suggested that HIIT may be a time-efficient strategy for improving health-related markers, including lipid profile, in different populations [1, 6, 7]. In general, HIIT programs with a weekly time commitment lower than the above-mentioned threshold, as well as lower than the minimal exercise recommendation for the general population [17], has been shown to improve blood lipids in studies with subjects with an altered blood lipid profile at baseline [26, 31]. However, conflicting results have been found in HIIT studies in healthy populations [7, 29]. Although the present 16-week progressive HIIT program was effective for reducing TG independently of subjects’ baseline levels, the HDL-C increase observed only in women with
metabolic diseases, and the LDL-C decrease observed only in women with altered lipid profiles at baseline support the hypothesis that exercise-induced improvements in blood lipid profile depend on its level at baseline. Moreover, it is noteworthy that the present HIIT-induced improvements on blood lipids were effective in restoring TC, LDL-C and HDL-C of DYS and DYSHG to levels similar to those of CON during follow-up, and that it occurred with a weekly time commitment 25% to 56% (66 to 112.6 min/wk divided in 3 exercise sessions) lower than the minimum recommended in current guidelines [17], which confirms the HIIT time-efficiency and suggests that lipid profile improvement may occur at low exercise volumes if high-intensity exercise is performed.

The mechanisms behind the exercise-training-induced benefits on blood lipid profile are not completely understood. However, it has been suggested that exercise training reduces VLDL and TG levels, leading to a decreased availability for exchanges with cholesteryl esters in HDL and LDL, which likely results in increased HDL-C levels and LDL particle size [30]. In addition, exercise training likely results in reduced HDL-C degradation and production of smaller HDL particles by the decrease of hepatic lipase activity, which would improve the HDL-C mediating export of excess cholesterol from peripheral tissues and its subsequent excretion via the liver [30]. Since the HIIT-induced blood cholesterol improvement, but not TG reduction, found in the present study was dependent on its baseline levels, it is possible to speculate that the lipid profile at baseline may affect the above-mentioned mechanism in sedentary obese women. However, future studies investigating the mechanisms underlying the HIIT-induced improvements in the blood lipid profile are necessary to confirm the present hypothesis.

The present HIIT program also promoted several health-related benefits in all groups, including improvements in systolic blood pressure, body weight, BMI, waist circumference, skinfold thickness, and endurance performance. Finally, the HIIT program reduced fasting glucose in women with metabolic disease (T2DM, DYS and DYSHG), which was dependent on its baseline levels, and resulted in the fasting glucose restoration of DYSHG women to levels similar to those of CON women during follow-up. Because the above improvements were found with a low and progressive volume of weekly exercise (see Table 1), the present finding is in accordance with previous studies showing the usefulness of HIIT as a time-efficient intervention for improving health-related variables in healthy subjects and in individuals with chronic disease [1, 7, 8, 13, 15].

Reduced risk of incidental hypertension as well as cardiovascular disease and mortality in dyslipidemic subjects appears to be associated with physical activity levels greater than the minimum recommended in current guidelines [39]. For example, merely satiety in all other populations, mainly dyslipidemic patients under drug treatment or long-standing T2DM patients with complications. The dietary and daily living physical activity changes during the intervention were not controlled, which is also a limitation of the present study. However, all groups were oriented to maintain their dietary and daily living physical activity patterns throughout the 16-week study period.

In summary, the 16-week HIIT program was effective for restoring the lipid profile in women with dyslipidemia, as well as for restoring fasting glucose in women with dyslipidemia associated with hyperglycemia. Moreover, the HIIT program was effective for improving blood pressure, endurance performance and anthropometry in all groups, as well as for reducing medication dosage used by T2DM women. Because these improvements occurred with a weekly time commitment 25% to 56% lower than the minimum recommended in current guidelines [17], the present findings suggest that HIIT may be a time-efficient intervention for counteracting dyslipidemia and improving health.

Acknowledgements

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Conflict of Interest

There are no conflicts of interest to declare.

References


