High-intensity Interval Training Frequency: Cardiometabolic Effects and Quality of Life

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ABSTRACT
The effects of high intensity interval training (HIIT) frequency on cardiometabolic health and quality of life were examined in 35 healthy inactive adults (age: 31.7 ± 2.6 yrs, VO2peak: 32.7 ± 7.4 ml·kg⁻¹·min⁻¹). Participants were randomly assigned to a control (CON) and two training groups, which performed 10×60-s cycling at ~83% of peak power, two (HIIT-2) or three times per week (HIIT-3) for eight weeks. Compared with CON, both training regimes resulted in similar improvements in VO2peak (HIIT-2: 10.8%, p = 0.048, HIIT-3: 13.6%, p = 0.017), waist circumference (HIIT-2: -1.4 cm, p = 0.048, HIIT-3: -2.4 cm, p = 0.028), thigh cross-sectional area (HIIT-2: 11.4 cm², p = 0.001, HIIT-3: 9.3 cm², p = 0.001) and the physical health component of quality of life (HIIT-2: 8.4, p = 0.001, HIIT-3: 12.2, p = 0.001). However, HIIT-3 conferred additional health-related benefits by reducing total body and trunk fat percentage (p < 0.05, compared with CON), total cholesterol and low-density lipoprotein-cholesterol (p < 0.02, compared with CON) and by improving the mental component of quality of life (p = 0.045, compared with CON). In conclusion, performing HIIT only twice per week is effective in promoting cardiometabolic health-related adaptations and quality of life in inactive adults. However, higher HIIT frequency is required for an effect on fat deposits, cholesterol and mental component of well-being.

Introduction
Physical inactivity is one of the leading risk factors for mortality and is responsible for an estimated 9% of premature deaths worldwide [26]. Current physical activity guidelines suggest that at least 30 min of moderate-intensity cardiorespiratory exercise, five days per week (≥ 150 min·wk⁻¹) or a minimum of three days of vigorous-intensity exercise performed at least 20 min each day (≥ 75 min·wk⁻¹), or a combination of both is required for health benefits [15]. Although the benefits of physical activity are well documented, approximately one third of the adult population remains physically inactive [17], and shortage of time is one of the main reasons given for not exercising [9].

Low-volume, high-intensity interval training (HIIT) describes exercise training sessions with ≤ 30 min duration, including ≤ 10 min of vigorous exercise interspersed with active or passive recovery periods [16]. Such protocols require lower weekly total work and training duration than the recommended public health guidelines [15], but elicit health-related adaptations such as improved cardiorespiratory fitness [31], insulin sensitivity [27] and antioxidant status [6], which are similar or even greater compared with continuous moderate-intensity training [46]. Despite the growing volume of evidence regarding the physiological adaptations to HIIT, there is limited information regarding its effect on quality of life. In a recent study, HIIT improved health-related quality of life in aging men, but this was mainly due to its effects on physical health components, and not on mental health components [25]. However, the contribution of HIIT on quality of life in inactive healthy adults and especially on the mental health function remains relatively under-examined.
In most of the previous training studies, HIIT was carried out with a frequency of three times per week. However, this frequency may not be attained by individuals who find lack of time as the main barrier for adherence in physical activity programs, and it is very interesting to determine whether reducing the frequency of exercise still offers some health benefits. In clinical and aging populations, some studies have recently used lower frequency HIIT due to the inability of the participants to follow or tolerate three sessions per week [1, 25]. However, there are limited and conflicting results regarding the efficacy of low frequency of HIIT on various health indices in healthy adults. A recent study [30] presented improvements in cardiorespiratory function and favorable adaptations in cardiac structure, after a severe-intensity interval training just once per week for three months in young healthy volunteers. However, some other studies showed no improvement in VO₂peak after interval training conducted once or twice per week [12, 23]. Therefore, it is unknown whether a low HIIT frequency may cause comparable physiological and health-related adaptations, as those achieved with higher HIIT frequencies. To date, there is no comprehensive study to evaluate the effect of different HIIT frequencies on physiological, metabolic and psychological variables associated with health and quality of life. Thus, the aim of the present study was to examine and compare the efficacy of HIIT with low and moderate training frequency (two and three times per week) on physiological, metabolic and psychological variables in healthy inactive adults. It was hypothesized that two sessions of HIIT each week may be equally effective as three sessions per week in improving VO₂peak, body composition, biochemical blood variables and quality of life, in unaccustomed individuals.

