Original Article

Effects of Aerobic and Anaerobic Exercise on Cardiac Risk Variables in Overweight Adults

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Summary

Background: **Aerobic exercise is an important ally in the fight against cardiovascular risk factors. However, the effects of high-intensity exercise on these factors are still poorly known.**

Objective: **To compare the effects of aerobic and anaerobic exercise protocols on cardiac risk factors.**

Methods: **22 individuals with mean age of 40±8 years were distributed into the following groups: control (CO), endurance training (ET) and interval training (IT). The protocols lasted 12 weeks, three times a week, with intensities of 10% below and 20% above the anaerobic threshold (AnT). The following measurements were taken: total body mass (TBM), body mass index (BMI), waist circumference (WC), hip circumference (HC), and body composition, in addition to plasma concentrations of glucose (GLU), total cholesterol (CHO), and triglycerides (TG). Waist-hip ratio (WHR) and conicity index (C index) were also calculated.**

Results: **The TBM, BMI, WC, GLU, and body composition variables showed significant changes in the ET and IT groups. CHO and HC values were significantly reduced in the ET group, whereas WHR showed a significant reduction in the IT group. AnT and C index in the IT group were significantly different in relation to ET.**

Conclusion: **In view of the differences found in the results of the variables studied in relation to the training performed, we conclude that an exercise program that includes both high and low-intensity activities is more efficient to ensure the reduction of a greater number of cardiac risk variables. (Arq Bras Cardiol 2008;91(4):200-206)**

Key words: **Body mass index; cholesterol; body composition; overweight; abdominal circunference; adult; exercise.**

Introduction

There is evidence showing both the beneficial effects of physical exercise on all the factors associated with metabolic syndrome in adults and the positive correlation of inactivity with all the risk factors that comprise this syndrome[1]. In this sense, several health organizations such as the American College of Sports Medicine[2], the Brazilian Society of Cardiology[3], and the American Diabetes Association[4] recommend the use of physical activity as a therapy for the risk factors associated with obesity.

The characteristics of the model of exercise traditionally used are low intensities, long sessions, and predominance of aerobic exercises. In fact, the biochemical adaptations induced by continuous exercise have been studied since the late 60's[5], and this type of physical activity was effectively proven to induce increased muscle oxidative capacity by increasing the activity of key enzymes of beta oxidation[6], which is a specific metabolic pathway of fatty acid oxidation, in addition to signaling and increasing the velocity of other metabolic pathways of the ATP resynthesis oxidative metabolism such as the Krebs cycle[7] and mitochondrial respiratory chain[8].

Recent studies also demonstrate that interval exercise is efficient in reducing fat percentage and plasma lipid levels in adolescents under certain circumstances[9,10]. In this sense, Stiegler and Cunliffe[11] made a recent and thorough review analyzing calorie restriction strategies associated or not with several types of physical exercise protocols and did not mention any study using a high-intensity activity protocol in the reduction of body composition and parameters of plasma lipid profile in adult individuals. Therefore, the objective of this study was to compare changes in these parameters induced by two physical activity protocols, one of them performed at low intensity and the other at high intensity in obese adults.

Methods

Subjects

Thirty healthy individuals were enrolled in this study. However, some of them dropped out and the study ended with the participation of 22 individuals (men, n = 8 and

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women, n = 14) with mean age of 40±8 years. The inclusion criteria were: BMI higher than 25, already situated in the overweight range[12], sedentary lifestyle for at least two years, and no medical contraindication, such as severe hypertension or heart diseases, for the practice of physical activities. Medical evaluation was performed by private physicians; after the patients were released for physical activities they were included in one of the experimental groups. This study was approved by the ethics committee of University of *Bahia* School of Medicine; after being fully informed of the possible risks and discomforts associated with the procedures the volunteers gave their informed consent.

The subjects were randomly assigned in equal proportions of men and women to one of the three experimental groups: sedentary control (CO), which did not perform any type of exercise; endurance training group (ET); and interval training group (IT). In the ET and IT groups, all variables, except for height, were measured before (PRE) and after (POST) the exercise protocols. For the CO group all variables were measured in the same period of the POST training assessments of the ET and IT groups. All measurements of the same period were taken within a seven-day interval at most.

