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Original Article

Impact of 5-week high-intensity interval training on indices of cardio metabolic health in men

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ABSTRACT

Purpose: To compare the acute and chronic effects of high-intensity intermittent training (HIIT) and moderate-intensity continuous training (MICT) on indices of cardio-metabolic health: (HDL-c, total cholesterol, triglycerides, heart ratio, and phase angle/PhA) in physically active men.

Methods: Twenty active men were randomly allocated to HIIT ($n = 10$), or MICT ($n = 10$) for 5 weeks, three times per week. HIIT consisted of running 5 km with 1-min at 100% of maximal aerobic speed interspersed by 1-min passive recovery while subjects in MICT group ran continuously the same 5 km at 70% of maximal aerobic speed. Blood samples were collected at different moments during the first and last exercise session. Before and after 5 weeks of both exercise training protocols, heart ratio (during exercise session) and PhA were measured pre and post-exercise training.

Results: Fasting HDL-c levels did not change after 5 weeks of HIIT or MICT. Perceptual variation of HDL pre and post training (fed state) tended to differ between HIIT and MICT ($p = 0.09$). All lipoproteins parameters (HDL-c, total cholesterol, triglycerides and non-HDL) were increased in post-acute exercise session compared to pre-exercise during the first and last training session, these being observed after both training protocols. PhA and heart rate measured at different times during the first and last training session were not affected in both training protocols.

Conclusion: These results indicate that HIIT and MICT modify the post-exercise lipoprotein profile acutely. On the other hand, only HIIT tended to increase HDL-c levels chronically.

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1. Introduction

Metabolic alterations such as increases in plasma concentrations of low-density lipoprotein (LDL-c), triacylglycerol (TAG), and total cholesterol (TC) as well as reductions in high-density lipoprotein (HDL-c) are well substantiated risk factors for

cardiovascular diseases (CVD) [23,26,29]. A lack of physical activity and excessive food intake are two important modifiable behaviors promoting the development of metabolic disorders [30] and the development of cardiovascular diseases; two major causes of death, worldwide [9,21].

Exercise training is well associated with improvements in plasma lipid profile [17,27,31] and cardiovascular health (decreased heart rate/pressure at rest and during an acute exercise session). Most interestingly, however, reductions in plasma LDL-c and TAG levels combined with increases in the concentrations of HDL-c have been reported after an acute bout of exercise [5,14,15]. Higher HDL-c concentrations seem to be more associated with to the acute

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effects of aerobic exercise when it is performed above 1100–1500 kcal of energy expenditure at approximately 70% of the VO_{2max} [6,13,14]. On the other hand, Lira et al. [15] showed that acute impact of a high-intensity continuous exercise (90% VO_{2max}) with low energy expenditure (~125 kcal) leads to a reduction of plasma LDL-c concentrations. Thus, different conditions of aerobic exercise and energy expenditure can promote positive changes to both HDL-c or LDL-c plasma levels. Some authors suggested that there is a minimal energy expenditure threshold that is necessary to trigger changes in plasma lipoprotein profiles [6,15].

These results, support the hypothesis suggesting that an acute session of a continuous moderate-to high-intensity aerobic activity modulates LDL-c and HDL-c plasma levels. However, there is limited information regarding the acute effects of intermittent high-intensity exercise on plasma lipid profiles. Intermittent exercise is a mode of training highly used by elite athletes. Our group previously examined blood lipid profile after two modes of high-intensity intermittent exercise (all-out exercise and fixed high-intensity intermittent exercise) and found that acute exercise session did not promote any change in the postprandial blood lipid profile [19]. However, there is no information regarding the potential effects of an intermittent high-intensity exercise bout on the improvement of blood lipoproteins profiles and cardiovascular health indices.

The primary purpose of the present study was to determine if a short high-intensity intermittent training program leads to similar improvements in fasting blood lipoproteins and phase angle than a continuous moderate-intensity program. The second objective was to determine whether an acute intermittent high-intensity exercise bout influences heart rate, plasma LDL-c and HDL-c levels in the postprandial state before and after training.

2. Methods

2.1. Subjects

Twenty healthy eutrophic men aged between 18 and 35 years whose physical and physiological characteristics were determined by DEXA (Lunar DPX-NT scanner General Electric Healthcare) (Table 1) were recruited for the study.

