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HIGH AND LOW IMPACT AEROBIC EXERCISE AS A METHOD OF EARLY PREVENTION OF HYPERCHOLESTEROLAEMIA DEVELOPMENT AMONG YOUNG WOMEN

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ABSTRACT

Purpose. Hypercholesterolaemia is a highly prevalent condition that has major health- and cost-related implications for the society. Aerobic-type exercise improves lipoprotein-lipid profiles, cardiorespiratory fitness and body composition in healthy young women. Thus, the aim of the study was to assess the impact of 9 weeks of low-high aerobic-type exercise on the lipid profile among young women. **Methods.** On the basis of the lipid profile, 64 women (median age, 21.8 years; range, 19.0–24.7 years) were divided into two groups: with low (LRH) and intermediate (IRH) risk of developing hypercholesterolaemia. The participants completed a 9-week-long low-high aerobic exercise programme. Before and after the training programme, we determined the lipid profile: triglycerides (TG), total cholesterol (TC), lipoprotein cholesterol: HDL-C and LDL-C, and glucose levels. Selected cardiorespiratory fitness variables and body composition were also determined. **Results.** It was found that aerobic-type fitness exercise in the IRH group caused statistically significant decreases in TC and TG levels in comparison with baseline values. Significant increase in maximum oxygen uptake and decrease in HDL-C in the LRH group were also observed. **Conclusions.** Aerobic fitness exercises, a combination of two alternating styles, could influence the blood lipid profile by decreasing plasma TC and TG levels. In non-athlete women, physical activity may be a good tool to prevent cardiovascular diseases.

Key words: aerobic effort, cardiorespiratory variables, hyperlipidaemia prevention, lipid profile, physical activity

Introduction

Hyperlipidaemia has become a global problem in developed countries nowadays. As the World Health Organization indicates, cardiovascular disease (CVD) causes 17 million deaths each year all over the world, and accounts for 30% of recorded deaths [1]. Additionally, CVD is known to cause vast morbidity and mortality not only in men, but also in women. This is why the American Heart Association and European Atherosclerosis Society addressed their recent recommendations in particular to women [2, 3]. Moreover, according to literature data, hyperlipidaemia is largely undertreated among the female population, although the incidence of hypercholesterolaemia in females is similar to that in males. In groups with multiple risk factors and/or monogenic dyslipidaemias, more aggressive intervention is recommended, e.g. lipoprotein apheresis in the case of familial hypercholesterolaemia in the homozygous and compound forms [2, 3].

Physical activity gains more and more popularity nowadays. It is an effect of an increasing role of health education, as well as widely understood civilisation habits [4]. It is well known that regular exercise constitutes a valued way to ease the global burden of chronic disease. Literature data confirm that exercise has an influence on glycaemia and triglyceridaemia in healthy individuals [5–7]. Moreover, clinical recommendations for CVD prevention systematically encourage women to perform at least 30-minute-long moderate-intensity physical activity (e.g. brisk walking) on most, if not all, days of the week [2]. Some literature data showed that effective hyperlipidaemia management could substantially reduce cardiovascular morbidity and mortality [8]. As expected, professional athletes, with their trainings and life-style, met the CVD prevention recommendations.

LeMura et al. [9] suggest that aerobic-type exercise could lead to an improvement of lipoprotein-lipid profiles, cardiorespiratory fitness, as well as body composition in healthy young women. Moreover, literature data demonstrate that Baduanjin exercise could modulate the blood lipid profile by decreasing plasma total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C) levels and increasing plasma high-density lipoprotein cholesterol (HDL-C) levels among non-athlete participants as compared with participants who did not practise the exercise [10]. Also, moderate-intensity training performed weekly during a 12-week-long (or longer) period was shown to sufficiently increase aerobic fitness in sedentary young men. On the other hand, supramaximal exercise did not influence

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the lipid metabolism in those men [11]. In addition, Hurley [12] observed a decrease in TG levels among non-athletes performing aerobic-type exercise. Concurrently, there were no changes in TC or lipoprotein levels in this group, as well as no changes in lipids or lipoproteins in the blood of inactive controls. Thus, it was stated that resistive training seemed not to influence the lipoprotein-lipid profiles among persons at risk of coronary heart disease. However, in the case of most physically inactive individuals, physical exercise is beneficial in general, including the impact on blood lipids. It should be noted that all the benefits of exercise-induced changes in the lipid profiles occur as far as the one performs the training.