Physical activity protocols

The physical activity programs lasted 12 weeks and were performed in a cycle ergometer. The initial duration was 20 minutes in the first week, with increments of 10 minutes per week until a total of 60 minutes per session was reached in the fourth week. The frequency was three times a week for both the ET and the IT groups.

The ET group performed the activity continuously, without pause, at an intensity 10% lower than the individual anaerobic threshold, whereas the activity pattern of the IT group was intermittent, that is, the exercises were alternated with regenerative pauses so that the subjects could complete the sessions. In the IT group, the exercise intensity was 20% above the individual anaerobic threshold and the duration of the sessions was similar to that of the ET group, with an exercise/pause ratio of 2:1 minutes. The intensity was controlled by heart rate using Polar model S610 l heart rate monitors.

Since the objective of this study was to analyze the effect of different types of physical activity on the reduction of cardiovascular risk parameters, we excluded the calorie intake reduction as a possible intervenient variable, so that the volunteers were strongly encouraged to keep their usual eating pattern. The experimental design of the physical activity protocols is shown in Table 1.

Energy expenditure estimate

Energy expenditure per session was estimated using the following equation proposed by the American College of Sports Medicine (ACSM)[13] and updated by Swain[14].

$$VO_2 = 7 + 1.8(\text{Watts})/M$$

Where VO_2 is the oxigen consumption (ml.Kg^{-1}.min^{-1}), *Watts* is the exercise load performed during the session and *M* is the individual's total body mass. The individuals energy expenditure was estimated from oxigen consumption induced by physical activity, considering that for each liter of oxigen consumed, approximately 20.9J of energy are spent[14].

Data collection

Anthropometric parameters

Height was measured using a Sanny professional stadiometer to the nearest 0.1 cm, with the subjects barefoot leaning their buttocks and shoulders against a vertical back. Total body mass (TBM) was measured using a Filizola digital scale to the nearest 100g, with the subjects wearing only shorts and top, in the case of women. Waist and hip circumferences were taken using a Sanny metal anthropometric tape measure to the nearest 0.1 cm. Body mass index (BMI) was calculated based on these data. We also calculated the waist/hip ratio (WHR) and the conicity index (C index), which establishes relations between TBM, height and waist circumference. The C index was calculated using the following equation, according to Pitanga and Lessa[15]:

$$\text{C Index} = \frac{\text{Waist Circunference (m)}}{0.109\sqrt{\dfrac{\text{Body weight (Kg)}}{\text{Height (m)}}}}$$

Body composition was measured using bioelectrical impedance analysis (BIA). Resistance and body reactance were measured using a body composition analyzer (HBF-306, Omron, Canada). For these measurements, the volunteers were instructed to remain fasted for 10 hours, to drink at least 2 liters of water, not to perform any kind of physical activity and not to drink alcoholic beverages the day before the measurements were taken.

Table 1 - **Experimental design of the physical activity protocols**

WEEK	1st		2nd		3rd		4th		5th – 12th	
Duration	20 min		30 min		40 min		50 min		60 min	
	Int	Sew	Int	Sew	Int	Sew	Int	Sew	Int	Sew
CO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ET	10%< thresh	3	10%< thresh	3	10%< thresh	3	10%< thresh	3	10%< thresh	3
IT	20%> thresh	3	20%> thresh	3	20%> thresh	3	20%> thresh	3	20%> thresh	3

CO - Control group; ET - Endurance Training; IT - Interval training; Int - Exercise intensity; Sew - Total number of sessions per week; thresh - Anaerobic threshold; N/A - Not assessed.