The protocol was approved by the University Research Ethics Committee of São Paulo State University (UNESP) for studies involving human participants (53297815.8.0000.5402). All subjects gave a written and informed consent in accordance with the Declaration of Helsinki.

2.2. Incremental test for determination of maximum speed

All subjects were first submitted to an incremental running test on a treadmill (Inbramed MASTER CI, Inbrasport®, Porto Alegre, Brazil) to determine their maximum oxygen consumption (Model

Quark PFT Ergo, Cosmed®, Rome, Italy). The initial speed was set at 8 km h⁻¹ and it was increased by 1 km h⁻¹ every 2 min until volitional exhaustion. Strong verbal encouragements were given during the test. Oxygen uptake consumption was evaluated throughout the test and the average measurements of the last 30 s were defined as the VO_{2peak} . The sVO_{2peak} was defined as the final incremental test speed when the subject was unable to complete the stage. The speed was expressed according to the time spent at the final stage of the test. This was determined as follow: $sVO_{2peak} = \text{speed of final complete stage} + [(\text{remaining time of the final incomplete stage}/120 \text{ s}) * 1 \text{ km h}^{-1}]$ [20].

2.3. Groups and exercise training program

Following the initial maximal endurance running test, subjects were stratified into two groups who had to undergo a 5-week training program (3 sessions/week) where they had to run a total of 5 km per session: 1) high intensity interval training (HIIT) where each bout consisted of 1 min of running at 100% of their sVO_{2peak} (n = 10) while achieving 1 min of passive recovery or; 2) moderate intensity continuous training (MICT) at 70% of their sVO_{2peak} (n = 10). For each exercise session, subjects of both MICT and HIIT groups performed a 5-min warm-up at 50% of their sVO_{2peak} and a 5-min passive recovery at 50% of their sVO_{2peak} .

2.4. Heart rate measurement

Heart rate was monitored using a heart rate analyzer Polar S810i (Polar®, Finland) with a recording strap positioned on the distal third of the sternum and a receiver placed on the wrist of participants [34]. For the HIIT group, HR values were recorded at the beginning and the end of each bout in all exercise session. For the MICT group, HR was recorded at 5-min intervals throughout each exercise session. The mean HR of each exercise session was calculated.

2.5. Phase Angle

The BIA (Xitron Hydra, model 4200, Xitron Technologies, San Diego, California) was used to estimate R, Xc, and subsequently the PhA was calculated as the arc-tangent $(Xc/R) \times 180^\circ/\pi$. All measurements were conducted during the morning. Prior to the tests all participants were instructed to remove all objects containing metal, to urinate about 30 min before initiating the test, to restrain from ingesting food or drinks for 4 h, to avoid strenuous physical exercise for at least 24 h, and restrain the consumption of alcoholic and caffeinated beverages for at least 48 h. Measurements were performed in lying supine position using two electrodes placed on the surface of the right hand and the right foot in accordance to described procedures [8]. The spectral bioelectrical impedance device was calibrated each day according to the manufacturer's recommendations. The test-retest measured 24 h apart resulted in an SEM of 15.6 Ω and ICC = 0.95 for R, 3.5 Ω and 0.96 for Xc, and 0.21° and 0.96 for PhA.

2.6. Acute exercise and blood collections

In the morning of the first and last training sessions, subjects arrived early to the laboratory after an overnight fast (12 h). The first blood sample was collected in the fasting state and a standard breakfast (corresponding to 25% of daily energy) was then ingested by every subject. Ninety minutes after breakfast the second blood sample was collected, and subjects started their respective exercise training session. Blood was then collected at different points in time: a) fasting state; b) pre-exercise in fed state; c) immediately

Table 1
Anthropometric and physiological characteristics of subjects.

	MICT	HIIT
Age (years)	24.6 ± 3.71	26.9 ± 4.70
Total body mass (kg)	76.1 ± 11.9	71.5 ± 6.21
BMI (kg/m ²)	23.7 ± 2.83	23.2 ± 1.58
VO_2 peak (ml.kg.min ⁻¹)	50.1 ± 3.08	54.0 ± 4.11
sVO_2 max (km/h)	13.9 ± 0.78	14.5 ± 1.03

Note. MICT = moderate-intensity continuous training (n = 10); HIIT = high-intensity intermittent training (n = 10); BMI = Body mass index; VO_{2peak} = peak oxygen consumption; sVO_{2max} = maximum speed reached in incremental test. Values presented as means ± SD.

