A Randomized Study on Lipids Response to Different Exercise Programs in Overweight Older Men

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Abstract ▼

This study compared the effects of 2 long-term training programs on blood lipid profiles in overweight older adults. 59 older men with BMI ≥ 25 and < 35 kg/m² ages 65–75 years were randomly assigned to an aerobic training group (ATG, n = 19), a mixed aerobic and resistance training group (MTG, n = 20), or a control group (n = 20). Both programs were moderate-to-vigorous intensity, involving 60-min training sessions 3 days/week for 32 weeks. Blood lipids were measured on 5 different occasions. Repeated measure ANCOVA was used for primary data analysis, and the independence between blood lipids variables and group factor was tested. Pre-to-post mean values of triglycerides, total cholesterol and low-density lipoprotein decreased in both ATG and MTG (−10.1 and −25.8, −1.0 and −17.6, −8.9 and −17.2 mg/dl, respectively), but not significantly. There was a significant association for triglycerides (P = 0.025) and total cholesterol (P = 0.025) in the MTG (baseline vs. post-test), with significant individual lipid profile modifications. The number of individuals with clinically high triglycerides and total cholesterol significantly decreased after the mixed training program. Combined aerobic and resistance training was more effective in the chronic modification of lipid profile.

Trial Registration: clinicaltrials.gov Identifier: NCT01874132

Introduction ▼

Dyslipidemia, particularly high serum levels of triglycerides (TGC), total cholesterol (Total-c), and low serum levels of high-density lipoprotein cholesterol (HDL-c), is known to be an important risk factor for cardiovascular morbidity and mortality among older population [12, 15, 17, 26]. In addition, overweight and obesity are highly associated with the major cardiovascular diseases risk factors, including dyslipidemia [15, 17]. Body mass index (BMI) is widely used as a surrogate measure of overweight and obesity. In adults, overweight is defined by a BMI ranging from 25 to 29.9 kg/m², and obesity is defined by a BMI of ≥30 kg/m² [17]. It can therefore be assumed that an intervention which combines BMI reduction and positive changes in blood lipid profiles would be highly effective in preventing cardiovascular diseases [1, 5, 16].

Traditionally, aerobic training has been proposed as an effective tool for improving cardiovascular protection, inducing positive changes in BMI [10, 18]. Additionally, the beneficial effects of aerobic training on blood lipid profiles are now consensually established [8, 14, 19, 23]. Due to the known benefits of aerobic training, the National Cholesterol Education Program recommendation calls for 30 min of regular moderate-intensity exercise such as walking, biking, and swimming activity on most days, if not all [15]. Furthermore, the American College of Sports Medicine exercise recommendations for older adults state that resistance training must be added to aerobic training once or twice a week, since it enhances muscular strength and functional capacity, and prevents sarcopenic obesity [7]. Nevertheless, there are few studies on the effects of resistance training in older adults lipid profiles, the most recent having shown little effectiveness in modifying lipid profiles [20, 22]. Some studies combining aerobic and resistance training have shown positive changes in older adults’ lipid profiles [24, 25, 27, 28]. However, to the best of our knowledge, only one study examining older individuals [3] was designed to ascertain whether improvements were due to a single exercise mode or to an additive effect of another one in combination (aerobic or resistance training mode). Therefore, the purpose of this study...
was to compare an aerobic training program with a mixed mode training program over long-term changes on blood lipids in overweight older men.

Materials and Methods

Participants
59 older men with BMI ≥ 25 and < 35 kg/m² ages 65–75 years (mean age 69.1 ± 5.0 years), living independently and in the same city (Maia, Portugal) were recruited to voluntarily participate in the study. The participants were randomly assigned to 3 groups: 19 to an aerobic training group (ATG); 20 to a mixed (aerobic and resistance) training group (MTG); and 20 to a non-exercising control group (CON). A summary of the recruitment strategy and allocation is presented in Fig. 1.