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Anaerobic threshold (AnT) determination

AnT was determined in a cycle ergometer with mechanical transmission (CEFISE/BIOTEC 2100). In order to determine the AnT, we used a discontinuous graded exercise protocol. After a 5-minute warm-up in the same cycle ergometer where the test would be conducted with a 15-Watt (W) load, the individuals pedaled at a constant speed of 28 $Km.h^{-1}$ with an initial load of 25 W, which was increased by 25 W every three minutes. At the end of each 3-minute stage, the heart rate (HR) was measured with a Polar (S610 I) cardiac monitor and a 50-μL blood sample was collected from the ear lobe in heparinized capillary tubes; while the volunteer started the next exercise stage, the sample's lactate concentration was determined using an Accutrend portable lactate analyzer (Roche)[16]. The duration of this procedure was shorter than 30 seconds. When a greater than or equal to 4 mM concentration was reached, the test would be interrupted. Thus, for each load, HR and plasma lactate concentration were observed. Using linear interpolation, the intensity (Watts) and HR corresponding to 4 mM of lactate were found and this intensity was assumed as the AnT[17].

Biochemical parameters

For measurement of plasma glucose (GLU), total cholesterol (CHO) and triglyceride (TG) levels the volunteers were instructed to remain fasted for ten hours before having their blood sample drawn. For determination of these parameters, 50-μL blood samples were drawn from the earlobe in heparinized capillary tubes and the blood was deposited in specific reagent strips for each determination performed in the Accutrend GCT portable instrument (Roche)[18].

Statistical analysis

The sample size was calculated using the PIFACE software[19]. Using the GraphPad Instat software (San Diego, CA), the data were applied to the Kolmogorov-Smirnov normality test and to the homoscedasticity test (Bartlett's test). After the descriptive analysis of the sample, the statistical tests that best suited the sample distribution were applied for the analysis of the intra and inter-group variables. These tests are mentioned in the legends of the tables and figures. P values < 0.05 were considered statistically significant.

Results

The baseline values of the variables studied in the CO, ET and IT groups did not show any statistically significant difference between one another in most of the cases, and demonstrated a satisfactory homogeneity between the groups at the PRE exercise time point.

Functional parameters (AnT)

Aerobic power, as measured by AnT, showed a significant increase ($p<0.05$) for the ET and IT groups in comparison to the CO group and to the PRE time point; the interval training protocol proved even more efficient in increasing AnT than the endurance protocol, as evidenced by the significant difference ($p < 0.05$) between ET and IT values at the POST time point (Figure 1).

Anthropometric parameters and energy expenditure:

Data of the anthropometric variables and those regarding the estimated energy expenditure of the CO, ET and IT groups are summarized in Table 2. Our data show that despite the greater exercise intensity in the IT group, the estimated calorie expenditure per session was not different among the groups.

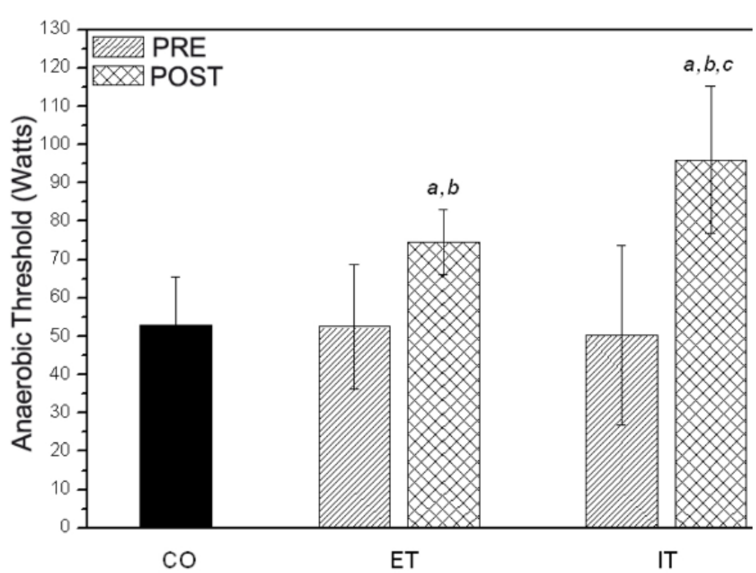

Figure 1 - Aerobic power of the CO (n=7), ET (n=8) and IT (n=8) groups before (PRE) and after (POST) 12 weeks of respective interventions. Data are expressed as mean±SD. a p<0.05 compared with CO, c p<0.05 compared with ET POS (One-way ANOVA with Tukey post-test), b p<0.05 compared with PRE (Wilcoxon test for paired samples).