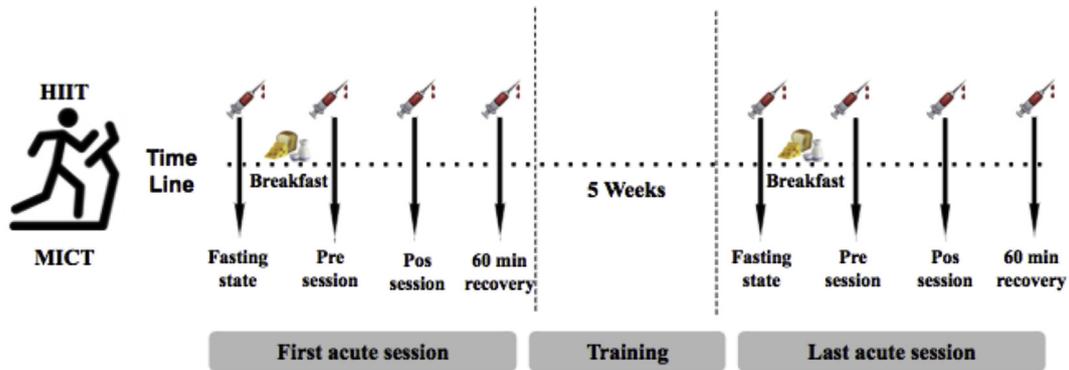


Fig. 1. Experimental study design performed to high intensity interval training (HIIT) and moderate intensity continuous training (MICT).

post-exercise and d) 1 h post-exercise (recovery) (Fig. 1). Five mL of blood was collected from a peripheral vein in vacutainer tubes (Becton Dickinson, Juiz de Fora, Brazil) by a professional nurse. Tubes were centrifuged at 3000 rpm for 15 min at 4 °C, and serum samples were stored at –20 °C for later use.

2.7. Plasma volume determination

For each sample of collected blood, an aliquot was kept in tubes with anticoagulant (EDTA K3, BD Vacutainer®) for hematocrit determination. Two capillary tubes were sealed with resin and allocated to dry before utilization. Posteriorly, 50 µL of blood aliquots were pipetted in duplicate into those tubes and centrifuged (MH 11.5 i INBRAS, Brazil) for 5 min at 11,500 rpm. This procedure was used to separate the hematocrit and identify the plasmatic volume changes over time using Van Beaumont equation [33].

2.8. Serum lipid profile

The concentrations of TAG, TC, and HDL-c were determined by a colorimetric method according to specific kits (Labtest®, Brazil). In addition, the non-HDL cholesterol (nHDL-c) was calculated by subtracting total cholesterol to HDL-c concentrations. All results were adjusted for individual changes in plasma volume.

2.9. Statistical analyzes

Shapiro-Wilk test were used to determine whether the data was normally distributed. Results are expressed as mean +standard deviation (SD). To analyze lipid profiles in the fasting state, a repeated measures 2-way ANOVA (Group and Training) was

conducted using the Bonferroni post-hoc test, when necessary. The Δ pre and post 5-weeks of training at different intensities (MICT and HIIT) were analyzed using a Mann-Whitney U test, and Δ values were presented in the median and interquartile range. Acute data were analyzed using a repeated measures 3-way ANOVA with group (MICT and HIIT), training (pre and post intervention), and time of measurement (pre, post, and 60 min of recovery) as independent variables using the Bonferroni post-hoc test, when necessary. Before these ANOVA analyses, the sphericity was tested by Mauchly’s test, with correction of Greenhouse-Geisser, when necessary. Statistical significance was set at 5% (P < 0.05) and analyses were conducted using SPSS 15.0 (SPSS Inc., Chicago, IL).

3. Results

Baseline characteristics of subjects did not differ between the two training modalities (Table 1). Body mass, lean mass and fat mass values were not significantly different between training protocols after 5 weeks of exercise intervention (data not showed).

3.1. PhA and heart rate

Phase angle (Table 2) and heart rate (Figs. 2 and 3) were measured before and after acute exercise. They did not show any differences either between groups or in response to training.

3.2. Lipid profile measured in the fasting state

Parameters of the lipid profile measured at rest in the fasting state before and after the training period are presented in Table 3. TC, TAG, HDL, and nHDL-c levels were measured in the fasting state

Table 2 Parameters of phase angle before and after 5-week of training at high and moderate intensities.

