Abstract

In this study we aimed to verify the effects of training on cardiovascular function, body composition, high-sensitive C-reactive protein (hs-CRP), and physical fitness of older adults. Fifty-four subjects were randomly allocated into Aerobic Training (AT), Strength Training (ST), or Waiting List (WL). Heart Rate Variability (HRV), Blood Pressure (BP), body composition (DXA), hs-CRP, and fitness (6MWT) were assessed at baseline and after a four-month intervention. To detect changes within groups (before vs. after) the paired t-test was employed. General linear models were used with time (before and after interventions/observation) as a within-subject factor, Group (ST, AT and WL) as a between-subjects factor, and gender as a covariate (P<0.05). After intervention, AT and ST demonstrated a better performance in 6MWT (+43.3m; +31.5m) and lower body fat (-1.5%; -1.2%), trunk fat (-0.9kg; -0.8kg), and systolic BP (-13.1mmHg; -8.7mmHg), additionally, AT lowered diastolic BP (-3.7mmHg). Excluding systolic and diastolic BP (-6.4mmHg; -3.1mmHg), no differences were observed in WL. These data suggest that four months of AT or ST can reduce total and trunk fat content and improve aerobic fitness in older adults. However, training has no effect on HRrest, HRV, and hs-CRP.

ABBREVIATIONS


INTRODUCTION

Despite the multifactorial nature of chronic conditions in general, it has become clear that inflammatory mechanisms are key players in pathological processes of several chronic diseases such as Cardiovascular Disease (CVD), type 2 diabetes, and Alzheimer’s disease [1]. In this sense, more emphasis has been placed on achieving inflammatory mediators that help clinicians and researchers better evaluate individuals at high risk of developing chronic conditions. From a burgeoning list of biomarkers linked to inflammation, high-sensitive C-reactive protein (hs-CRP) has been shown to have a direct effect in atherosclerotic promotion and inflammation [2].

Heart-Rate Variability (HRV), in its turn, is a measure of cardiac autonomic function that also has been found to be associated with CVD and all-cause mortality [3,4]. Therefore, it is not surprising that reduced HRV is associated with subclinical inflammation in diseased and apparently healthy subjects [3,5]. In fact, it was suggested that an autonomic imbalance in favour of the sympathetic system may interact with inflammation processes to play an important role in diseases such as...
atherosclerosis, diabetes mellitus, coronary artery disease, hypertriglyceridaemia, and obesity [3].

Increased abdominal, visceral adiposity and low physical fitness are other aspects that have been linked with subclinical inflammation and increased CVD risk [6]. Despite the lack of clarity in the causal pathway of the associations between inflammation, autonomic balance, and adiposity, it is important to consider that older adults are much more likely to present these conditions that are themselves associated with inflammation [7]. Thus, it seems urgent to develop and implement effective therapies that target prevention of inflammation, obesity, and reduced HRV in this population. In this context, exercise training seems to be complementary to or substitute for pharmacotherapy.

Regardless, it is widely presumed that regular exercise training induces positive adaptations in the body composition [8,9], the autonomic nervous system [10,11], and sub-clinical inflammation [7,12]. There is little evidence regarding the extent of the training-associated benefits on HRV and low-grade inflammation of apparently healthy older adults. A great part of the results in this field comes from cross-sectional studies of younger or older-diseased populations. Another limitation that could be pointed out on previous researches is that only few experimental studies have investigated strength training as an intervention and high-intensity exercise training as capable of diminishing inflammatory biomarkers and increasing HRV in non-diseased older adults. The main studies on this topic have included only diabetic individuals [13] or pulmonary or cardiovascular or dialysis patients in their samples and have chosen moderate intensity in their protocol prescription despite emerging evidences that high-intensity exercise training could be more effective than moderate intensity in decreasing inflammation of diseased older adults [13] and overweight individuals [14]. Thus, the main purpose of this study was to verify the effects of two High-Intensity Training Regimens on Inflammation (hs-CRP), HRV, fat content (assessed by DXA), and fitness in community-dwelling older adults.