Materials and Methods

Participants

Forty-one inactive healthy adults (age range: 27–37 yrs) were initially recruited. Following medical screening by a certified physician, thirty five of them (n = 35, age: 31.7 ± 2.6 yrs, BMI: 23.7 ± 4 kg·m⁻²), were eligible to participate in the study and provided written informed consent after being fully informed of the research procedures. Inclusion criteria were: (a) inactive lifestyle for the past year before the study, (b) nonsmokers, (c) without diet habits during the intervention period. They recorded a 72-h food diary before the baseline blood testing and replicated this before subsequent tests. They were also asked to refrain from alcohol and vigorous physical activities for 48 h before the testing days. No participant withdrew from the study and no adverse events or musculoskeletal injuries were reported throughout the intervention.

Study design

Participants were randomly assigned to one of the two training groups, who performed HIIT two times per week (HIIT-2: n = 14, 8 females/6 males, age: 31.5 ± 3.5yr) and three times per week (HIIT-3: n = 13, 6 females/7 males, age: 31.9 ± 2.4yr) or to a control group (CON: n = 8, 4 females/4 males, age: 31.7 ± 0.8yr). Initially, all participants of the HIIT-2 and HIIT-3 groups went through a 3-week pre-conditioning, familiarization and testing period (as described below), to avoid an abrupt increase in physical activity and exercise intensity. Afterwards, the HIIT-2 and HIIT-3 intervention groups trained two and three times per week respectively, over an 8-week period with the same HIIT protocol; whereas the participants in the CON group continued their usual daily activities for the same time period. All participants completed a series of tests at the beginning and after an 8-week period including measurement of VO₂peak, body composition, biochemical blood variables and evaluation of quality of life. Body composition, VO₂peak, and blood tests were also performed for HIIT-2 and HIIT-3 after four weeks of training.

Participants were asked to maintain their habitual lifestyle and diet habits during the intervention period. They recorded a 72-h food diary before the baseline blood testing and replicated this before subsequent tests. They were also asked to refrain from alcohol and vigorous physical activities for 48 h before the testing days. No participant withdrew from the study and no adverse events or musculoskeletal injuries were reported throughout the intervention.

Testing and training

A pre-conditioning phase, consisting of three training sessions that included continuous incremental cycling and 5-7 x 60-s moderate to high-intensity bouts interspersed with 60 s of low intensity exercise, served as a preparation for training and as familiarization with the testing and training procedures. The following analyses and tests were conducted over three separate visits, at least 4 days after the last pre-conditioning session and were repeated after training.

Blood analyses

Participants visited the laboratory after overnight fasting and venous blood samples (~ 10 mL) were taken from an antecubital vein to obtain concentrations of glucose, insulin, glycosylated hemoglobin (HbA1c), C-reactive protein (CRP), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and triglycerides (TG). An amount of ~ 7 mL was collected in plain tubes and allowed to clot for 30 min. Then the samples were centrifuged at 4000rpm for 8 min and the serum was decanted. Insulin concentration was determined using chemiluminescent microparticle immunoassay (CMIA) technology (Abbott Architect Plus analyzer). Glucose was analyzed using the enzymatic UV test (hexokinase method) ( Beckman Coulter AU 680 analyzer). The intra-assay coefficients of variation (CV) for glucose and insulin were 0.51-0.7 % and 1.9-5.2 %, respectively. TC, HDL-C and TG were determined using the enzymatic color test (Beckman Coulter AU 680 analyzer). CRP was analyzed using the immuno-turbidimetric test (Beckman Coulter AU 680 analyzer). Furthermore, ~ 3 mL was drawn into EDTA tubes and HbA1c was measured using the immuno-inhibition test ( Beckman Coulter AU 480 analyzer). Low-density lipoprotein cholesterol (LDL-C) and very low-density lipoprotein cholesterol (VLDL-C) were calculated using the Friedwald’s equations [14]. Atherogenic index was calculated as TC/HDL.
Oral glucose tolerance test (OGTT)

After ingestion of 75 g of glucose, 2-3 mL of blood was collected at 60 and 120 min later, for glucose and insulin determination. Insulin sensitivity was calculated using the insulin sensitivity index (ISI), as described by Matsuda and DeFronzo [28]. In addition, insulin resistance was calculated using the insulin resistance homeostatic model assessment (HOMA-IR) [29]. Glucose and insulin area under the curve (AUC) values were calculated using the trapezoidal rule. All participants abstained from exercise and followed a pre-recorded diet for 72 h prior to OGTTs to avoid the effects of acute exercise.