	HIIT			MICT		
	Pre	Post	Δ%	Pre	Post	Δ%
	mean (SD)	mean (SD)		mean (SD)	mean (SD)	
IW (L)	28.21 ± 3.67	28.31 ± 3.60	0.35	29.80 ± 4.01	29.40 ± 3.52	-1.34
EW (L)	16.35 ± 2.12	16.32 ± 1.92	-0.18	17.70 ± 2.42	17.34 ± 2.23	-2.05
PAra (°)	6.32 ± 0.59	6.40 ± 0.67	1.26	5.72 ± 0.47	5.25 ± 1.76	-8.37
PAla (°)	6.15 ± 0.58	6.14 ± 0.64	-0.04	5.24 ± 1.73	5.20 ± 1.73	-0.87
PAt (°)	10.14 ± 1.50	10.45 ± 1.37	3.07	8.39 ± 2.88	8.55 ± 2.90	1.96
PArl (°)	7.10 ± 0.39	7.25 ± 0.52	2.11	5.99 ± 1.97	6.00 ± 2.15	0.20
PAll (°)	6.95 ± 0.46	7.16 ± 0.57	2.97	5.94 ± 1.92	6.11 ± 1.94	2.89

Note. MICT = moderate-intensity continuous training (n = 8); HIIT = high-intensity intermittent training (n = 10); IW = Intracellular Water; EW = Extracellular Water; PAra = Phase Angle right arm; PAla = Phase Angle left arm; PAt = Phase Angle trunk; PArl = Phase Angle right leg; PAll = Phase Angle left leg; (L) = Liters; (°) = degrees; SD = standard deviation; Δ% = percentual difference between pre and post-training.

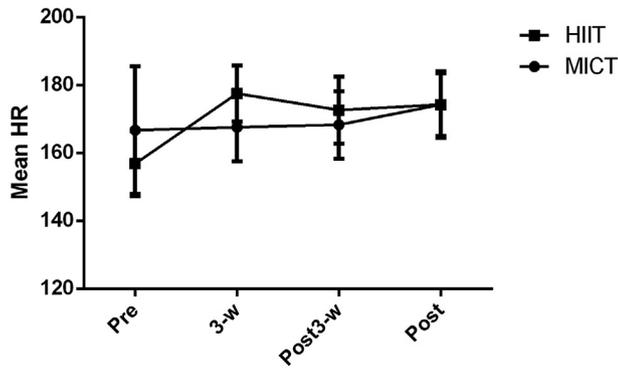


Fig. 2. Mean HR during different sessions of the training period. Note. MICT = moderate-intensity continuous training (n = 10); HIIT = high-intensity intermittent training (n = 10); Mean HR = Mean Heart Rate; Pre = Pre-training; 3-w = 3 weeks of training; Post3-w = Post 3 weeks of training; Post = Post 5 weeks of training. Values are presented as mean \pm SD.

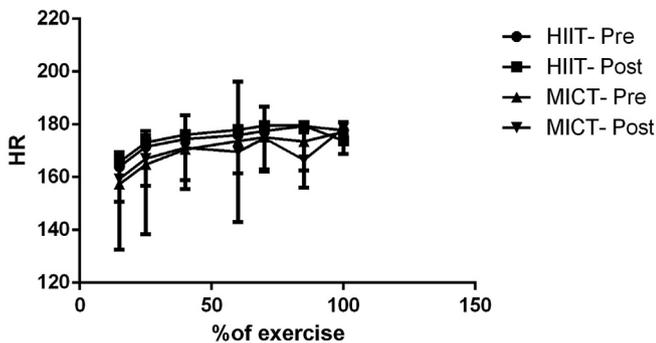


Fig. 3. HR kinetics during the initial and final session of the HIIT and MICT groups. Note. MICT = moderate-intensity continuous training (n = 10); HIIT = high-intensity intermittent training (n = 10); HR = Heart Rate; Pre = Pre-training; Post = Post 5 weeks of training. Values presented in mean and standard deviation.

(before the acute exercise) and they did not show any difference either between groups or in response to training. Comparisons of the Δ revealed a tendency towards an increase in HDL after HIIT (Median [IQR]) and MICT (Median [IQR]) (U = 28; p = 0.09) when compared to MICT.