Table 2 - **Anthropometric parameters and estimated energy expenditure of individuals of the CO, ET and IT groups**

Variables	CO	ET PRE	ET POST	IT PRE	IT POST
Height (m)	1.69±0.1	1.62±0.1	ND	1.66±0.05	ND
Waist (cm)	98.7±14	89.1±7.5	87.5±7 b	84.84±10.5	84.12±10.3 a,b
Hip (cm)	112.6±7.1	103.2±9.1	102.3±8.7 b	104.7±9.4	100.7±8. a,b,c
TBM (kg)	94.1±20.6	74.8±12.2	73.5±11.6 a,b	80.1±14.2	78.9±14.1 a,b
BMI (Kg/m^2)	32.6±4.7	27.5±1.9a	27.1±1.8 a,b	28.3±3.7	27.9±3.7 b
WHR	0.87±0.1	0.86±0.07	0.85±0.07	0.81±0.08	0.79±0.07 b,c
C	1.21±0.1	1.21±0.07	1.20±0.07 b	1.21±0.08	1.12±0.05 b,c
% fat	35.5±6.6	31.9±3.7	31±4.1 a,b	29.5±7.6	28.9±7.4 a,b
% fat-free mass	64.4±6.6	68±3.7	68.9±4.1 b	70.5±7.6	71.2±7.7 b
Estimated energy expenditure* (kJ)	ND	ND	1343.3±334.78	ND	1434.7±287.54

*Results expressed as mean±SD. a p<0.05 compared with CO (One-way ANOVA with Tukey post-test), b p<0.05 compared with PRE (Student's t test for paired samples), c p<0.05 compared with ET POST (Student's t test for non-paired samples). ND - Not determined. CI - Conicity index * Energy expenditure per training session.*

Waist and hip circumferences as well as TBM showed a significant reduction ($p<0.05$) in relation to the CO group and also in relation to the PRE time point for both training protocols. Hip measurement also showed a significant difference ($p<0.05$) between the ET and IT groups at the POST time point.

BMI in the PRE ET group was statistically lower ($p<0.05$) in comparison to the CO group. However, after the endurance training protocol, a significant difference was found in the ET group between the PRE and POST time points; eventhough no significant difference had been found in relation to the CO group, the p value obtained in the comparison between the POST ET group and the CO group was 0.06, thus showing a reduction trend in relation to this group.

For WHR, a significant reduction ($p<0.05$) was found in the IT group. Although the ET group had shown a reduction trend in relation to baseline, it did not reach a significant difference, with a p value of 0.08.

As regards the C index, both protocols were efficient in significantly reducing ($p<0.05$) its values in relation to the respective PRE time points. The IT group showed an even greater reduction ($p<0.05$) when compared to the ET group. As regards body composition, both the ET and IT groups had a significant reduction ($p<0.05$) in body fat percentage and also a significant increase in fat-free mass.

Biochemical parameters

The results of the biochemical parameters are shown in Figures 2, 3 and 4. Among them, GLU responded to both treatments, and its concentration was significantly reduced