Literature data confirm that increased aerobic energy expenditure might be associated with a highly favourable stabilization of both established and emerging cardiovascular risk predictors [13, 14]. Therefore, an increase in physical activity within the whole population is recommended to withdraw adverse lipid abnormalities. It is even more important among people with a higher cardiovascular risk. Since hypercholesterolaemia is a condition that has major health- and cost-related implications for the society, it is essential to design adequate fitness programmes to prevent its early symptoms.

Taking these data into account, one can conclude that proper aerobic fitness may be a good and attractive tool to prevent hypercholesterolaemia, especially in women. Thus, the aim of the study was to evaluate the impact of 9-week-long aerobic-type exercise on the lipid profile among young women.

Material and methods

Experimental approach to the problem

Clinical recommendations for CVD prevention encourage women to undertake at least 30-minute-long moderate-intensity physical activity in order to withdraw adverse lipid abnormalities [2]. Moreover, it is suggested that aerobic-type exercise could lead to an improvement of lipoprotein-lipid profiles, cardiorespiratory fitness, as well as body composition in healthy young women [9].

Therefore, our study was aimed at the evaluation of the lipid profile: TG, TC, lipoprotein cholesterol: HDL-C and LDL-C, and glucose levels, as well as selected cardiorespiratory fitness and body composition variables in young women. The women were divided, on the basis of their lipid profile, into two groups: with low (LRH) and intermediate (IRH) risk of developing hypercholesterolaemia, and completed a 9-week low-high aerobic exercise programme.

The main aerobic routine consisted of two combined types of aerobic exercises – of low and high impact. During the former one (low impact), all the movements were performed with at least one foot standing on the floor, whereas during the high impact styles, the participants could run, hop, jump with a variety of flight phases [15]. Both types of exercise were incorporated into music of variable tempo. The whole aerobic exercise programme was divided into 3 stages, 3 weeks each, with an increasing workload.

The lipid profile and selected cardiorespiratory fitness and body composition variables were determined before and at the end of the training programme to test our hypothesis that 9 weeks of aerobic-type exercise would have a beneficial impact on the lipid profile in young women, especially those in the IRH group.

Participants

The total of 64 young female university students (median age, 21.8 years; range, 19.0–24.7 years) met the inclusion criteria for the study. They had performed regular physical activity within the previous half a year. They declared not to have had any metabolic diseases or CVD in the past. All the participants were non-smokers, and they refrained from taking any medications (including cardiovascular drugs, oral contraceptives, steroidal anti-inflammatory drugs) or supplements (including products containing high amounts of phenylalanine or L-carnitine) known to affect metabolism. On the basis of their lipid profile, the participants were divided into two groups: LRH (median age, 21.0 years; range, 19.0–23.8 years) and IRH (median age, 22 years; range, 19.4–24.7 years). According to the clinical recommendations for CVD prevention [2], the groups represented TC levels lower than or equal to 4.93 mmol · L^{-1} and higher than 4.93 mmol · L^{-1}, respectively [16]. Table 1 presents baseline characteristic of both studied groups.

The participants were recommended to follow the same diet as they applied during the 6 months before the study. They had an individual energetic balance calculated (the difference between the energy provided with the food and that expended by their medium physical activity before the observation). Then they were instructed to maintain a zero balance with a 100 kcal tolerance during the study. However, the application of these recommendations was not controlled.

The study was performed in accordance with all ethical standards [17]. The participants were fully informed of all aspects of the experiment before providing their consent to participate. The study was approved by the local Ethics Committee and followed the Declaration of Helsinki.