All participants received medical approval to participate in the study. Exclusion criteria included the following: smoking; diabetes; severe hypertension; history of falls, neurological, mental or cognitive disorders, and orthopedic, pulmonary or cardiac problems (e.g. arrhythmias, history of angina, myocardial infarction, coronary bypass surgery, valvular disease) that could restrict their activity. Additionally, none of the participants had a previous history of exercise training or recreational sports, and the CON did not participate in any structured exercise during the study period.

None of the participants was using lipid-lowering drugs or others that would alter vascular function, and all were instructed to continue their normal diet during the course of the study. Furthermore, participants did not receive any nutritional counseling. Both verbal and written consent were obtained from each participant before testing and training, and all were informed of the objectives, procedures and potential risk or discomfort. The ethics review board for human investigation of the University of Trás-os-Montes e Alto Douro granted approval for this study (ref. 001.032011). All regulations for the protection of human participants were followed in accordance with the Declaration of Helsinki as well as the international ethical standards according to Harriss and Atkinson [9].

Training program protocols
The training programs were developed with the aim of improving all components of functional fitness, in accordance with the methods previously reported [2, 21]. Both consisted of 3 sessions each week for 32 consecutive weeks and were planned for moderate-to-vigorous intensity. According to the current position of the American College of Sports Medicine [7], moderate intensity represents a perceived exertion of 12–13 points (Borg scale of 6–20) [4] and a range on 50–69% of one-repetition maximum (1-RM). The vigorous intensity represents a perceived exertion of 14–17 points and a range of 70–84% of 1-RM.

Fig. 1 Consolidated Standards of Reporting Trials diagram showing the flow of participants through the study.
The average adherence rate to all training sessions was 82% in the ATG and 86% in the MTG. However, the participants were informed that a minimum of 77 sessions during the 32 weeks (80% compliance) was required to be included in the analysis. Before training, all participants received 2 weeks of familiarization sessions with the training equipment and exercises to be used in the intervention. All sessions lasted approximately 60 min and were always supervised by a professionally qualified instructor.

**Aerobic training program:** The ATG trained twice per week in a land environment (Mondays and Wednesdays) and once per week in an aquatic environment (Fridays), with training sessions separated by a minimum of 48 h. This program was divided into 4 microcycles with different routines applied every 8 weeks (microcycle I: weeks 1–8; II: weeks 8–16; III: weeks 16–24; IV: weeks 24–32). All aerobic training sessions consisted of: (i) a 10-min warm-up period, which included walking and flexibility exercises; (ii) a 30-min cardiorespiratory period, including walking and/or jogging and/or dancing patterns, with intensity perceived as moderate; (iii) a 10-min muscular endurance, which included 3 exercises (3 sets, 15–20 repetitions) using only bodyweight and gravity for strengthening the lower and upper limbs in a land environment, and water resistance in an aquatic environment; and (iv) a 5-min cool-down period, which included breathing and stretching exercises. When the aerobic training sessions were carried out exclusively in the aquatic environment, agility exercises were carried out in an informal game format (e.g., relay races, water volleyball and water polo), lasting approximately 10 min. These were carried out after the flexibility workout and before the cool-down period.

**Mixed mode training program:** The training sessions for the MTG included the same format as aforementioned. However, the aerobic training sessions on Mondays were replaced by a resistance training session. The intensity of the resistance training session was set to 65% of 1-RM on the first 8 weeks (3 sets, 10–12 repetitions); 75% of 1-RM for weeks 8–24 (3 sets, 8–10 repetitions); 70% of 1-RM for weeks 24–28 (3 sets, 8–10 repetitions); and 65% of 1-RM for weeks 28–32 (3 sets, 10–12 repetitions). Rest periods were 30 s between sets and 1 min between exercises. Each session always began with a 10-min warm-up on either a bicycle ergometer or treadmill at low-work level, followed by static stretching exercises. The main part of the sessions consisted of a circuit of 7 exercises: bench press, leg press, lateral pull-down, leg extension, military press, leg curl and arm curl, in this order and carried out with conventional variable resistance devices (PANATTA, Fitline 2000 series, Italy). In addition, the participants carried out floor exercises for the abdominals and erector spinae muscle groups, and ended with a cool-down period, which included breathing and stretching exercises. As it was expected that participants increase their maximum strength, 1-RM values were taken at the first workout of week 1, week 8, week 16 and week 24, and at the last workout of week 32, allowing periodic adjustment of the resistance training intensity. The 1-RM test was measured only for the MTG and always by the same instructor.