MATERIALS AND METHODS

Participants and study design

The study design is presented in Figure 1. Community-dwelling and independent older adults in the Porto area were recruited using advertisement in newspapers. At the screening, one hundred and eight volunteers completed a health history questionnaire to record past and present conditions and medications. The selection criteria of the sample were the following: (i) aged more than 60 years; (ii) not have participated in regular exercise training in the previous six months, which means not be involved in supervised exercise of moderate to vigorous intensities for 20 minutes or more at least twice a week; (iii) no present acute or terminal illness; (iv) not have a diagnosis

**Figure 1** Diagram describing study design, recruitment, and retention of participants.
of severe or uncontrolled hypertension or any cardiovascular and/or respiratory disorder; (v) not have any neurological, skeletal-muscle or joint disorders or any disturbance that would preclude the participation from exercise or testing; and (vi) not be under pharmacological therapies that could reduce safety during exercise. One hundred and five older adults (78 women and 27 men) were able to participate in the study. After screening, the subjects were randomly allocated into three groups: Aerobic Training (AT), Strength Training (ST), and Waiting List (WL). Individuals included in this longitudinal study took part in a four-month intervention/observation period. An attendance rate of at least 80% of the training previewed sessions was required of the subjects to consider their “completion” of the training program. Additionally, older adults who were absent for eight or more consecutive sessions were excluded. Data was collected for all variables at baseline (before) and after the four-month intervention/observation period (after). During the four months 51 subjects were lost: 2 due to malignant diseases (1 AT, 1 WL); 3 (WL) could not perform fitness tests due to low back pain; 2 (1 ST, 1 WL) due to knee surgery; 1 (WL) due to cerebral stroke; 2 (1ST, 1 AT) could not exercise due to abdominal hernia; 2 (ST) could not exercise due to aortitis; 1 (ST) could not exercise due to fall injuries; 1 (ST) gave up due to medical advice; 1 (WL) moved from Porto; 24 (8 ST, 9 AT, and 7 WL) due to lack of time; 5 due to loss of motivation (2 ST, 3 AT); and 3 (ST) did not achieve the 80% frequency of total exercise sessions. Four (3 ST, 1 WL) were lost from the final analysis because of missing data in at least one of the time points. According to the Helsinki Declaration, the nature, benefits, and risks of the study were explained to the volunteers, and their written informed consent was obtained. All methods and procedures were approved by the Institutional Review Board.

Training protocols

For both training protocols, older adults trained three times per week (non-consecutive days) for eight months and each exercise session lasted approximately 50 min. Aerobic Training (AT) comprised 10 min warm-up, 30 min of rhythmic exercise, (mainly walking, but including also dancing and stepping) at 50%-80% HR_{max} followed by a 10 min cool-down. To increase functional fitness so participants could sustain 30 min continuous walking at target, training duration and intensity were gradually increased during the first 4 weeks. Resistance Training (RT) comprised 10 min warm-up that included stretching, followed by nine exercises (leg press, chest press, leg extension, seated row, seated leg curl, abdominal flexion, biceps curl, low-back extension, and triceps extension) for all major muscular groups; and a ten-min cool-down. During the first week of RT, the participants were familiarised with the variable resistance machines (Nautilus Sports/Medical Industries, Independence, VA) by performing one set of 12-15 repetitions (reps) without load. Participants were taught proper lifting techniques and safety precautions. To minimise excessive BP responses, individuals were told to avoid extended breath-holding (Valsalva manoeuvre), during their reps [12]. One Repetition Maximum (1RM) for each exercise was calculated after which participants performed two sets of 12-15 reps at 50-60% of 1RM. After each month, 1RM was re-evaluated. At the second month, resistance increased to 80% of the new 1RM and repetitions interval decreased to 8-12 (two sets still). Every month 1RM was measured intending to maintain an adequate training stimulus (80% 1RM). Participants were instructed to start with 8 reps and increase this number to 12, always feeling they could perform a high number of reps with the same load. If they easily achieve the 12th rep. they should increase the load. Concentric and eccentric movements were performed at a rate of three seconds [8]. A 2-minute rest between each set of reps was provided. All sessions were performed under the supervision of a physical education teacher. During the study period, individuals randomised to the Control group were contacted by phone every two months to certify that they were still interested in participating in the program. At these moments, they were also asked not to change their lifestyle. After the observation period, they were invited to participate in specific exercise programs designed for seniors at the Faculty of Sport.