Procedures

Study design

Before the proper experiment, the participants implemented a week-long (3 times, 30 minutes each) familiarization exercise programme at the intensity of about 50% of their maximum heart rate (HR_{max}). An electroni-

Table 1. The effect of aerobic-type exercise training on the body composition and cardiorespiratory fitness measurements among young women before (pre-training) and after (post-training) the 9-week-long training programme

	Training Group			
	LRH (*n* = 32)		IRH (*n* = 32)	
	pre-training	post-training	pre-training	post-training
Weight (kg)	60.9 (56.9–64.8)	60.4 (55.7–64.5)	58.7 (55.4–61.5)	58.1 (55.9–60.8)
BMI (kg · m^{-2})	22.0 (19.6–24.3)	22.1 (19.4–24.0)	21.0 (19.9–22.0)	21.0 (19.8–21.8)
VO_{2max} (mL · kg^{-1} · min^{-1})	33.5 (31.3–36.1)	34.8* (32.7–39.6)	33.5 (31.0–36.5)	34.7 (30.9–39.8)
V_{Emax} (L · min^{-1})	76.9 (66.9–85.9)	80.3 (70.9–88.3)	71.1 (62.3–90.4)	80.7 (60.7–92.4)
HR_{max} (beats · min^{-1})	186 (185–191)	189 (185–194)	191 (182–193)	188 (183–192)
VO_2/AT (mL · kg^{-1} · min^{-1})	26.2 (23.7–28.7)	26.9 (24.6–29.7)	25.6 (24.4–27.9)	26.5 (23.5–30.1)

The data are presented as medians (interquartile ranges).
LRH – group of participants with a low risk of developing hypercholesterolaemia, IRH – group of participants with an intermediate risk of developing hypercholesterolaemia, *n* – number of participants, BMI – body mass index, VO_{2max} – maximum oxygen uptake, V_{Emax} – maximum minute ventilation, HR_{max} – maximum heart rate, VO_2/AT – anaerobic threshold (gas exchange anaerobic threshold)
* $p = 0.0011$. The significance level of the differences observed between the analysed time-points (pre-training vs. post-training) was assessed with Wilcoxon's matched pairs test. The statistical power of the test was equal to 0.91. The value of $p \leq 0.05$ was considered to denote a significant difference.

cally braked cycle ergometer with a gas analyser (Oxycon Pro, Erich JAEGER GmbH, Hoechberg, Germany) was used to determine the individuals' HR_{max}, as described earlier [18].

After this stage, the proper training was started. Each training lasted 60 minutes and consisted of a warm-up routine (10 minutes), the main aerobic routine, being a combination of low and high impact exercises (43 minutes), and stretching and breathing exercises (7 minutes). The whole exercise programme, prescribed for 9 weeks, was divided as follows: (i) 3 weeks (9 training units), at ca. 50–60% of HR_{max}, tempo 135–140 beats per minute (BPM); (ii) 3 weeks (9 training units), at 55–65% of HR_{max}, tempo 135–140 BPM; (iii) 3 weeks (9 training units), with the intensity of 60–70% of HR_{max}, tempo 140–152 BPM. All the 27 training units were administered and supervised by the same instructor.

Cardiorespiratory fitness measurements

All participants were characterised by selected cardiorespiratory fitness parameters: maximum oxygen uptake (VO_{2max}), HR_{max}, maximum ventilation (V_{Emax}), anaerobic threshold (VO_2/AT), and body composition (body mass, body mass index [BMI]) before and after completing the 9-week-long training period, as previously described [19].

Biochemical analyses

Blood plasma was obtained in accordance with the standard diagnostic procedures. Biochemical analyses were performed twice: before the start and after the completion of the training programme.

Fasting blood samples were obtained in the morning. Blood samples were centrifuged (300 × g, 15 minutes, room temperature) in order to receive blood plasma that was used to determine the lipid profile: the TG, TC, HDL-C, LDL-C, and glucose levels.

The levels of the lipid profile parameters were determined and validated with the use of standard diagnostic procedures according to the manufacturers' protocols, as described elsewhere [18, 20]. Briefly, plasma TG and TC levels were identified with the diagnostic colorimetric enzymatic method (BioMaxima S.A., Lublin, Poland), with the absorption measurement at $\lambda = 510$ nm at 37°C. HDL-C plasma levels were established with the human anti-β-lipoprotein antibody and colorimetric enzymatic method (BioMaxima S.A., Lublin, Poland), whereas plasma LDL-C levels were determined with the direct method (PZ Cormay S.A., Łomianki, Poland), and ΔA measurements were conducted at $\lambda = 600$ nm at 37°C. All the analysis procedures were validated with the use of multiparametric control serum (BIOLABO S.A.S, Maizy, France), as well as control serum of normal

(BioNormL) and high level of lipid profile (BioPathL) (BioMaxima S.A., Lublin, Poland).