Quality of life

Quality of life was assessed by the Short-form 36 Health survey (SF-36) [45]. The reliability and validity of the Greek version of SF-36 have been documented [33]. In our study, the reliability (i.e., internal consistency) of the SF-36 constructs was calculated with Cronbach’s coefficient alpha, showing good internal consistency (Cronbach’s alpha = 0.842). The SF-36 is a self-administered 36 item survey that produces scores on eight constructs, which are summarized in two components: the physical health and the mental health components.

Body composition assessment

Percent of body fat was estimated using standard equations after measuring skinfold thickness [21]. Moreover, trunk fat percentage and waist circumference were measured using a validated bioelectrical impedance device (Viscan Tanita abdominal fat analyzer AB140, ICC = 0.996) [8]. Thigh circumference was measured at the midpoint of the anterior surface of the right thigh, midway between patella and inguinal fold. Thigh lean cross-sectional area (CSA) was estimated from the thigh circumference and the thigh skinfold thickness, using the multiple regression equation provided by Housh et al. [20].

Cardiorespiratory fitness assessment

Peak oxygen uptake (VO2peak) was determined using a ramp test (15-20 W min-1) to exhaustion on a cycle ergometer (Monark LC6 NOVO, Sweden). VO2peak was defined as the highest 30 s average for VO2, if at least three of the following criteria were met: a plateau in VO2 despite increasing intensity, RER > 1.15, heart rate within 10 beats of age-predicted maximum, and a rating of perceived exertion (RPE) of 18 or greater. Wpeak was determined as the power of age-predicted maximum, and a rating of perceived exertion was calculated according to each participant’s new VO2peak for the remaining period, in order to maintain the target relative intensity. Training sessions were held on non-consecutive days throughout each week, and were all supervised by one of the authors.

Statistical analysis

Differences in baseline values were tested with one-way Analysis of Variance (ANOVA). A mixed factor two-way analysis of covariance (time x group ANCOVA), using the pre-training values as the covariate, was employed to compare the dependent variables between and within groups. Also, to compare the responses between the three groups (CON, HIIT-2 and HIIT-3) an ANCOVA was performed using the baseline values as the covariate and the pre-post change as the dependent variable. When a significant main effect or interaction was observed (p < 0.05), a Tukey’s post-hoc test was performed. For pairwise comparisons, the magnitude of effect sizes were determined by calculating Cohen’s d (small effect = 0.20-0.49, medium effect = 0.50-0.79 and large effect ≥ 0.80). All statistical procedures were performed using SPSS version 20. Statistical significance was accepted at p ≤ 0.05 and variables are presented as mean ± SD. Pre-post training changes for each variable are presented as mean and 90% confidence intervals (90%CI).

Results

There were no baseline differences between groups in any variable (p > 0.05) and no significant change in any variable was observed in the CON group. Adherence was the same in both training groups (97.8%). Mean work per session (including intervals and recovery) was similar between the two training groups (HIIT-2: 107 ± 31 kJ, HIIT-3: 117 ± 27 kJ, p = 0.388), and total work was significantly higher in HIIT-3 compared to HIIT-2 (2815 ± 61 vs 1719 ± 497 kJ, p < 0.001). Fidelity of exercise training was calculated according to Taylor et al. [41], using a cut-point of 80% of maximal heart rate as a criterion for satisfactory exercise intensity for all bouts. Thus fidelity was similar in both groups, with participants in the HIIT-2 group attaining the criterion in 145 of 160 bouts (90.6%) and participants in the HIIT-3 group attaining it in 215 of the 240 bouts (89.6%).