Measures

During assessment, the test administrator and the time of day used for collection remained constant.

Anthropometrics and body composition

Body weight was measured to the nearest 0.1kg with an electronic weight scale (SECA 708). Subjects were weighed barefoot wearing light clothing. Height was measured to the nearest 1mm with a standard stadiometer. Body Mass Index (BMI) was determined as weight divided by height squared (kg/m²). Percent of total Body Fat (%BF) and trunk fat were determined by whole body scan using a Dual-energy X-ray Absorptiometry (DXA – Hologic QDR-4500, software for windows XP, version 12.4) with subjects in the supine position. All scans were analysed by the same investigator. The rationale of body composition analysis with DXA is described elsewhere [15].

Cardiovascular function

Resting Blood Pressure and Heart Rate (HR_{rest})

Resting BP and HR were measured by an automated blood pressure monitor (Colin, DP 8800). After remaining 15 minutes at rest in a quiet, temperature-controlled room, BP measurements were taken with the subjects seated in an upright position with the arm comfortably placed at heart level. The average of three measures for SBP, DBP, and HR was entered as data. The analyses were conducted between 8:00 and 11:00am, by the same investigator.

Heart-rate Variability: Before HRV recordings, subjects were instructed to 1) not consume coffee, cola beverages, tea, or chocolate for 12h; 2) not smoke for 12h; 3) not drink alcoholic beverages for 48h; 4) sleep enough during the previous night, and 5) avoid exercise and strenuous physical loads for 48h before the measure [15]. After a 15-min supine rest the R-R intervals were recorded over 5-min with a Polar recorder (Polar NV, Kempele, Finland). The high-frequency power (HF, power in the 0.15 – 0.40 Hz band) was calculated to reflect Frequency Domain (FD) and the Square Root of the Mean Squared Differences of Successive Normal-to-Normal Intervals (RMSSD) to reflect Time Domain (TD). The FD and TD indexes are expressed as absolute values (ms²/Hz and ms, respectively). The breathing frequency was not controlled [16].
hs-CRP analysis

Blood samples were collected from participants in the morning (between 8 and 11 a.m.), after a 12-hour fast, before and after intervention. The last blood sample was collected at least 24 hours before the last acute bout of exercise training. All blood was collected, processed, divided into aliquots, and stored at 80°C until analysis. According to manufacturer’s instructions, Serum C-reactive protein (CRP) levels were measured using a highly sensitive assay (Dade Behring Cardio Phase-s-CRP using the Behring Nephelometer BNI; Dade Behring, Marburg, Germany).

Physical fitness assessment

Physical fitness was assessed using the six-minute walk test (6MWT), which is a commonly used physical performance measure in research [17], particularly to obtain valid measures of sub maximal (80% VO2max) physical endurance in older adults [18,19]. This test measures the distance covered when subjects are instructed to walk as quickly as they can for six minutes. Walks were conducted in a flat fifty-meter rectangular course, marked off in five-meter segments. If necessary, subjects were allowed to stop and rest.

Habitual physical activity and dietary intake

Participants were instructed not to change their daily-living PA routines or dietary patterns during the course of the study. To confirm that older adults did not modify their routines, their PA was also assessed before and after the four-month period.

Habitual physical activity

Habitual physical activity levels were assessed using accelerometers (Actigraph GT1M, Actigraph LLC, Pensacola, FL) as an objective measure of daily physical activity, using a minute measurement interval (epoch). Participants were instructed to wear the accelerometer over their right hip for a seven-day period (five weekdays and two weekend days). Exceptions included time spent sleeping, showering, and participating in water-based activities. Participants were asked to maintain usual activities and record them in a diary. To the best of our knowledge, there are no appropriate cut-point values that represent meaningful intensity categories (sedentary, moderate, and vigorous) in older adults; therefore, in the current study, physical activity levels were expressed as the average counts per minute over the seven days.