Statistical analyses

Since the number of participants in each group was low, all data are presented as medians (interquartile ranges). Statistical analyses were performed with the use of the STATISTICA data analysis software system, version 10 (StatSoft, Inc., 2011). The significance level of the differences observed between the analysed time points (before the start vs. after the completion of the training programme) was calculated with Wilcoxon's matched pairs test. The statistical power of the tests was established with the G*Power software, version 3.1.9.2 (http://www.gpower.hhu.de). Each time, the value of $p \leq 0.05$ was considered to denote a significant difference.

Results

All women in both the LRH and IRH study groups completed the designed 9-week-long aerobic exercise training programme.

Table 1 presents the changes in the body composition and cardiorespiratory fitness measures in the participants before and after the training programme. There were no significant changes in body mass and BMI values after the completion of the programme. With regard to the cardiorespiratory fitness variables, there was only a significant increase in the VO_{2max} ($p = 0.0011$) in the LRH group. Interestingly, cardiorespiratory fitness variables did not change ($p > 0.05$) during the training programme in the IRH group. It is worth noting that the median V_{Emax} was almost equal in both studied groups of participants after the training course as compared with their baseline values, which were slightly lower in the IRH group.

Figures 1–4 summarise the analysed lipid profile parameters, namely the TC, HDL-C, LDL-C, and TG plasma levels. Before the start of the training programme, the mean level of TC in the IRH group was about 23% higher than in the LRH group (Figure 1). It was found that after 9 weeks of aerobic-type fitness exercise, the mean TC level in the IRH group was significantly ($p = 0.000001$) lower in comparison with its baseline values. However, the TC level did not change after the training programme in the LRH group (Figure 1).

Statistically significant ($p = 0.0258$) changes in HDL-C were observed only in the LRH group (Figure 2).

Interestingly, there were no changes in LDL-C levels after the training programme in either group (Figure 3).

The baseline median TG level in the IRH group was about 19% higher than in the LRH group (Figure 4). The combined two styles (low and high impact) of exercise repeated 3 times a week for 9 weeks demonstrated a high influence on the TG blood plasma level in the IRH group. The training programme caused a statistically significant ($p = 0.0147$) decrease in the TG level in the IRH group.

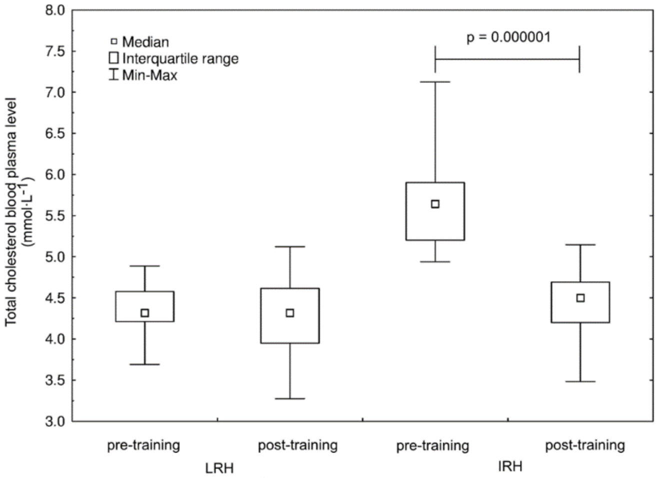

Figure 1. Median of total cholesterol (TC) plasma level (mmol · L^{-1}) in the group of participants with low risk of developing hypercholesterolaemia (LRH) and in the group of participants with intermediate risk of developing hypercholesterolaemia (IRH) before (pre-training) and after (post-training) 9 weeks of the training programme. The midpoints represent medians; boxes represent interquartile ranges; whiskers represent minimum and maximum values (min-max). The significance levels of the differences observed between the analysed time-points were assessed with Wilcoxon's matched pairs test. The statistical power of the test was equal to 1.00. The value of $p \leq 0.05$ was considered to denote a significant difference. TC plasma levels were measured among 64 participants – 32 in each studied group