Body composition

No significant changes in body weight and BMI were observed for any group. After eight weeks of intervention waist circumference was significantly reduced in HIIT-2 (-1.4 cm, 90%CI = -0.4 to -2.5 cm) and HIIT-3 (-2.4 cm, 90%CI = -1.3 to -3.5 cm) compared with both their respective baseline values (p < 0.001). Fidelity of exercise training was calculated according to Table 1 and compared with the change observed in the CON group (HIIT-2: p = 0.048, d = 0.56 and HIIT-3: p = 0.028, d = 1.05) with no difference between the two HIIT groups (p < 0.001). Thigh lean CSA was significantly and similarly increased in both training groups at the end of the 8-week training period (HIIT-2: 11.4 cm2, 90%CI = 8.5 to 14.3 cm2; HIIT-3: 9.3 cm2, 90%CI = 4.9 to 13.7 cm2, both p < 0.01), and this increase was greater compared with that of the CON group (HIIT-2: p = 0.001, d = 2.15 and HIIT-3: p = 0.001 and d = 1.36, respectively). Body fat was reduced by 0.7% (90%CI = -0.3 to -1.1%, p = 0.033) and trunk fat percentage was reduced by 1.8% (90%CI = -1.0 to -2.5%, p = 0.002) only in HIIT-3 (p < 0.001). These reductions in body fat and trunk fat were greater compared with the CON condition (p < 0.05,
The present study demonstrated that HIIT performed either two or three times per week, leads to significant improvements in VO2peak, waist circumference, thigh lean CSA and the physical health component of quality of life. Most importantly, the magnitude of these training-induced adaptations was unaffected by training frequency, as it was similar in the two training groups. However, there were additional health-related benefits in the group that trained three times per week, i.e., reduction of body fat and trunk fat percentage, decrease of total cholesterol and LDL-C, and improvement of the mental health component of quality of life.

Some studies that used HIIT or sprint training with a frequency of one to two sessions per week for 4-6 weeks, reported no effect

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>CON</th>
<th>HIIT-2</th>
<th>HIIT-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>8 weeks</td>
<td>Baseline</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.4±12.2</td>
<td>67.4±13.1</td>
<td>66.5±18.9</td>
</tr>
<tr>
<td>BMI (kg · m⁻²)</td>
<td>23.4±3.1</td>
<td>23.4±3.4</td>
<td>23.6±4.6</td>
</tr>
<tr>
<td>%Body Fat</td>
<td>16.6±6.7</td>
<td>17.1±6.9</td>
<td>18.8±5.7</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>88.8±8.7</td>
<td>88.5±8.9</td>
<td>89.9±12.6</td>
</tr>
<tr>
<td>%Trunk fat</td>
<td>25.5±7.3</td>
<td>25.4±7.6</td>
<td>28.3±7.2</td>
</tr>
<tr>
<td>Thigh lean CSA (cm²)</td>
<td>135.6±20.3</td>
<td>133.9±21.4</td>
<td>122.2±30.5</td>
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</tbody>
</table>

* and ** p<0.05 and p<0.01 from the corresponding baseline value; † and ‡: p<0.05 and p<0.01 from CON; #: p<0.05 from HIIT-2

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
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<th>HIIT-2</th>
<th>HIIT-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>8 weeks</td>
<td>Baseline</td>
</tr>
<tr>
<td>VO2peak (ml . kg⁻¹ . min⁻¹)</td>
<td>23.4±3.1</td>
<td>23.4±3.4</td>
<td>23.6±4.6</td>
</tr>
</tbody>
</table>

Fig. 1

Cardiorespiratory fitness

After four weeks of training, VO2peak significantly increased only in HIIT-3 (by 11.6 %, p=0.002, Cohen’s d=0.47) but not in HIIT-2 (2.2 %, p>0.05, Cohen’s d=0.11). After eight weeks of training, VO2peak was significantly and similarly increased in HIIT-2 by 3.5 ml · kg⁻¹ · min⁻¹ (90 %CI = 2.2 to 4.7 ml · kg⁻¹ · min⁻¹) or 10.8 % (p=0.017, Cohen’s d=0.56) and in HIIT-3 by 4.5 ml · kg⁻¹ · min⁻¹ (90 %CI = 2.3 to 6.7 ml · kg⁻¹ · min⁻¹) or 13.6 % (p=0.001, Cohen’s d=0.55). Both increases were greater (HIIT-2: p=0.048, d=1.21 and HIIT-3: p=0.017, d=1.06, respectively) compared with the change observed in the CON group (0.2 ml · kg⁻¹ · min⁻¹, 90 %CI = -1.6 to 1.9 ml · kg⁻¹ · min⁻¹) (Fig. 1).