Statistical analysis

Univariate, bivariate, and multivariate analyses were conducted, respectively. When data was not normally distributed, transformations or the use of non-parametric statistics were used. Baseline characteristics between groups were compared using a one-way ANOVA test with Turkey’s post hoc test. To detect changes within groups (before vs. after) the paired t-test was employed. General linear models were used with Time (before and after interventions/observation) as a within-subject factor, Group (ST, AT, and WL) as a between-subjects factor, and gender as a covariate. These analyses intended to verify whether the variances observed before and after intervention/observation could be attributed to training and whether the variances observed between interventions were different. Skewed variables were logarithmically transformed when appropriate. All data was analyzed using SPSS 17.0 for Windows.

RESULTS AND DISCUSSION

Results are shown as mean with standard deviations (M±SD; parametric data). Values correspond to body composition, blood pressure and HR at rest, HRV, hs-CRP, measures of physical fitness, and PA of the fifty-four older adults who reached inclusion criteria, completed the interventions, and attended all tests and protocols. The ST group was comprised of fourteen subjects, six men and eight women with a mean age of 67.3±4.9 years. In this group, six individuals had controlled hypertension, four had dislipidemia, three were diabetic, two were former smokers and one was on Hormone Replacement Therapy (HRT). The AT had twenty subjects, three men and seventeen women, who were 69.2±5.7 years. Nine of them were hypertensive, ten had dislipidemia, and two were diagnosed as diabetic. Two individuals in AT previously smoked and three were in HRT. Finally, the WL group was comprised of twenty subjects, four men and sixteen women, with a mean age of 67.8±5.5 years. In this group, thirteen individuals had controlled hypertension, seven had dislipidemia, six had controlled diabetes, and two of them were former smokers. (Table 1) presents the M±SD obtained by the older adults before (baseline) and after intervention/observation as well as the differences that were observed between groups at baseline. After training, both AT and ST groups demonstrated diminished %BF and reduced trunk fat. No differences were observed in body composition parameters for WL. Concerning BP, low levels of SBP were found in all study groups, after training and observation periods. On the other hand, low levels of DBP were just observed for AT and WL. No differences were observed in measures of HRrest and HRV before and after training/observation. Similarly, serum levels of hs-CRP did not change after interventions. A better performance on the 6MWT was achieved in AT (almost 43m) and in ST (almost 31m), nevertheless no differences were observed in WL. Finally, training groups increased their habitual PA, after training. Despite randomization, few differences were observed when groups were compared at baseline. At this time, ST had a higher HF component of HRV than AT (P=0.03) and WL (P=0.01). ST also had a lower HRrest (P=0.02) and a better performance in the 6MWT (P<0.01) than WL. General linear models (Table 2) demonstrate that interventions (time) explained 17.5%, 24.6%, 33.9%, 15.4%, and 15.3% of %BF, trunk fat, SBP, DBP variances, respectively. Interactions between time and group (time*group) indicated that for %BF (P<0.01) and trunk fat (P=0.03) variances within groups were not the same. Interactions between time and gender (time*gender) were just observed for SBP variances. The results of this study suggest that four months of moderate to high-intensity aerobic or strength training has a positive effect on body composition, PA, and aerobic fitness of apparently healthy older adults that are translated in a diminished total and trunk fat content, increased habitual PA, and in a better performance on 6MWT after the training period. However, training regimens do not have substantial effect on HRrest, BP, vagal tonus assessed by HF and RMSSD nor on subclinical inflammation assessed by hs-CRP. The current findings extend those of previous studies in several ways. First, it is generally accepted that both AT [11] and ST [9,10] decrease percentage of total body fat and trunk fat...
Table 1: Characteristics of the sample and outcomes at baseline (before) and after training (strength or aerobic) or observation (waiting list). Values normally distributed are represented by means with standard deviations and values not normally distributed are represented by medians with percentiles 25 and 75 (25th – 75th percentiles).