3.3. Lipid profiles in response to an acute exercise session

Metabolic responses measured immediately before (in the fed state) and at different time points after an acute exercise session before and after the training program are shown in Table 4. There was no significant difference between MICT and HIIT groups in response to training. Nevertheless, TAG, TC, HDL-c, and n-HDLc

levels were increased (p < 0.05) immediately after the end of the session in all training conditions.

4. Discussion

The main findings of the study were that an acute session of MICT and HIIT training both increased lipid values. In comparison to pre-training values, higher TAG, TC, HDL-c and nHDL-c concentrations were measured after the 5 weeks of training. In addition, we observed a tendency (p < 0.09) for higher HDL-c levels in HIIT compared with MICT in the fasting state.

Fasting or postprandial plasma lipoprotein profiles were previously measured in response to an exercise bout [15,16,19]. In response to the 5-week training program the present study shows that 5-km both HIIT and MICT bouts tended to increase fasting HDL-c levels. HDL-c levels were increased by ~3% in the HIIT group (pre-training 37 ± 5 and post-training 38 ± 6 mg/dL), therefore, theoretically providing a protective effect in physically active men. In this context, it is interesting to recall the meta-analysis conducted by Kelley et al. [10] showing that aerobic exercise training (70–75% VO_2 max) was effective in reducing LDL-c (–3%) while increasing HDL-c (+3%). This meta-analysis reinforced the idea that even small increases in HDL-c levels induce relevant clinical outcomes. In addition, the strong tendency for TC (p < 0.09) to be higher after the HIIT vs. MICT might be related, at least in part, to increased cholesterol exchanges and higher presence of cholesterol in the HDL particle.

The possible mechanism involved in the modulation of HDL-c levels following HIIT might be related to the action of two enzymes involved in HDL metabolism, cholesteryl ester transfer protein (CETP) and lecithin-cholesterol acyltransferase (L-CAT) [4,7]. Exercise training modulates the activity of both enzymes. In a recent study, Casquero et al. [2] reported that chronic endurance training at moderate intensity in mice resulted in decreases in CETP activity. A lower CETP activity could reduce the transfer of cholesterol from TG-rich lipoproteins to HDL while potentially increasing HDL-c levels. An increase in LCAT activity as previously reported in response to exercise training [18]. This effect could be mediated through the increased transfer of plasma membrane cholesterol to the HDL particle. It is thus possible that high-intensity training may affect one or both of these critical enzymes regulating of HDL levels while moderate intensity training would have more limited effects on a short-term basis. High intensity interval training induces a greater oxygen deficit and promotes major physiological perturbations which could result in higher resting metabolic rate and influence the activity of CETP and LCAT enzymes involved in the regulation of HDL particles.

Overall HDL cholesterol content in the plasma was previously reported to play a crucial role in lipid metabolism. Recent studies recently suggested that HDL cholesterol functionality is more important than its concentration *per se* in some diseases [11,12,24].

Table 3
Changes in the lipid profile in the fasting state before and after training.

	HIIT			MICT		
	Pre mean (SD)	Post mean (SD)	Δ median (IQR)	Pre mean (SD)	Post mean (SD)	Δ median (IQR)
TC	180 \pm 36	172 \pm 36	–3.0 (–24.3, 20.9)	187 \pm 48	159 \pm 39	3.9 (–20.7, 9.5)
TAG	133 \pm 26	131 \pm 31	–4.6 (–15.7, 7.4)	124 \pm 24	126 \pm 18	5.5 (–3.3, 12.5)
HDL-c	37 \pm 5	38 \pm 6	1.4 (–1.1, 3.4)*	39 \pm 5	37 \pm 5	–2.4 (–3.6, –1.6)
nHDL-c	142 \pm 35	134 \pm 34	–3.4 (–26.1, 19.6)	147 \pm 46	121 \pm 39	4.3 (–22.6, 13.4)

Note. MICT = moderate-intensity continuous training (n = 10); HIIT = high-intensity intermittent training (n = 10); TC = total cholesterol; TAG = triacylglycerol; HDL-c = high-density lipoprotein; nHDL-c = non-HDL cholesterol; SD = standard deviation; IQR = interquartile range (25, 75); Δ = difference between rest and immediately post-session. * = tendency for difference between groups for Δ (p < 0.09). Lipid profile is expressed in mg/dL.

Table 4

Lipid profiles before and after an acute running session of 5 km prior and after achieving a 5-week of training program at high or moderate intensities.