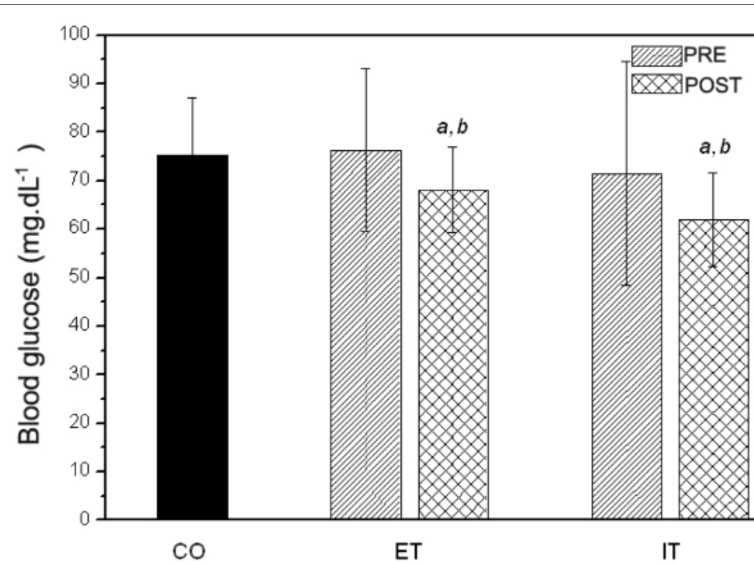

Figure 2 - Blood glucose in the CO (n=7), ET (n=8) and IT (n=8) groups before (PRE) and after (POST) 12 weeks of the respective interventions. Data are expressed as mean±SD. a p<0.05 compared with CO (One-way ANOVA and Tukey post-test), b p<0.05 compared with PRE (Wilcoxon test for paired samples).

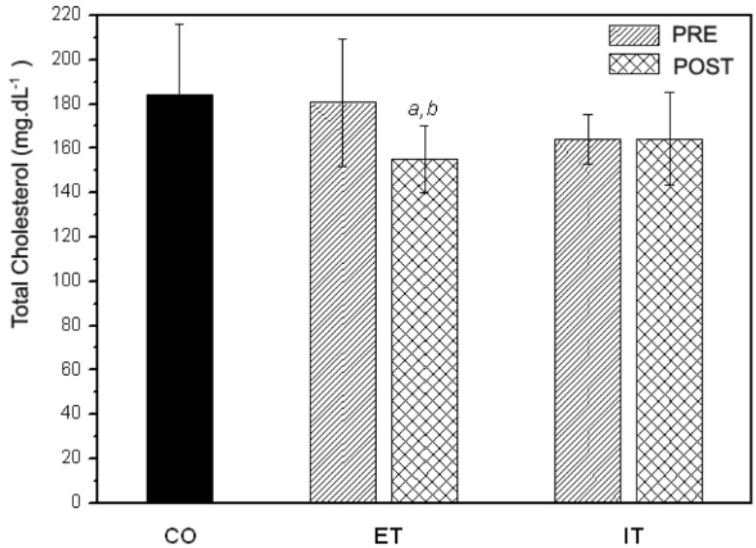

Figure 3 - Total plasma cholesterol in the CO (n=7), ET (n=8) and IT (n=8) groups before (PRE) and after (POST) 12 weeks of the respective interventions. Data are expressed as mean±SD. a p<0.05 compared with CO (Kruskal-Wallis and Dunn's post-test), b p<0.05 compared with PRE (Mann-Whitney test for paired samples).

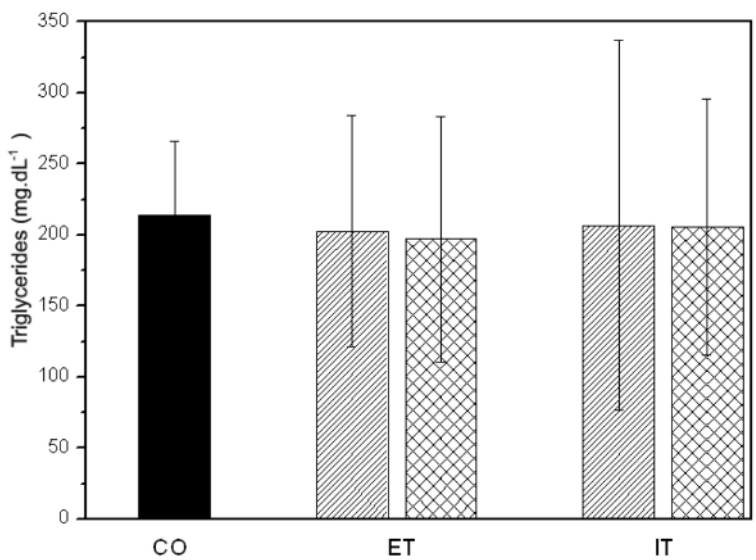

Figure 4 - Plasma triglyceride levels in the CO (n=7), ET (n=8) and IT (n=8) groups before (PRE) and after (POST) 12 weeks of the respective interventions. Data are expressed as mean±SD.

in both groups, although the values were within the normal range at all time points assessed. On the other hand, although CHO had also remained within normal values, only the ET group demonstrated a significant reduction in its values when compared to PRE ET and CO.