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>ST (n=14)</th>
<th>AT (n=20)</th>
<th>WL (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>Body composition</td>
<td>28.6</td>
<td>28.1</td>
<td>27.9</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>34.7</td>
<td>33.5*</td>
<td>38.5</td>
</tr>
<tr>
<td>%BF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk fat (kg)</td>
<td>11.7</td>
<td>10.9*</td>
<td>12.4</td>
</tr>
<tr>
<td>Blood Pressure(mmHg) and Heart Rate(bpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP prest</td>
<td>132.7</td>
<td>124.0*</td>
<td>137.2</td>
</tr>
<tr>
<td>DBP prest</td>
<td>72.6</td>
<td>70.4</td>
<td>72.5</td>
</tr>
<tr>
<td>HR prest</td>
<td>61.6†</td>
<td>64.3</td>
<td>66.4</td>
</tr>
<tr>
<td>Heart-rate Variability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF, ln (ms²/Hz)</td>
<td>2.55†‡</td>
<td>2.34</td>
<td>2.07</td>
</tr>
<tr>
<td>RMSSD, ln</td>
<td>1.56</td>
<td>1.42</td>
<td>1.31</td>
</tr>
<tr>
<td>hs-CRP, ln</td>
<td>-0.69</td>
<td>-0.73</td>
<td>-0.72</td>
</tr>
<tr>
<td>Physical fitness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6MWT (m)</td>
<td>616.4†</td>
<td>647.9*</td>
<td>545.0</td>
</tr>
<tr>
<td>Physical Activity levels(counts/min)</td>
<td>367.4</td>
<td>424.9*</td>
<td>324.1</td>
</tr>
</tbody>
</table>

Abbreviations: BMI – Body Mass Index; %BF – Percent of Body Fat; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure; HR – Heart-Rate; HF – High-Frequency Power; RMSSD – Square Root of the Mean Squared Differences of Successive Normal-to-Normal Intervals; Hs-CRP – High-Sensitive C-Reactive Protein; 6MWT – Six-Minute Walk Test.

*Differences between before and after interventions/observation; † Differences between ST and WL, at baseline; ‡ Differences between ST and AT, at baseline (p<0.05).

Table 2: General Linear Models with Time (before and after interventions/observation) as within-subject factor.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>F</th>
<th>P</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body composition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>1.55</td>
<td>0.22</td>
<td>0.03</td>
</tr>
<tr>
<td>%BF</td>
<td>11.84</td>
<td>&lt;0.01</td>
<td>0.18</td>
</tr>
<tr>
<td>Trunk fat</td>
<td>18.24</td>
<td>&lt;0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>Blood Pressure and Heart Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP prest</td>
<td>28.76</td>
<td>&lt;0.01</td>
<td>0.34</td>
</tr>
<tr>
<td>DBP prest</td>
<td>9.01</td>
<td>&lt;0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>HR prest</td>
<td>0.37</td>
<td>0.54</td>
<td>0.01</td>
</tr>
<tr>
<td>Heart-rate Variability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF, ln</td>
<td>1.03</td>
<td>0.32</td>
<td>0.02</td>
</tr>
<tr>
<td>RMSSD, ln</td>
<td>2.66</td>
<td>0.11</td>
<td>0.05</td>
</tr>
<tr>
<td>hs-CRP, ln</td>
<td>0.62</td>
<td>0.44</td>
<td>0.02</td>
</tr>
<tr>
<td>Physical fitness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6MWT</td>
<td>9.01</td>
<td>&lt;0.01</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Abbreviations: BMI – Body Mass Index; %BF – Percent of Body Fat; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure; HR – Heart-Rate; HF – High-Frequency Power; RMSSD – Square Root of the Mean Squared Differences of Successive Normal-to-Normal Intervals; Hs-CRP – High-Sensitive C-Reactive Protein; 6MWT – Six-Minute Walk Test.