Blood biochemical parameters

Fasting blood glucose and insulin and their respective AUC were not significantly changed in any of the three groups after the intervention (Table 2). Blood insulin concentration at the end of the OGTT was significantly reduced in both HIIT-2 and HIIT-3 (HIIT-2: -11.8 mU · L⁻¹, 90 %CI = -5.6 to -18.0 mU · L⁻¹, p=0.002, Cohen’s d=0.77 and HIIT-3: -10.4 mU · L⁻¹, 90 %CI = -4.4 to -16.4 mU · L⁻¹, p=0.008, Cohen’s d=0.42, respectively). However, this decrease in both training groups was not significantly different compared with the change observed in the CON group. Insulin sensitivity (ISI), HOMA-IR scores, HbA1c and CRP did not change significantly after the intervention (Table 2).

TC and LDL-C were significantly reduced only in the HIIT-3 group (TC: -0.39 mmol · L⁻¹, 90 %CI = -0.26 to -0.52 mmol · L⁻¹, p=0.008, Cohen’s d=0.58 and LDL-C: -0.32 mmol · L⁻¹, 90 %CI = -0.21 to -0.43 mmol · L⁻¹, p=0.009, Cohen’s d=0.49, respectively) (Table 2). The reductions of TC and LDL-C were significantly greater than the changes observed in the CON (TC: p=0.017, d=1.53 and LDL-C: p=0.019, d=1.62) and HIIT-2 group (TC: p=0.032, d=0.76 and LDL-C: p=0.029, d=0.84). However, HDL-C, TG, VLDL-C and atherogenic index remained unchanged (Table 2).

Quality of life

The physical health component was improved similarly after HIIT-2 (8.4, 90 %CI = 3.5 to 13.4, p=0.001, Cohen’s d=0.86) and HIIT-3 (12.2, 90 %CI = 5.5 to 19, p=0.001, Cohen’s d=0.97; see Fig. 2). Both groups improved significantly compared with CON (HIIT-2: p=0.001, d=1.12 and HIIT-3: p=0.001, d=1.21). Mental health component was significantly elevated in both HIIT-2 (7.3, 90 %CI = -0.3 to 14.0, p=0.003, Cohen’s d=0.54) and HIIT-3 (8.9, 90 %CI = 3.0 to 14.8, p<0.001, Cohen’s d=0.69) compared with the baseline value. However, this improvement was significantly higher compared with the CON group only for HIIT-3 (p=0.045, Cohen’s d=0.64) but not for HIIT-2 (p=0.17, Cohen’s d=0.38).
on VO\textsubscript{2}max [12, 23]. This finding is in agreement with our result that after the initial four weeks of training, there was no improvement of cardiorespiratory fitness in HIIT-2. However, at the end of the 8-week training period, VO\textsubscript{2}peak improved in HIIT-2 as much as in HIIT-3 group, with the later group showing no further improvement from four to eight weeks of training. This may suggest that eight sessions of HIIT, as performed by the HIIT-2 group in the first four weeks, may not be adequate for VO\textsubscript{2}max improvement, and a larger number of sessions (≥ 12) is required to elicit cardiorespiratory adaptations during HIIT. Therefore, the cumulative training volume may also be important when the frequency of training is low, in order to induce cardiorespiratory adaptations. For example, Adamson et al. [1] reported an 8 % improvement in VO\textsubscript{2}peak after eight weeks of short duration HIIT performed twice per week in middle aged untrained population. Furthermore, Nakahara et al. [30] presented an 11 % improvement in VO\textsubscript{2}max after severe-intensity interval training performed only once a week for three months. The importance of training volume for cardiorespiratory fitness improvement during HIIT has been examined by keeping training frequency at three times per week, and manipulating the session exercise volume. For example, Tjonna et al. [42] have shown that when the frequency of HIIT training between groups was held constant (three times per week), the lower volume HIIT had a similar impact on VO\textsubscript{2}max, compared with a 4-fold higher volume HIIT. Their findings show that training session volume may not be of prime importance for cardiorespiratory adaptations during HIIT.