Data regarding TG concentrations are shown in Figure 4. Although for some groups, at certain time points, values above the recommended range had been found, none of the exercise protocols was efficient in significantly reducing their levels; only the ET group showed a mild downward trend. The IT group, in turn, showed a sideways trend, and the CO group, an upward trend.

Discussion

The fact that lipid oxidation takes place exclusively inside the mitochondria via oxidative pathways[20], in addition to the predominance of the utilization of fatty acids as energy substrate, and also the chronic oxidative adaptations observed in long-duration exercises performed at low intensity[21], led to the belief that only this type of exercise would be efficient in reducing body fat percentage, whereas high-intensity exercises were presumed not to be efficient for this purpose, since they oxidize predominantly carbohydrate as the energy substrate. In fact, consistent data from the literature show the efficacy of endurance exercises in reducing body fat percentage and consequently TBM[11], in addition to its protective effect regarding the cardiovascular risk, since this type of exercise also contributes to the maintenance of adequate plasma lipid and lipoprotein levels[22]. On the other hand, other studies demonstrated that high-intensity exercises are also effective in inducing significant adaptations in the oxidative capacity[23]. However, few data are available in the literature as regards the effects induced by high-intensity anaerobic exercises on anthropometric variables and the plasma lipid profile related to cardiac risk.

As expected, our results for the ET group corroborate data from the literature, demonstrating mild but statistically significant changes in the main anthropometric and plasma markers of cardiac risk, in addition to the functional capacity as assessed by the aerobic capacity measured with AnT in relation to the controls[24-27].

As regards anaerobic exercises applied to the IT group, their intensity was determined based on data obtained by Silveira and Denadai[28], who demonstrated that the greater inhibition of the glycolytic pathway during high-intensity interval exercises occurred at intensities corresponding to 120 to 130% of the AnT.

Our data obtained in overweight adults showed responses similar to those obtained in obese adolescents in relation to TBM, BMI, fat mass percentages, fat-free mass, plasma GLU, and waist circumference measurements[9,10,29], where no significant differences were found between the types of exercises. However, both proved efficient in reducing the levels of these variables and also in significantly increasing the fat-free mass in comparison to the values obtained before the exercise protocols. Although the types of exercises used in this study are not the main form of increasing muscle mass, the results observed were probably due to the low physical fitness level of the study participants.

Like in other studies, CHO was reduced only in response to the aerobic exercise protocol in the ET group[10,30].

Cross-sectional and longitudinal studies have demonstrated the influence of exercise-induced energy expenditure on the majority of the variables previously mentioned[31]; therefore, the similar responses obtained for these parameters may be explained by the estimated energy expenditure induced by the training protocols, which did not show a significant difference between the ET and IT groups.

As regards AnT, our data corroborate those of other studies that also demonstrated more significant effects induced by higher intensity exercises on the increase of this variable both in sedentary individuals and in endurance athletes[32,33]. Although the intracellular mechanisms that regulate these adaptations are not fully understood, higher intensity levels of exercise are believed to be more efficient in activating the mechanism responsible for the control of mitochondrial protein expression[34].

As regards the C index, our data are novel, since no other study has analyzed the effect of physical exercise on this parameter to date. The C index establishes a wider parameter of body fat distribution and demonstrated a high degree of affinity and specificity with cardiac risk in the population of Salvador[15]. Our data showed that ET and IT were efficient in reducing C index levels, which probably resulted from the reduction in waist and mainly hip circumferences. Like for the C index, WHR also showed a significant reduction only in the IT group, thus effectively responding specifically to IT. The fact that the IT group induced a more efficient action specifically for these two indexes may be due to the greater adrenaline secretion in response to more intense exercises, which would increase lipolysis levels in the intra-abdominal and mainly subcutaneous fat tissue located in the hip region[35-37]. Finally, regarding TG, although other studies have demonstrated reduced plasma levels of this variable in young individuals and adults in response to exercise[9,10,31], the ET group presented only a downward trend. However, no significant differences were found, probably due to the high coefficient of variability observed in the groups, which resulted from a high lipid content in the diet of these individuals.