Content in individuals with a wide range of ages. Secondly, improvements in aerobic capacity after AT [16,20,21] and ST [22] were also observed in other studies. In addition, many studies [20,23] verified lower levels of SBP and DBP after exercise training. However, in this study we cannot affirm that the lowering effect in BP was related to training once the WL group did no exercise and also demonstrated a reduced SBP and DBP after the four-month study period. Results concerning HRV and hs-CRP in older ages are more conflicting in literature. The term heart-rate variability means the oscillations between consecutive instantaneous normal-to-normal RR intervals and represents vagal and sympathetic cardiac control [16]. The HF and RMSSD indexes have been chosen to assess HRV because it is well accepted they reflect uniquely vagal control, while the lower frequencies reflect unknown physiologic responses with no determined mixes of vagal and sympathetic control [5,10]. In this study, low-grade inflammation was assessed by CRP since high concentrations of this protein beyond a prominent biomarker of low-grade chronic inflammation [12,24]. It is related with several cardiovascular disease risk factors including smoking, blood pressure, diabetes, BMI, abdominal adiposity (7), and HRV parameters (5). As mentioned above, results from prospective studies investigating the effects of training on HRV of apparently healthy individuals are inconclusive. Some researches [16,20,21],
as the present, observed no effect of training on HRV while others have [9,15]. Another point that should be considered is that results of previous studies are limited by having no control group, small sample size, only men included in the study sample, different mean age of the study sample, use of different protocols when assessing HRV (equipments, recording period, HRV indexes), and designing training (volume, intensity, frequency, type). Therefore, it is difficult to compare and generalise the results. Studies reinforcing our HRV results include Perini, Fisher et al. [20] in which eighteen subjects exercised (in cycle ergometers, at an intensity of 40-100% of their maximum) three times per week, for 60 minutes per session, during eight weeks. After training no changes in body composition nor in resting HR occurred. The same was true for total power LF and HF power components. Resting BP and DBP decreased after training and aerobic power and exercise capacity increased [20]. Loimaala, Huikuri et al. [21] studied 83 Finnish apparently healthy sedentary men (35-55 years) who were randomised into moderate-intensity aerobic training (60% of their VO_{2max}), high-intensity aerobic training (75% of the VO_{2max}) or controls. Training sessions were 4-6 times per week, and the duration of the study was five months. After intervention, HR decreased, VO_{2max} and endurance time increased in high-intensity training compared with the controls, no significant changes were observed in either time or frequency domain measures of HRV (SDNN, pNN50 and HF). Schuit, van Amelsvoort et al. [10] observed an increase in total 24-h HRV (SDNN measured by 24-h ECG) and in the very low and low-frequency component, after six months of training (mainly aerobic training, 60-80% of maximum capacity), in older subjects (N=51, 60-80 years). However, no differences were observed in the HF domain, as in the study by Uusitalo, Laitinen et al. [16] in which a sample of 89 apparently healthy men (57.4±2.9 years) was randomised into a control and training group. Training group and controls were followed-up for a period of five years. During this period, the exercising group trained three times per week (mainly aerobic training), 45-60 minutes each session, at an intensity corresponding to 40-60% of their VO_{2max}. After five years, individuals in the training group demonstrated a higher aerobic fitness. However, no differences were observed in autonomic regulation (measured by five-minute recordings), BMI nor in waist/hip circumference [16]. On the other hand, Tulppo, Hautala et al. [15] designed a study to examine the effects of aerobic training and training volume on time domain and on spectral and fractal HR dynamics over a 24-h period (assessed by Polar R-R recorder) in 55 healthy sedentary men. The training period was eight weeks, including six sessions per week at an intensity of 70-80% HR_{rest} lasting for 30 minutes each session in the moderate-volume group and 60 minutes each session in the high-volume group. These authors observed that aerobic training results altered autonomic regulation of HR toward vagal dominance (increased HF and reduced LF, both in normalised units). Another study [9] demonstrated that regular endurance training (three to four days per week, during 30 weeks) results in a marked increase in VO_{2max}, small reductions in body weight and body fat, lowered HR_{rest}, and in an increased HRV (index of cardiac vagal tone) in middle-aged older men. As we can see most studies focused the effects of aerobic training on HRV, nonetheless, few studies aimed to verify the effects of strength training on HRV and their results are also conflicting. Two studies [23-25] were found targeting whether strength training improves cardiac autonomic control in healthy older adults with conflicting