In order to control the target intensity of the different training programs, the values of perceived exertion using the Borg scale were recorded by all participants at all training sessions.

**Measurements**

The measurements were performed in the morning following an overnight fast, in a quiet room with an ambient temperature of 22°C and always by the same technicians. Each participant reported to the facilities at 7 a.m. on 5 separate occasions (baseline, after 8 weeks, after 16 weeks, after 24 weeks, and after 32 weeks). Participants did not perform physical exercise, and abstained from alcohol and caffeine consumption for at least 24 h before testing. They were additionally not feverish or dehydrated.

Height and weight were measured on a standard scale with a stadiometer (SECA 770, Seca Corporation, Hamburg, Germany), and BMI was further calculated using the standard formula: weight (kg)/height^2 (m).

**Blood samples:** Peripheral blood samples were drawn with participants in a seated position. Venous blood samples were obtained from the antecubital vein and then placed on ice, allowed to clot and transported to a reference laboratory (LabMED, Portugal) for analysis. In the laboratory, the blood samples were centrifuged (Advia 1650; Siemens, Frimley, UK) at 3800 rpm (2870 g) for separation of serum. Serum lipid TGC, Total-c, HDL-c and low-density lipoprotein cholesterol (LDL-c) were analyzed by enzymatic techniques (Boehringer Mannheim, Mannheim, Germany).

**Statistical analysis**

Normal distribution was tested with the Shapiro-Wilk test, and the skewness and kurtosis indices were analyzed. Because of its nonparametric distribution, a logarithmic transformation was applied to the TGC and HDL-c. However, the results are presented in the original units for comparison with other studies. Analysis of Covariance (ANCOVA) was used to determine whether significant differences existed between the control and experimental groups in post-test measurements, with baseline measurements used as covariates in the analysis. The effects of time and group*time interaction for BMI, TGC, Total-c, HDL-c and LDL-c were determined by using repeated-measures ANCOVA with baseline as the covariate. A Bonferroni test was used for post-hoc comparisons.

To analyze the pre-to-post risk factor changes independently of pre-to-post mean changes, the independence of TGC, Total-c, LDL-c and HDL-c were determined by using repeated-measures ANCOVA with baseline as the covariate. A Bonferroni test was used for post-hoc comparisons.

Results

Fig. 1 shows the flow of participants through the study. A total of 48 participants completed the study and were included in the analysis.

The arithmetic mean of perceived exertion reported gradually increased from 11.0 ± 2.9 to 12.9 ± 1.5 points in the land-based aerobic training, 13.2 ± 0.7 to 13.7 ± 0.8 points in the aquatic aerobic training, and 13.4 ± 1.3 to 14.1 ± 1.5 points in the resistance...
training. No significant differences were observed between intensities.