Based on our data, we conclude that TBM, waist circumference, fat-free mass and fat mass percentages, BMI, and GLU seem to have a similar response to the ET and IT training protocols. This similarity may possibly be specifically linked to the calorie expenditure induced by exercise, regardless of its intensity. Our data corroborate this conclusion, since the calorie expenditure demanded both by ET and IT was not significantly different. CHO levels were significantly reduced specifically in response to the ET protocol, whereas hip circumference, WHR, C index and AnT had more significant alterations in the IT group in comparison to the ET group. Therefore, these data suggest that an exercise program including activities with both aerobic and anaerobic characteristics seems more complete to cause an impact on a greater number of variables related to cardiac risk in overweight adults.

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Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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References

1. Pate RR, Pratt M, Blair SN, Haskell WR, Macera CA, Bouchard C, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA. 1995; 273 (5): 402-7.

2. American College of Sports Medicine. ACSM stand position on the appropriate intervention strategies for weight loss and prevention of weight gain for adults. Med Sci Sports Exerc. 2001; 33: 2145-56.

3. Sociedade Brasileira de Cardiologia. IV Diretrizes Brasileiras de Hipertensão Arterial. Arq Bras Cardiol. 2004; 82 (supl. 4): 1-14.

4. American Diabetes Association. ADA stand position: physical activity/ exercise and diabetes mellitus. Diabetes Care. 2003; 26: 573-7.

5. Holloszy JO. Biochemical adaptations in muscle: effects of exercise on mitochondrial oxygen uptake and respiratory enzyme activity in skeletal muscle. J Biol Chem. 1967; 10; 242 (9): 2278-82.

6. Carter SL, Rennie CD, Hamilton SJ, Tarnopolski MA. Changes in skeletal muscle in males and females following endurance training. Can J Physiol Pharmacol. 2001; 79 (5): 386-92.

7. Booth FW, Thomason DB. Molecular and cellular adaptation of muscle in response to exercise: perspectives of various models. Physiol Rev. 1991; 71 (2): 541-85.

8. Wibom R, Hultman E, Johansson M, Matherei K, Constantin-Teodosiu D, Schantz PG. Adaptation of mitochondrial ATP production in human skeletal muscle to endurance training and detraining. J Appl Physiol. 1992; 73 (5): 2004-10.

9. Fernandez AC, Mello MT, Tufik S, Castro PM, Fisberg M. Influência do treinamento aeróbio e anaeróbio na massa de gordura corporal de adolescentes obesos. Rev Bras Med Esporte. 2004; 10 (3): 152-8.

10. Sabia RV, Santos, JE, Ribeiro, RPP. Efeito da atividade física associada à orientação alimentar em adolescentes obesos: comparação entre o exercício aeróbio e anaeróbio. Rev Bras Med Esporte. 2004; 10 (5): 349-55.

11. Stiegler P, Cunliffe A. The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weight loss. Sports Med. 2006; 36 (3): 239-62.

12. Kuczmarski RJ, Flegal KM. Criteria for definition of overweight in transition: background and recommendations for the United States. Am J Clin Nutr. 2000; 72: 1074-81.

13. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. Baltimore:Williams and Wilkins; 1995.

14. Swain DP. Energy cost calculations for exercise prescription: an update. Sports Med. 2000; 30 (1): 17-22.

15. Pitanga FJG, Lessa I. Sensibilidade e especificidade do índice de conicidade como discriminador do risco coronariano de adultos em Salvador, Brasil. Rev Bras Epidemiol. 2004; 7 (3): 259-69.

16. Fell JW, Rayfield JM, Gulbin JP, Gaffney PT. Evaluation of the accusport lactate analyser. Int J Sports Med. 1998; 19 (3): 199-204.

17. Heck H, Mader A, Hess G, Mucke S, Muller R, Hollmann W. Justification of the 4-mmol/l lactate threshold. Int J Sports Med. 1985; 6: 117-30.

18. Moses RG, Calvert D, Storlien LH. Evaluation of the accutrend GCT with respect to triglyceride monitoring. Diabetes Care. 1996; 19(11): 1305-6.