<table>
<thead>
<tr>
<th>Variable</th>
<th>CON</th>
<th>HIIT-2</th>
<th>HIIT-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>8 weeks</td>
<td>Baseline</td>
</tr>
<tr>
<td>Fasting glucose (mmol·L(^{-1}))</td>
<td>5.0 ± 0.2</td>
<td>5.0 ± 0.3</td>
<td>5.0 ± 0.3</td>
</tr>
<tr>
<td>Fasting insulin (mU·L(^{-1}))</td>
<td>6.2 ± 1.1</td>
<td>6.3 ± 1.6</td>
<td>6.0 ± 3.1</td>
</tr>
<tr>
<td>Glucose at end of OGTT (mmol·L(^{-1}))</td>
<td>4.5 ± 0.3</td>
<td>4.4 ± 0.8</td>
<td>4.6 ± 0.9</td>
</tr>
<tr>
<td>Insulin at end of OGTT</td>
<td>27.3 ± 13.2</td>
<td>21.9 ± 10.2</td>
<td>35.5 ± 19.1</td>
</tr>
<tr>
<td>Glucose AUC (mmol·min·L(^{-1}))</td>
<td>602 ± 77</td>
<td>592 ± 86</td>
<td>619 ± 108</td>
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<tr>
<td>Insulin AUC (mU·min·L(^{-1}))</td>
<td>4258 ± 2480</td>
<td>3795 ± 1869</td>
<td>4926 ± 2823</td>
</tr>
<tr>
<td>ISI</td>
<td>8.6 ± 2.9</td>
<td>9.0 ± 3.2</td>
<td>8.5 ± 3.4</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>1.4 ± 0.2</td>
<td>1.4 ± 0.4</td>
<td>1.3 ± 0.8</td>
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<tr>
<td>HbA1c (%)</td>
<td>5.2 ± 0.3</td>
<td>5.2 ± 0.2</td>
<td>5.3 ± 0.3</td>
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<tr>
<td>CRP (mg·L(^{-1}))</td>
<td>0.9 ± 0.4</td>
<td>1.1 ± 0.6</td>
<td>1.6 ± 1.1</td>
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<tr>
<td>TG (mmol·L(^{-1}))</td>
<td>0.78 ± 0.15</td>
<td>0.71 ± 0.21</td>
<td>0.80 ± 0.28</td>
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<td>TC (mmol·L(^{-1}))</td>
<td>4.86 ± 0.55</td>
<td>4.85 ± 0.72</td>
<td>4.76 ± 0.82</td>
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<tr>
<td>HDL-C (mmol·L(^{-1}))</td>
<td>1.45 ± 0.23</td>
<td>1.41 ± 0.25</td>
<td>1.43 ± 0.30</td>
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<tr>
<td>LDL-C (mmol·L(^{-1}))</td>
<td>3.06 ± 0.58</td>
<td>3.12 ± 0.76</td>
<td>2.97 ± 0.87</td>
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<tr>
<td>VLDL-C (mmol·L(^{-1}))</td>
<td>0.35 ± 0.07</td>
<td>0.32 ± 0.10</td>
<td>0.36 ± 0.13</td>
</tr>
<tr>
<td>Atherogenic Index</td>
<td>3.46 ± 0.70</td>
<td>3.56 ± 0.91</td>
<td>3.48 ± 1.00</td>
</tr>
</tbody>
</table>

* and * * : p<0.05 and p<0.001 from the corresponding baseline value.

Fig. 2 Quality of life (SF-36) physical (left panel) and mental (right panel) health component at baseline and after eight weeks of intervention for each group. * and * * : p<0.05 and <0.02 from baseline; †: p<0.05 from CON.
but our data suggest that accumulation of total HIIT volume, through different training frequencies, may influence the time course, but not the final magnitude of training adaptations. However, the relative importance of training frequency and volume, to determine the minimal effective training regime during HIIT requires further investigation.

The magnitude of VO$_{2}$peak improvement found in the present study (3.5-4.5 ml · kg$^{-1}$ · min$^{-1}$) is consistent with meta-analysis data reporting increases of 3.8 ml · kg$^{-1}$ · min$^{-1}$ after HIIT [4]. One potential mechanism explaining a significant part of the improvement in VO$_{2}$peak may be an increase in stroke volume, due to plasma/blood volume expansion in response to HIIT [2, 44]. Interestingly, a recent study [2] has shown that the increase in cardiac output in response to HIIT may follow different time courses, depending on the HIIT regime. In the present study, the different time-course of VO$_{2}$peak improvement in HIIT-2 and HIIT-3 may depend on either the training frequency and/or the cumulative volume of training. Thus, in HIIT-2 the low training frequency and total volume may not be adequate to increase O$_2$ delivery in the first four weeks of training. On the other hand, a plateau of central adaptations may explain the lack of improvement in VO$_{2}$peak in the last four weeks of training in the HIIT-3 group.