Descriptive characteristics at baseline and absolute changes during the study period are shown in Table 1. All study groups had overweight BMI values (25–29.9 kg/m²) over the entire course of the study. At baseline no significant differences across groups were observed in BMI and lipid profiles. Repeated-measures ANCOVA with baseline as covariate was used to analyze the data. There were no significant effects of group or time for BMI or inter-group * time interaction in BMI and for the blood lipids variables (Table 1). There were no significant associations for TGC, Total-c, LDL-c and HDL-c in the ATG (X²=0.0, P=1.000, X²=2.0, P=0.361, X²=2.3, P=0.522 and X²=1.0, P=0.595, respectively) and CON (X²=3.3, P=0.191, X²=0.5, P=0.776, X²=0.6, P=0.896 and X²=0.8, P=0.660, respectively), i.e., the number of subjects at risk of dyslipidemia did not change. However, the X² test identified a significant association for TGC and Total-c in the MTG (X²=7.4, P=0.025 for both), but not for the LDL-c and HDL-c (X²=6.5, P=0.088 and X²=2.7, P=0.256, respectively). For the MTG participants, the adjusted residuals revealed significant favorable modifications (baseline vs. week 32) in TGC and Total-c. After 32 consecutive weeks of combined training, the counts observed in the High Levels category for TGC and Total-c significantly decreased compared to baseline (25.0% vs. 0.0% and 37.5% vs. 0.0% for TGC, Total-c, respectively). Table 2 shows the summary of the cross tabulation for TGC and Total-c categories in the MTG.

**Table 1** Body mass index (BMI), triglycerides (TGC), total cholesterol (Total-c), low-density lipoprotein cholesterol (LDL-c) and high-density lipoprotein cholesterol (HDL-c) measurements for the aerobic training group (ATG, n=15), mixed model training group (MTG, n=16) and control group (CON, n=17), over 32 weeks.

<table>
<thead>
<tr>
<th></th>
<th>baseline</th>
<th>week 8</th>
<th>week 16</th>
<th>week 24</th>
<th>week 32</th>
<th>P-values *</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI (Kg/m²)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATG</td>
<td>28.0 ± 3.5</td>
<td>27.9 ± 3.5</td>
<td>27.5 ± 4.0</td>
<td>27.3 ± 4.4</td>
<td>28.2 ± 3.5</td>
<td>0.345</td>
</tr>
<tr>
<td>MTG</td>
<td>26.4 ± 2.5</td>
<td>26.6 ± 2.8</td>
<td>26.6 ± 2.4</td>
<td>26.6 ± 2.4</td>
<td>26.3 ± 2.7</td>
<td>0.768</td>
</tr>
<tr>
<td>CON</td>
<td>27.1 ± 3.2</td>
<td>27.1 ± 3.9</td>
<td>27.9 ± 3.4</td>
<td>27.4 ± 3.2</td>
<td>27.4 ± 3.0</td>
<td>0.213</td>
</tr>
<tr>
<td><strong>TGC (mg/dl)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATG</td>
<td>114 ± 56.6</td>
<td>86.5 ± 31.6</td>
<td>103 ± 31.7</td>
<td>101 ± 26.7</td>
<td>104 ± 59.7</td>
<td>0.682</td>
</tr>
<tr>
<td>MTG</td>
<td>112 ± 56.8</td>
<td>101 ± 43.4</td>
<td>91.8 ± 32.4</td>
<td>96.4 ± 35.7</td>
<td>86.5 ± 35.7</td>
<td>0.432</td>
</tr>
<tr>
<td>CON</td>
<td>93.5 ± 32.1</td>
<td>117 ± 48.8</td>
<td>122 ± 71.3</td>
<td>110 ± 66.1</td>
<td>107 ± 54.2</td>
<td>0.657</td>
</tr>
<tr>
<td><strong>Total-c (mg/dl)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ATG</td>
<td>194 ± 31.3</td>
<td>195 ± 28.7</td>
<td>200 ± 15.6</td>
<td>196 ± 21.2</td>
<td>193 ± 27.3</td>
<td>0.379</td>
</tr>
<tr>
<td>MTG</td>
<td>207 ± 30.7</td>
<td>205 ± 40.1</td>
<td>195 ± 32.8</td>
<td>196 ± 32.7</td>
<td>189 ± 26.9</td>
<td>0.449</td>
</tr>
<tr>
<td>CON</td>
<td>191 ± 30.5</td>
<td>196 ± 27.0</td>
<td>210 ± 23.5</td>
<td>202 ± 25.6</td>
<td>200 ± 25.5</td>
<td>0.721</td>
</tr>
<tr>
<td><strong>LDL-c (mg/dl)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATG</td>
<td>126 ± 24.4</td>
<td>120 ± 25.2</td>
<td>125 ± 11.9</td>
<td>122 ± 15.5</td>
<td>117 ± 19.0</td>
<td>0.779</td>
</tr>
<tr>
<td>MTG</td>
<td>137 ± 30.5</td>
<td>127 ± 31.8</td>
<td>125 ± 23.9</td>
<td>122 ± 23.3</td>
<td>120 ± 23.1</td>
<td>0.841</td>
</tr>
<tr>
<td>CON</td>
<td>128 ± 22.8</td>
<td>120 ± 20.6</td>
<td>133 ± 23.0</td>
<td>122 ± 22.5</td>
<td>125 ± 22.6</td>
<td>0.964</td>
</tr>
<tr>
<td><strong>HDL-c (mg/dl)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATG</td>
<td>52.5 ± 6.8</td>
<td>52.4 ± 7.2</td>
<td>50.7 ± 7.8</td>
<td>48.4 ± 6.0</td>
<td>48.7 ± 6.3</td>
<td>0.642</td>
</tr>
<tr>
<td>MTG</td>
<td>56.1 ± 13.0</td>
<td>52.6 ± 12.4</td>
<td>52.1 ± 10.4</td>
<td>52.4 ± 10.5</td>
<td>52.0 ± 9.4</td>
<td>0.720</td>
</tr>
<tr>
<td>CON</td>
<td>52.5 ± 12.1</td>
<td>51.0 ± 10.5</td>
<td>51.9 ± 12.1</td>
<td>53.3 ± 12.5</td>
<td>52.1 ± 13.3</td>
<td>0.996</td>
</tr>
</tbody>
</table>