19. Lenth RV. Java applets for power and sample size [Computer software]. [cited on 2007 Nov 17]. Available from: http://www.stat.uiowa.edu/~rlenth/Power.

20. Voët D, Voët JG, Pratt CW. Fundamentals of biochemistry. New York: John Wiley & Sons Inc; 1999.

21. Romijn JA, Coyle EF, Sidossis LS, Gastaldelli A, Horowitz JF, Endert E, et al. Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. Am J Physiol. 1993; 265 (3 Pt 1): E380-91.

22. Hamilton MT, Areiqat E, Hamilton DG, Bey L. Plasma triglyceride metabolism in humans and rats during aging and physical inactivity. Int J Sport Nutr Exerc Metab. 2001;11 (Suppl): S97-104.

23. Smolka MB, Zoppi CC, Alves AA, Silveira LR, Marangoni S, Pereira-da-Silva L, et al. HSP72 as a complementary protection against oxidative stress induced by exercise in the soleus muscle of rats. Am J Physiol Regul Integr Comp Physiol. 2000; 279 (5): 1539-45.

24. Grediagin A, Cody M, Rupp J, Benardot D, Shern R. Exercise intensity does not effect body composition change in untrained, moderately overfat women. J Am Diet Assoc. 1995; 95 (6): 661-5.

25. Wilmore JH, Despres JP, Stanforth PR, Mandel S, Rice T, Gagnon J, et al. Alterations in body weight and composition consequent to 20 wk of endurance training: the HERITAGE Family Study. Am J Clin Nutr. 1999; 70 (3): 346-52.

26. Crampes F, Marion-Latard F, Zakaroff-Girard A, De Glisezinski I, Harant I, Thalamas C, et al. Effects of a longitudinal training program on responses to exercise in overweight men. Obes Res. 2003; 11 (2): 247-56.

27. Smith DA, O'Donnell TV. The time course during 36 weeks' endurance training of changes in VO2 max. and anaerobic threshold as determined with a new computerized method. Clin Sci. 1984; 67 (2): 229-36.

28. Silveira LR, Denadai, BS. Efeito modulatório de diferentes intensidades de esforço sobre a via glicolítica durante o exercício contínuo e intermitente. Rev Paul Educ Fis. 2002; 16 (2):186-97.

29. Terada S, Yokozeki T, Kawanaka K, Ogawa K, Higuchi M, Ezaki O, et al. Effects of high-intensity swimming training on GLUT-4 and glucose transport activity in rat skeletal muscle. J Appl Physiol. 2001; 90 (6): 2019-24.

30. Aellen R, Hollmann W, Boutellier U. Effects of aerobic and anaerobic training on plasma lipoproteins. Int J Sports Med. 1993; 14 (7): 396-400.

31. Durstine JL, Grandjean PW, Cox CA, Thompson PD. Lipids, lipoproteins, and exercise. J Cardiopulm Rehabil. 2002; 22 (6): 385-98.

32. Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. Sports Med. 2002; 32 (1): 53-73.

33. Kraus WE, Houmard JA, Duscha BD, Knetzger KJ, Wharton MB, McCartney JS, et al. Effects of the amount and intensity of exercise on plasma lipoproteins. N Engl J Med. 2002 7; 347 (19): 1483-92.

34. Zoppi CC. Mecanismos moleculares sinalizadores da adaptação ao treinamento físico. Rev Saúde Com. 2005; 1 (1): 60-70.

35. Arner P, Kriegholm E, Engfeldt P, Bolinder J. Adrenergic regulation of lipolysis in situ at rest and during exercise. J Clin Invest. 1990; 85 (3): 893-8.

36. Enevoldsen LH, Stallknecht B, Fluckey JD, Galbo H. Effect of exercise training on in vivo lipolysis in intra-abdominal adipose tissue in rats. Am J Physiol Endocrinol Metab. 2000; 279 (3): E585-92.

37. Enevoldsen LH, Stallknecht B, Langfort J, Petersen LN, Holm C, Ploug T, et al. The effect of exercise training on hormone-sensitive lipase in rat intra-abdominal adipose tissue and muscle. J Physiol. 2001; 536 (Pt 3): 871-7.