results. One of them [23] (N=9, 60-69 years) demonstrated that 12 weeks of isokinetic eccentric strength training (two days per week, 2-4 sets of 8-12 reps. at 75-80% peak torque) involving knee flexion and knee extension leads to an autonomic imbalance towards a sympathetic modulation predominance (LF increase and HF decrease). Additionally, no changes in weight, BMI, HR_{rest} and DBP were found while a decrease in SBP was observed. The second [26], demonstrated no training influence on HRV after 8-month high-intensity (80% 1RM) strength training. As observed with HRV, there are only a few prospective studies investigating the effects of training on inflammation in healthy individuals and the number is even smaller when just the studies focused on older adults are considered. Nicklas, Hsu et al. [24] observed that after long-term (12months) moderate-intensity exercise intervention aiming to verify the effects of training on two prominent biomarkers of inflammation (CRP and interleukin-6; IL-6) in elderly men and women, training did not affect CRP, in accord with current results, but lowered systemic concentrations of IL-6. Authors cited the fact there is a non-observation of fat reduction in their sample after intervention as a possible explanation to the lack of training effect on CRP [27]. Conversely, Stewart, Flynn et al. [28], observed cardio respiratory fitness improvements and a significant decrease in serum CRP concentration after the 12-week exercise training intervention (mixing aerobic and strength training, three times per week) despite no observed changes in %BF. Wanderley et al. [26] demonstrated that 8 months of high-intensity aerobic or strength training is effective in diminishing %BF in healthy older adults. However, just aerobic training reduced hs-CRP of older adults at great CVD risk (hs-CRP >3.0 mg/dL). In the present study, training reduced %BF and trunk fat (measure of central fat) and no changes were observed in CRP. These findings in association with Nicklas, Hsu et al. [24], Wanderley et al. [26] and Stewart, Flynn et al. [28] suggest that reduced inflammation and body fat are positive but independent effects of training or perhaps the present training duration and/or volume were not sufficient to observe effects on low-grade inflammation. Another possible explanation for an independent exercise effect of adiposity, inflammation, and autonomic imbalance could be the recent concept of metabolic inflexibility that was reviewed by Bergouignan et al. [29]. Authors suggest that in diseased populations (obese, insulin resistant and diabetic) the adaptation caused by the metabolic deregulation is not normalised after weight and fat loss. The same could be true for an older population that generally presents insulin resistance, high blood pressure values, dislipidemia and autonomic imbalance. Although there are several strengths such as the inclusion of two different types of high-intensity exercise training and the use of DXA to assess body composition, this study also has some limitations: the breathing frequency was not measured when evaluating HRV; the relatively short duration of the intervention; the convenience of small sample size. Additionally, it would be important to consider for follow-up research the assessment of a broad number of inflammatory biomarkers as well the assessment of HRV and HR in exercise situations. A more prolonged period of intervention is also recommended. Finally, many recent studies have explored the associations and the
influence of sedentary behaviour and adiposity on inflammation and its associated chronic conditions and have demonstrated that sedentary behaviour is an independent predictor of metabolic risk, even when exercise is performed at a level that meets current recommendations [6,29,30]. Therefore, an interesting focus of future research might be to define cut-off points to the sedentary behaviour in older adults and also explore the effect of sedentary time of older adults, even when they are considered as exercisers.

CONCLUSION

In summary, taking into account strengths and limitations, the findings demonstrate that four months of high-intensity aerobic or strength training can reduce total and trunk fat content and improve aerobic fitness and habitual PA; all of them are believed to lower the risk of developing chronic conditions. However, training regimens do not have substantial effect on HRrest, BP, or strength training can reduce total and trunk fat content and influence of sedentary behaviour and adiposity on inflammation and its associated chronic conditions and have demonstrated that sedentary behaviour is an independent predictor of metabolic risk, even when exercise is performed at a level that meets current recommendations [6,29,30]. Therefore, an interesting focus of future research might be to define cut-off points to the sedentary behaviour in older adults and also explore the effect of sedentary time of older adults, even when they are considered as exercisers.

ACKNOWLEDGEMENTS

The authors would like to thank the volunteers of this study. Without their selfless contribution, this study would not have been possible. This work was supported by the Portuguese Foundation for Science and Technology (grant numbers, PTDC/DES/108780/2008 and SFRH/BD/33124/2007).

REFERENCES