		Pre-training Mean \pm SD			Post-training Mean \pm SD		
		Pre-exercise	Post-exercise	60-min	Pre-exercise	Post-exercise	60-min
HIIT	TC	161 \pm 37	173 \pm 35 ^a	172 \pm 41	161 \pm 28	173 \pm 35 ^a	166 \pm 26
	TAG	129 \pm 25	136 \pm 28 ^a	132 \pm 25	137 \pm 32	142 \pm 25 ^a	132 \pm 17
	HDL-c	27 \pm 4	33 \pm 6 ^a	31 \pm 7	28 \pm 6	32 \pm 6 ^a	28 \pm 5
	nHDL-c	133 \pm 38	140 \pm 35 ^a	141 \pm 44	132 \pm 30	140 \pm 36 ^a	137 \pm 25
MICT	TC	162 \pm 32	187 \pm 37 ^a	155 \pm 31	172 \pm 35	178 \pm 38 ^a	177 \pm 53
	TAG	143 \pm 21	151 \pm 30 ^a	131 \pm 21	154 \pm 46	167 \pm 44 ^a	141 \pm 24
	HDL-c	34 \pm 8	40 \pm 7 ^a	34 \pm 6	35 \pm 8	39 \pm 9 ^a	34 \pm 9
	nHDL-c	127 \pm 31	147 \pm 34 ^a	121 \pm 28	120 \pm 59	139 \pm 35 ^a	143 \pm 55

Note. MICT = moderate-intensity continuous training (n = 10); HIIT = high-intensity intermittent training (n = 10); TC = total cholesterol; TAG = triacylglycerol; HDL-c = high-density lipoprotein; nHDL-c = non-HDL-cholesterol; SD = standard deviation. Lipid profile is express in mg/dL. ^a = significantly different from pre-exercise. Lipid profile is express in mg/dL.

Results derived from other recent studies proposed the importance of physical exercise to induce the increment of reverse cholesterol transport (RCT) [22,24].

Phase angle and heart rate measured are metabolic health indices and they presented no significant differences in response to the training regimen before and after individual bouts tested in the present study. Previous studies indicated a positive effects of chronic exercise training on phase angle [25], mainly for special groups (i.e. older population) [3,28]. This beneficial response being correlated with inflammatory markers [32]. Dos Santos et al. [3] suggested that training and improvements in body composition increase phase angle whereas detraining results in a marked decrease in PhA. These last results lead us to hypothesize that the physical condition of our participants (physically active, healthy and eutrophic) may explain the absence of changes in the phase angle as well as in heart rate.

4.1. Lipid profile in link with acute exercise session

Regarding the response to an acute exercise session in the pre-training and post-training conditions, there was no change following both training protocols. Recently, Panissa et al. [19] compared the effects of different high-intensity exercise programs (all-out exercise and fixed high-intensity intermittent exercise) on postprandial lipid profile responses. They were not able to find any influence of both exercise modes on lipid metabolism. In this regard, Magkos [16] and Lira [13] put forward the hypothesis that there is a minimum threshold of energy expenditure necessary to change the lipoprotein profile following acute exercise. They suggested that it is necessary to exercise with energy expenditure between 1.100 and 1.500 kcal and at approximately 70% VO₂max to obtain an effect on HDL-c. They also observed that individuals have to reach between 500 and 600 kcal of energy expenditure before having an effect on TAG and VLDL plasma levels. Our group previously showed that both training protocols used in the present study increase energy expenditure by ~500 kcal per session [1]. The present absence of training effect in response to an acute exercise session might therefore, be explained by the fact that energy expenditure was too low to affect the plasma lipid profile. Thus, more studies would be needed for a better understanding of the mechanisms underlying these responses. Hence, it would be of particular interest to determine whether the same effects are observed in sedentary individuals with dyslipidemia or obesity. In addition, our research group recognizes the need of advanced and more sophisticated technologies to help determine the functionality of HDL-c.

Taken together, our data indicate that both HIIT and MICT may alter the lipoprotein profile following an acute session of exercise.

However, in response to chronic exercise training, only HIIT depicted a trend towards increasing HDL-c levels in the fasting state. It is suggested that the intensity of the exercise should also be considered when prescribing a training program aimed at increasing HDL-c levels.

Author contributions

Study design and organization of the manuscript were performed by FSL, VP, and EC. Data analysis, statistical analysis, and the first draft of the manuscript were performed by FSL, BMA, CF, VP, LMT, JML, and DHSP. The manuscript review was performed by LMT, JML, DHSP, and FSL. The final approval for publication was performed by FSL and LMT.