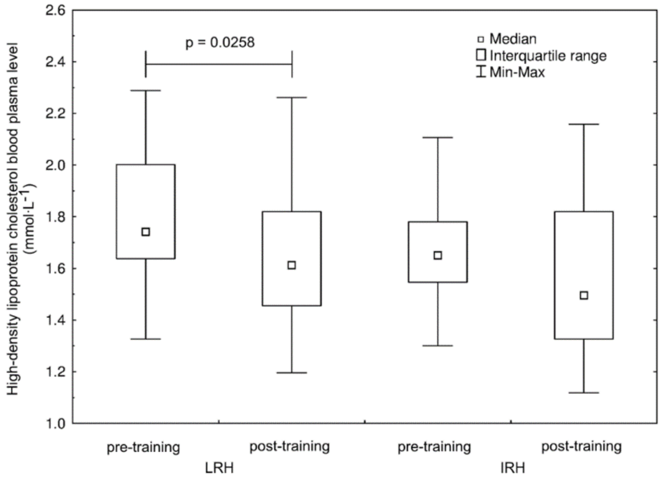

Figure 2. Median of high-density lipoprotein cholesterol (HDL-C) plasma level (mmol · L^{-1}) in the group of participants with low risk of developing hypercholesterolaemia (LRH) and in the group of participants with intermediate risk of developing hypercholesterolaemia (IRH) before (pre-training) and after (post-training) 9 weeks of the training programme. The midpoints represent medians; boxes represent interquartile ranges; whiskers represent minimum and maximum values (min-max). The significance levels of the differences observed between the analysed time-points were assessed with Wilcoxon's matched pairs test. The statistical power of the test was equal to 0.96. The value of $p \leq 0.05$ was considered to denote a significant difference. HDL-C plasma levels were measured among 64 participants – 32 in each studied group

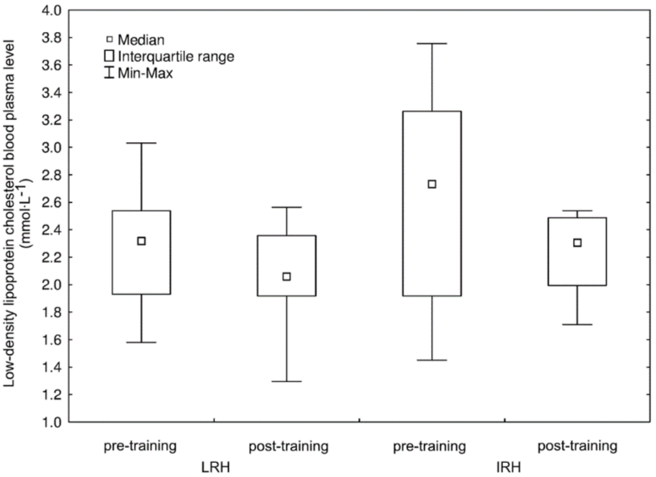

Figure 3. Median of low-density lipoprotein cholesterol (LDL-C) plasma level (mmol · L^{-1}) in the group of participants with low risk of developing hypercholesterolaemia (LRH) and in the group of participants with intermediate risk of developing hypercholesterolaemia (IRH) before (pre-training) and after (post-training) 9 weeks of the training programme. The midpoints represent medians; boxes represent interquartile ranges; whiskers represent minimum and maximum values (min-max). LDL-C plasma levels were measured among 64 articipants – 32 in each studied group