*Significance level of ANCOVA with baseline as covariate

Values represents means ± standard deviation. G = group; T = time; G*T = group*time interaction

**Table 2** Cross tabulation for triglycerides and total-cholesterol categories in the mixed model training group (baseline vs. week 32).

<table>
<thead>
<tr>
<th></th>
<th>Triglycerides</th>
<th>Total-cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>baseline</td>
<td>week 32</td>
</tr>
<tr>
<td><strong>desirable</strong> ^a  n</td>
<td>10</td>
<td>16 (100%)</td>
</tr>
<tr>
<td><strong>adjusted residuals</strong></td>
<td>-1.8</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>high normal</strong> ^b n</td>
<td>2</td>
<td>0 (0%)</td>
</tr>
<tr>
<td><strong>adjusted residuals</strong></td>
<td>1.5</td>
<td>-1.5</td>
</tr>
<tr>
<td><strong>high</strong> ^c n</td>
<td>4</td>
<td>0 (0%)</td>
</tr>
<tr>
<td><strong>adjusted residuals</strong></td>
<td>2.1*</td>
<td>-2.1*</td>
</tr>
</tbody>
</table>

^aTGC<150 mg/dl, Total-c<200 mg/dl [15], ^b TGC=150–199 mg/dl, Total-c=200–239 mg/dl [15], ^c TGC≥200 mg/dl, Total-c≥240 mg/dl [15], ^p<0.05

identified in the MTG, particularly the positive pre-to-post variation of TGC and Total-c classification.

Blood lipids are affected by non-modifiable risk factors including sex, age, and genetics [15]. On the other hand, dietary habits (particularly the amount of saturated fat and dietary cholesterol), physical activity and body weight are considered modifiable factors. In the present study, diet was not controlled, exercise was increased and BMI remained unchanged. There was no intra-group change in BMI throughout the 32 weeks of training, suggesting that the reduction in the lipid profiles risk might be independent of loss of body weight, which is in conflict with other studies [11, 28].