Conflicts of interest

The authors have no conflicts of interest that are directly relevant to the content of this article.

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References

- [1] Cabral-Santos C, Gerosa-Neto J, Inoue DS, Panissa VLG, Gobbo LA, Zagatto AM, et al. Similar anti-inflammatory acute responses from moderate-intensity continuous and high-intensity intermittent exercise. *J Sports Sci Med* 2015;14(4):849.
- [2] Casquero AC, Berti JA, Teixeira LLS, de Oliveira HCF. Chronic exercise reduces CETP and mesterolone treatment counteracts exercise benefits on plasma lipoproteins profile: studies in transgenic mice. *Lipids* 2017;52(12):981–90.
- [3] Dos Santos L, Cyrino ES, Antunes M, Santos DA, Sardinha LB. Changes in phase angle and body composition induced by resistance training in older women. *Eur J Clin Nutr* 2016;70(12):1408. DURSTINE, J. Larry et al. Lipids, lipoproteins, and exercise. *Journal of Cardiopulmonary Rehabilitation and Prevention*, v. 22, n. 6, p. 385–398, 2002.
- [4] Durstine JL, Grandjean PW, Cox CA, Thompson PD. Lipids, lipoproteins, and exercise. *J Cardpul Rehabil Prev* 2002;22(6):385–98.
- [5] Elmer DJ, Laird RH, Barberio MD, Pascoe DD. Inflammatory, lipid, and body composition responses to interval training or moderate aerobic training. *Eur J Appl Physiol* 2016;116(3):601–9.
- [6] Ferguson MA, Alderson NL, Trost SG, Essig DA, Burke JR, Durstine JL. Effects of four different single exercise sessions on lipids, lipoproteins, and lipoprotein lipase. *J Appl Physiol* 1998;85(3):1169–74.
- [7] Grandjean PW, Crouse SF, Rohack JJ. Influence of cholesterol status on blood lipid and lipoprotein enzyme responses to aerobic exercise. *J Appl Physiol* 2000;89(2):472–80.