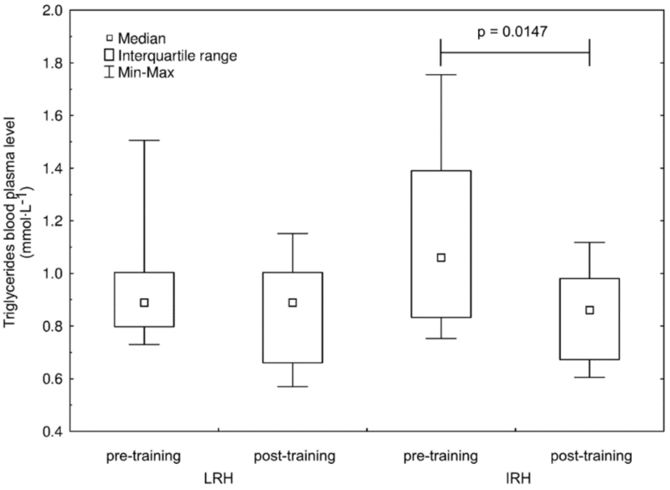

Figure 4. Median of triglycerides (TG) plasma level (mmol · L^{-1}) in the group of participants with low risk of developing hypercholesterolaemia (LRH) and in the group of participants with intermediate risk of developing hypercholesterolaemia (IRH) before (pre-training) and after (post-training) 9 weeks of the training programme. The midpoints represent medians; boxes represent interquartile ranges; whiskers represent minimum and maximum values (min-max). The significance levels of the differences observed between the analysed time-points were assessed with Wilcoxon's matched pairs test. The statistical power of the test was equal to 0.99. The value of $p \leq 0.05$ was considered to denote a significant difference. TG plasma levels were measured among 64 participants – 32 in each studied group

Figure 5 summarises median glucose plasma levels before and after the training programme in both the LRH and IRH groups. In the LRH group, the plasma glucose concentration was almost the same during the 9 weeks of the aerobic exercise programme (3.86 [3.72–4.25] mmol · L^{-1} at the beginning of the programme vs. 3.97 [3.69–4.25] mmol · L^{-1} in the 9th week). The median (interquartile range) glucose level in the IRH group was equal to 3.97 (3.50–4.22) mmol · L^{-1} before the 9-week-long aerobic exercise programme and 3.86 (3.16–4.13) mmol · L^{-1} after the training programme. There were no significant changes ($p > 0.05$) in the glucose level in either of the studied groups.

Discussion

The relationship between nutrition, which supplies energy, and exercise, which consumes energy, is highly relevant to metabolic control in both healthy people and those affected by chronic diseases [21]. Exercise, nutrition, and pharmacologic agents can significantly vary postprandial glycaemic and triglyceridaemic responses. These three factors might be applied simultaneously. Since the glycaemic and lipaemic responses are time-dependent, the result of such three-way treatment could depend, at least in part, on the time sequence in which the elements are implemented [8, 10, 22].

Literature data prove that aerobic-type exercise could lead to an improvement of lipoprotein-lipid profiles, cardiorespiratory fitness, as well as body composition

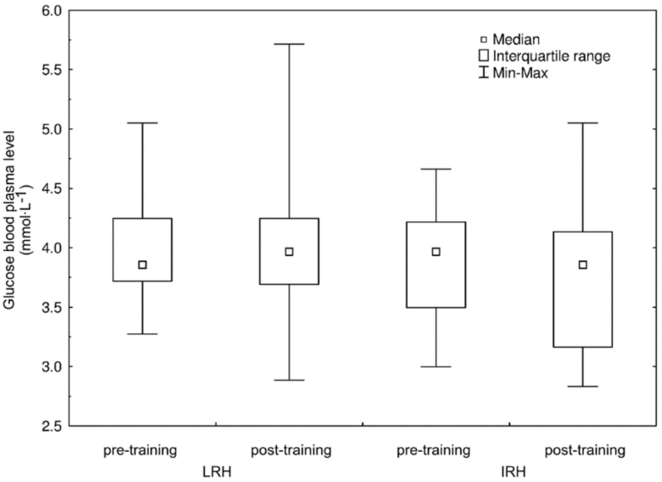

Figure 5. Median of glucose plasma level (mmol · L^{-1}) in the group of participants with low risk of developing hypercholesterolaemia (LRH) and in the group of participants with intermediate risk of developing hypercholesterolaemia (IRH) before (pre-training) and after (post-training) 9 weeks of the training programme. The midpoints represent medians; boxes represent interquartile ranges; whiskers represent minimum and maximum values (min-max). Glucose plasma levels were measured among 64 participants – 32 in each studied group