More favorable changes in response to training occur usually in those with more pronounced dyslipidemia at baseline. Given the clinically normal baseline mean levels of TGC, Total-c, LDL-c and HDL-c, more favorable changes in response to training occurred typically in those with more pronounced dyslipidemia at baseline.

**Discussion**

In this study the pre-to-post mean values of blood lipids did not change with exercise, regardless of the exercise mode considered. However, a significant change in the lipid profiles risk was
HDL-c in the participants of the present study, it is not surprising that there were no significant change in pre-to-post mean values. Nevertheless, both training groups presented reductions of TGC (−10.1 and −25.8 mg/dl in the ATG and MTG, respectively), Total-c (−1.0 and −17.6 mg/dl in ATG and MTG, respectively) and LDL-c (−8.9 and −17.2 mg/dl in ATG and MTG, respectively) unlike CON (+13.5 and +8.7 mg/dl in TGC and Total-c, respectively). The length of both training programs, 32 weeks, which can be considered as a long-duration intervention, might represent a dependent variable that, by itself, increased the possibility of inducing consistent changes in lipid profile. Traditionally, most studies on older adults lipid profiles response to exercise have short duration. We found only one study over 30 weeks (36 weeks exactly, with low aerobic training intensity), which also reported decreases in TGC, Total-c and LDL-c without being statistically significant, but with a significant increase in HDL-c [14]. According to the National Cholesterol Education Program [15] and to the last task force for the management of dyslipidemias of the European Society of Cardiology and the European Atherosclerosis Society [6], the decrease in LDL-c values is considered the first target for the improvement of lipid profiles among older adults. The elevated plasmatic concentration of LDL-c is an important trigger factor for atherosclerosis [1,17]. In this study both training groups decreased the HDL-c values (−7% and −8% for ATG and MTG, respectively). Nevertheless, both groups completed the study with normal HDL-c values (40–60 mg/dl) and with a favorable LDL-c/HDL-c ratio.

In the MTG, significant individual modifications were identified in TGC and Total-c after 32 weeks of training, with a significant reduction in the number of participants classified as having high levels (TGC<200 mg/dl and Total-c ≥240 mg/dl) [15]. The same was not observed in the ATG, suggesting that aerobic training was not as effective in modifying lipid profiles as when combined with resistance training.

It might be suggested that exercise intensity influenced the different responses from the groups. The current exercise recommendations for older adults state that aerobic training of moderate to vigorous intensity should be performed at least 3 times a week, and resistance, complemented by 2 weekly sessions of resistance training [7]. However, many participants could not comply with that exercise frequency. Therefore, the present study tested whether the substitution of one session of aerobic training with one session devoted to resistance training could have an additive effect to those observed in response to aerobic training alone. While both training programs were planned for intensities recommended by the American College of Sports Medicine [7], the mixed mode training was more intense because of the nature of the resistance training exercises and the differences in the perceived exertion reported by the participants of both trained groups. Therefore, the higher stress induced by mixed mode training may have been responsible for the larger responses observed in TGC and Total-c.

A limitation of this study is that diet was not controlled. Dietary composition might be a potential confounder for the changes in lipid profiles. To minimize any confounding effects associated with variation in diet, the participants were informed to maintain their usual dietary habits throughout the study period. The fact that daily occupational and recreational physical activity was not controlled might also be considered a limitation. It is conceivable that as participants become fitter and obtain an increased sense of vigor, they would be more prone to become more active, despite some studies not reporting a significant relationship between improvements in cardiovascular disease risk factors and the levels of daily physical activity [13].

In conclusion, exercise training is a safe non-pharmacological measure and can lower, though not significantly, blood lipids values in overweight older men, independent of BMI reductions. Moreover, mixed model training programs have shown effectiveness in reducing the risk of dyslipidemia, suggesting an additive effect of the resistance-training mode.

Acknowledgements

We express our deep appreciation to all of the participants and senior citizen volunteers of Maia city.

Conflict of interest: There is no conflict of interest declared.

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