Recent meta-analyses have reported the positive impact of HIIT on body composition indices like fat mass and waist circumference [24, 47]. In the present study even though body weight remained unchanged, the percentage of total body and trunk fat, was decreased in HIIT-3. Moreover, waist circumference was reduced in both training groups (Table 1). Similarly in the recent meta-analysis of Wewoge et al. [47], it was shown that HIIT can reduce whole-body fat mass and waist circumference in the absence of body mass changes. A decrease in these indirect indices of abdominal adiposity [10] may reduce the risk of cardiovascular diseases and type 2 diabetes [13]. A possible mechanism that may promote fat loss during HIIT is the significant catecholamine response to high-intensity exercise, that enhances lipolysis [48]. The reduction in trunk fat may be explained by the increased concentration of β-adrenergic receptors in abdominal tissue compared to subcutaneous fat [36]. Another potential mechanism that could be involved in the reduction of fat mass is an increased fat oxidation following HIIT [3], that is possibly linked with increased mitochondrial biogenesis and function [5]. Additionally, post-exercise oxygen consumption (EPOC) and appetite suppression following high-intensity exercise could also be involved [19, 38]. Furthermore, in the present study, both training groups increased thigh lean CSA, indicating a gain in leg muscle mass. Increased muscle mass may elevate basal metabolic rate [39], and thus increased fat oxidation during rest, and may also improve insulin sensitivity [40].

Recently, emphasis has been placed on the effectiveness of HIIT on blood glucose regulation [4, 22]. Controversial results have been reported for healthy normal weight adults, while data from populations with impaired metabolic control show positive effects [4, 22]. In the present study, insulin at the end of the OGTT was lowered in both training groups compared with baseline, but this decrease was not significantly different compared with the CON group (Table 2). No other significant changes were observed in other OGTT parameters, whereas HbA1c was also unaltered, possibly due to the fact that baseline values were within the normal range, indicating a healthy population [22] (Table 2). Insulin sensitivity also failed to show significant improvements in both training groups. The lack of a significant effect on either HIIT-2 or HIIT-3 on glycemic control in healthy individuals may be explained by both the normal health status of our subjects and the possibility that a higher exercise volume and/or training duration was required. For example, a recent study by Ramos et al. [35] showed that a higher, rather than a lower HIIT volume (4 × 4 vs. 1 × 4 min, 3 times per week) was effective for improving insulin quality in participants with metabolic syndrome after 16 weeks of training.

In the present study, only HIIT-3 resulted in significant changes in total cholesterol and LDL-C (Table 2). This is in agreement with some studies showing reductions in TC and LDL-C, after HIIT in inactive individuals [32, 37]. However, other studies failed to show improvements in blood lipid profile [27, 31]. Decreases in TC and LDL-C are important as this decreases the risk of cardiovascular diseases [34]. The fact that HIIT-2 failed to induce any influence in lipid profile may be explained by the possibility of a training volume threshold which should be surpassed to induce favorable blood lipid changes [31] and thus a longer training period of low frequency HIIT may be needed to elicit positive changes in cholesterol.

Cross-sectional studies have shown that persons attaining the recommended levels of physical activity are more likely to have better quality of life levels [7, 43]. In the present study, despite the low weekly training time commitment compared with public health guidelines, HIIT-3 improved both physical and mental health components, while HIIT-2 improved only the physical health component. Therefore, the beneficial health-related effects of HIIT on general population also include an improvement of quality of life of the participants. In the present study, the lack of an effect of HIIT-2 on the mental aspect may suggest that an increased training frequency of HIIT or a longer duration of training may be necessary to elicit positive psychological effects on quality of life in inactive adults.

In conclusion, the present study showed that HIIT-2 may improve particular cardiometabolic health indices and the physical component of quality of life following eight weeks of training in inactive men and women. However, HIIT-3 conferred additional health-related benefits by reducing total body and abdominal fat, TC and LDL-C and by improving the mental component of quality of life. Importantly, the present study adds to the existing knowledge of positive effects of HIIT and shows that despite a low training frequency (i.e., two times per week), HIIT can still promote specific health-related adaptations in inactive populations in a time-efficient way.

Conflict of Interest

The authors declare no conflict of interest.

References