in healthy young women [9]. Our study indicated that a 9-week-long aerobic exercise programme caused decreases in some lipid profile parameters in the IRH group of women. The combined two styles (low and high impact) repeated 3 times a week for 9 weeks had an important influence on plasma TC levels in that group. It was also found that the training programme affected TG levels, causing a significant decrease in the IRH group. The decrease of those lipid profile parameters in the IRH group was significant as the levels after the completion of the programme reached the values recommended by the European Society of Cardiology and the European Atherosclerosis Society [23, 24]. Moreover, in the LRH group of studied women, the same type of physical fitness did not have an impact on the lipid profile except for HDL-C levels. It was also observed that the training programme did not influence glycaemia in either studied group. The research by Ferguson et al. [25] indicated that a decrease in the time of exercise performed at 70% of VO_{2max} attenuated the effect of exercise on plasma TG, HDL-C, and LDL-C concentrations. Within a male group, acute as well as chronic high-intensity aerobic exercise reduced TC, LDL-C, very low-density lipoprotein (VLDL), and TG levels [11]. On the other hand, the results of our study are not in agreement with Hurley [12], who noticed a decrease in TG levels but no alteration in TC or lipoprotein levels in the blood of non-athletes participating in an aerobic-type exercise programme. There were also no changes concerning lipids or lipoproteins in the group of inactive controls [12]. Gibala and McGee [26] stated that high-intensity interval training was a powerful, time-efficient strategy which induced metabolic adaptations, usually linked with endurance training. They demonstrated that 6 sessions of high-intensity interval training (Wingate test) over 2 weeks or the total of approximately 15 minutes of very intense exercise increased the skeletal muscle oxidative capacity and the endurance performance, and changed metabolic control during aerobic-based exercise. Our study indicated that an aerobic fitness programme which combined different types of aerobic exercise might turn out an effective type of physical activity to normalise the lipid profile in young women. Ortega et al. [27] showed that concurrent aerobic exercise training could be a prevention method applied to modulate the concentration of TC and LDL-C in young women on a high lipid diet. Moreover, they found that aerobic exercise training improved cardiorespiratory fitness in the studied participants.

Literature data indicate that the achievement of an ‘energy expenditure threshold’ can induce changes in blood lipid levels. We contend that proper aerobic-type exercises not only allow to achieve the ‘energy expenditure threshold’, but also offer an attention-grabbing form of physical activity for women of all ages. The results of our study are in agreement with data obtained by Lippi et al. [14], and confirm that elevated aerobic energy expenditure might be associated with a highly favourable stabilization of most established and emerging cardiovascular risk predictors. This is why an increase in aerobic physical activity within the population, especially among people with a higher cardiovascular risk, should be recommended to withdraw adverse lipid abnormalities. Additionally, according to Perrone and Brunelli [3], hyperlipidaemia is a metabolic disorder more frequently undertreated in women than in men, although the ratio of hypercholesterolaemia is similar among both sexes. Hypercholesterolaemia is a highly prevalent condition that has major health- and cost-related implications for the society [28]. Therefore, adequate fitness programmes aiming to prevent early symptoms of hypercholesterolaemia in young women confer health benefits and help to improve their lifestyle. Moreover, the type of activity should be fitted to different age and sex groups, since the main target is to convince people to perform physical activity, especially as the problems of overweight and CVD risk appear already among pupils [29, 30]. Taking this into account, the ‘energy expenditure threshold’ seems to be a very important factor to consider when designing physical activity whose objective is CVD prevention in non-athletes. It has to be added that the benefits of a superior lipid profile are sustained as far as one performs the training.

Conclusions

1. An aerobic fitness programme, a combination of two different types of aerobic exercise (low and high impact), repeated 3 times a week for 9 weeks could modulate the blood lipid profile by decreasing plasma TC and TG levels in the IRH group participants.
2. The beneficial effect occurs at an early stage of hyperlipidaemia risk, as it was observed in the IRH group (TC level higher than $4.93 \text{ mmol} \cdot L^{-1}$).
3. We recommend a combination of two different types of aerobic exercise (low and high impact), repeated 3 times a week, as a valuable training programme in the case of individuals with altered plasma TC and TG levels to help them prevent early symptoms of hypercholesterolaemia and CVD.
4. A proper aerobic fitness programme not only allows to achieve the ‘energy expenditure threshold’ needed to influence the lipid profile, but also provides an interesting form of physical activity for women of all ages.

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