- [8] Jaffrin MY, Morel H. Body fluid volumes measurements by impedance: a review of bioimpedance spectroscopy (BIS) and bioimpedance analysis (BIA) methods. *Med Eng Phys* 2008;30(10):1257–69.
- [9] Kaess BM, Preis SR, Lieb W, Beiser AS, Yang Q, Chen TC, et al. Circulating brain-derived neurotrophic factor concentrations and the risk of cardiovascular disease in the community. *J Am Heart Assoc* 2015;4(3). e001544.
- [10] Kelley GA, Kelley KS, Tran ZV. Aerobic exercise and lipids and lipoproteins in women: a meta-analysis of randomized controlled trials. *J Wom Health* 2004;13(10):1148–64.
- [11] Kosmas CE, Martinez I, Sourlas A, Bouza KV, Campos FN, Torres V, et al. High-density lipoprotein (HDL) functionality and its relevance to atherosclerotic cardiovascular disease. *Drugs Context* 2018;7.
- [12] Kontush A. HDL particle number and size as predictors of cardiovascular disease. *Front Pharmacol* 2015. <https://doi.org/10.3389/fphar.2015.00218>.
- [13] Lira FS, Carnevali LC, Zanchi NE, Santos RV, Lavoie JM, Seelaender M. Exercise intensity modulation of hepatic lipid metabolism. *J Nutr Metabol* 2012;2012: 809576. <https://doi.org/10.1155/2012/809576>. Epub 2012 Apr 2.
- [14] Lira FS, Yamashita AS, Uchida MC, Zanchi NE, Gualano B, Martins E, et al. Low and moderate, rather than high intensity strength exercise induces benefit regarding plasma lipid profile. *Diabetol Metab Syndrome* 2010;2(1):31.
- [15] Lira FS, Zanchi NE, Lima-Silva AE, Pires FO, Bertuzzi RC, Santos RV, et al. Acute high-intensity exercise with low energy expenditure reduced LDL-c and total cholesterol in men. *Eur J Appl Physiol* 2009;107(2):203–10.
- [16] Magkos F. Basal very low-density lipoprotein metabolism in response to exercise: mechanisms of hypotriacylglycerolemia. *Prog Lipid Res* 2009;48(3): 171–90.
- [17] Mann S, Beedie C, Jimenez A. Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations. *Sports Med* 2014;44(2):211–21.
- [18] Marniemi J, Dahlström S, Kvist M, Seppänen A, Hietanen E. Dependence of serum lipid and lecithin: cholesterol acyltransferase levels on physical training in young men. *Eur J Appl Physiol Occup Physiol* 1982;49(1):25–35.
- [19] Panissa VLG, Julio UF, Diniz TA, Antunes BDMM, Lira FS, Takito MY, Franchini E. Postprandial lipoprotein profile in two modes of high-intensity intermittent exercise. *J Exerc Rehabil* 2016;12(5):476.
- [20] Panissa VLG, Azevedo NR, Julio UF, Andreato LV, e Silva CP, Hardt F, Franchini E. Maximum number of repetitions, total weight lifted and neuromuscular fatigue in individuals with different training backgrounds. *Biol Sport* 2013;30(2):131.
- [21] Pedersen BK. The disease of physical inactivity – and the role of myokines in muscle–fat cross talk. *J Physiol* 2009;587(Pt23):5559–68.
- [22] Rocco DDFM, Okuda LS, Pinto RS, Ferreira FD, Kubo SK, Nakandakare ER, et al. Aerobic exercise improves reverse cholesterol transport in cholesteryl ester transfer protein transgenic mice. *Lipids* 2011;46(7):617–25.
- [23] Rodríguez-Colón SM, He F, Bixler EO, Fernandez-Mendoza J, Vgontzas AN, Calhoun S, et al. Metabolic syndrome burden in apparently healthy adolescents is adversely associated with cardiac autonomic modulation—penn State Children cohort. *Metabolism* 2015;64(5):626–32.
- [24] Rosenson RS, Brewer Jr HB, Ansell BJ, Barter P, Chapman MJ, Heinecke JW, et al. Dysfunctional HDL and atherosclerotic cardiovascular disease. *Nat Rev Cardiol* 2016;13(1):48.
- [25] Silva AM, Gobbo L, Sardinha L, Cyrino ES. Hypertrophy-type resistance training improves phase angle in young adult men and women. *Int J Sports Med* 2016;37:1–6.
- [26] Soares-Miranda L, Sandercock G, Vale S, Santos R, Abreu S, Moreira C, Mota J. Metabolic syndrome, physical activity and cardiac autonomic function. *Diabetes Metabol Res Rev* 2012;28(4):363–9.
- [27] Sousa N, Mendes R, Abrantes C, Sampaio J, Oliveira J. A randomized study on lipids response to different exercise programs in overweight older men. *Int J Sports Med* 2014;35(13):1106–11.
- [28] Souza MF, Tomeleri CM, Ribeiro AS, Schoenfeld BJ, Silva AM, Sardinha LB, Cyrino ES. Effect of resistance training on phase angle in older women: a randomized controlled trial. *Scand J Med Sci Sports* 2017;27(11):1308–16.
- [29] Stevens SL, Wood S, Koshiaris C, Law K, Glasziou P, Stevens RJ, McManus RJ. Blood pressure variability and cardiovascular disease: systematic review and meta-analysis. *BMJ* 2016;354:i4098.
- [30] Tran DMT, Zimmerman LM. Cardiovascular risk factors in young adults: a literature review. *J Cardiovasc Nurs* 2015;30(4):298–310.
- [31] Tolfrey K, Jones AM, Campbell IG. The effect of aerobic exercise training on the lipid-lipoprotein profile of children and adolescents. *Sports Med* 2000;29(2): 99–112.
- [32] Tomeleri CM, Ribeiro AS, Cavaglieri CR, Deminice R, Schoenfeld BJ, Schiavoni D, et al. Correlations between resistance training-induced changes on phase angle and biochemical markers in older women. *Scand J Med Sci Sports* 2018;28(10):2173–82. <https://doi.org/10.1111/sms.13232>. Epub 2018 Jun 25.
- [33] Van Beaumont W. Evaluation of hemoconcentration from hematocrit measurements. *J Appl Physiol* 1972;32(5):712–3.
- [34] Vanderlei LCM, Silva RA, Pastre CM, Azevedo FMD, Godoy MF. Comparison of the Polar S810i monitor and the ECG for the analysis of heart rate variability in the time and frequency domains. *Braz J Med Biol Res* 2008;41(10):854–9.