Method of Heart Rate Variability Threshold Applied in Obese and Non-obese Pre-adolescents

Mário Augusto Paschoal and Caio Cesar Fontana
Pontifícia Universidade Católica de Campinas, Campinas, SP - Brazil

Abstract

Background: **The detection of anaerobic threshold (AT) by heart rate variability analysis (HRVt) may mean a new way to assess the cardiorespiratory capacity (CRC) in pre-adolescents.**

Objective: **To test the method of HRVt to detect AT in non-obese (NO), obese (O) and morbidly obese (MO) pre-adolescents in order to determine differences in their CRC.**

Methods: **Were studied 30 pre-adolescents, aged between 9 and 11 years, divided into three groups of ten pre-adolescents each: a) NO group - body mass index (BMI) between 5 and 85 percentiles of the chart of National Center for Chronic Disease Prevention and Health Promotion.; b) O group - BMI between 95 and 97 of the same chart; c) MO group - BMI with percentile over 97. All were submitted to an incremental protocol conducted on a treadmill, and the heart rate was recorded for the detection of the HRVt when the beat-to-beat variability (SD1), extracted from the RR intervals, reached the value of 3 ms.**

Results: **The mean values obtained at HRVt were higher for the NO group, which included: a) VO2 (ml/kg/min) NO = 27.4 ± 9.2; O = 13.1 ± 7.6, and MO = 11.0 ± 1.7 b) HR (bpm): NO = 156.3 ± 18.0, O = 141.7 ± 11.4 and 137.7 ± 10.4 MO; c) distance (m): NO = 1194.9 ± 427.7, O = 503.2 ± 437.5 and MO = 399.9 ± 185.1.**

Conclusion: **HRVt was effective for evaluation of CRC and could be applied as an alternative method to ergoespirometry in certain situations. (Arq Bras Cardiol. 2011; [online].ahead print, PP.0-0)**

Keywords: **Anaerobic threshold; heart rate; child; obesity.**

Introduction

The evaluation of cardiorespiratory capacity (CRC) of obese children and adolescents has currently gained greater importance. In addition to the findings that changes in cardiac autonomic control and high levels of cholesterol, triglycerides and blood glucose may predispose to the genesis of cardiovascular disorders, it is understood that the decrease in physical capacity is also a key component to reducing the quality and possibly the expectancy of life in these children and adolescents[1-5].

The employment of physical activity as a therapy, as well as its prescription and proper control, is an extremely good chance of preventing and reversing obesity in children[6]. For this, these children should first have their physical fitness evaluated in order to set up an initial proposal for an appropriate physical aerobic work intensity.

With the intention of classifying healthy people or patients at levels of functional capacity, determining stages of stratification of cardiovascular risk and measuring aerobic capacity, since the twentieth century, several protocols have been created to evaluate cardiorespiratory capacity (CRC). At the same time, technology geared to the collection and recording of data during the performance of these protocols has greatly evolved[7].

Despite this undeniable progress since the 80s of last century, the interest with respect to data collected during the CRC assessments remained restricted to the values obtained at certain times of the incremental test, such as anaerobic threshold (AT), respiratory compensation point and peak exertion[8,9].

With respect to LA, it should be noted that it allows setting the time of stress in which anaerobic metabolism begins to supplement aerobic metabolism as an energy source for muscles at work[8-10].

Thus, we can distinguish two physiological states during exercise: one below the AT in which the cardiorespiratory responses are stable and oxygen supply and consumption (VO_2) are balanced, and another above the AT, in which organic reactions are not balanced, there is an intense production of carbon dioxide and changes in blood pH, causing an unstable behavior or cardiorespiratory variables[8,11].

Currently, one of the forms used for the determination of AT is a heart rate variability threshold (HRVt). According to some authors[12,13], using the SD1 index (standard deviation of instantaneous RR intervals) of the Poincaré plot, there is a

Mailing address: Mário Augusto Paschoal •
Rua Ferreira Penteado, 1242/72 - Cambuí - 13010-041 - Campinas, SP - Brazil
E-mail: fisioni@puc-campinas.edu.br, mapascka@gmail.com
Manuscript received April 26, 2010; revised manuscript received November 3th, 2010; accepted January 19, 2011.

possibility of identifying HRVt, which would correspond to the ventilatory AT (threshold 1) or lactate threshold.

Despite some differences, data obtained during incremental stress testing, comparing the HRVt with ventilatory AT and lactate threshold, showed good correlation rates and strengthened the hypothesis that the HRVt could be a way for a reliable determination of AT[13,14]. Hence, HRVt could be considered an indicator of aerobic capacity and be used as a physiological parameter to control and prescribe exercise, physical training and risk stratification[13,15]. However, as HRVt is a recent methodology, its application to pre-adolescents is not found in the literature.

Based on these statements, this study tested this methodology as a means of detecting AT and, especially, determining the CRC in non-obese, obese and morbidly obese pre-adolescents.

Method

Individuals

From 64 pre-adolescent students from state schools in the northwest region of Campinas, SP, aged between 9 and 11, 30 sedentary pre-adolescent were selected through calculation of simple random sampling on categorical variables, divided into three groups: group A, comprising 10 non-obese (NO) pre-adolescents with BMI percentile between 5 and 85, from the chart of the National Center for Chronic Disease Prevention and Health Promotion[16]; group B consisted of 10 obese (O) pre-adolescents, with body mass index (BMI) percentile between 95 and 97; and group C with 10 morbidly obese (MO) pre-adolescents with percentile greater than 97.

Those responsible for the pre-adolescents were informed about the relevance of the study and the experimental procedures before giving their approval by signing an informed consent, as established by resolution 196/96 of the Declaration of Helsinki and approved by the Research Ethics Committee (Case No. 138/06).

The inclusion criteria were applied from the screening of volunteers for the values of their BMI. In the first approach, done in the schools, we used a portable scale and tape measure. The pre-selected ones, which also met the other inclusion criteria of not using any medication that could interfere with the data studied and not doing physical activity or sports for at least 06 months, were asked to go to the outpatients department of the University to continue in the selection process, which consisted of a more detailed anthropometric and clinical evaluation.

Since the day prior to scheduled and on the day of their attendance at the outpatients department, the volunteers were instructed not to consume caffeine-based beverages, and soft drinks, teas, chocolate and any medication. They were also advised to sleep at least 08 hours of peaceful sleep and keep their routine activities.

Anthropometric evaluation

The volunteers, wearing only shorts (boys) and shorts and tops (girls), were placed on a Filizola™ scale, with a weight scale of 100 to 100 g, and a height of 1 cm in cm, in order to calculate the BMI values.

Clinical evaluation

It involved an interview and evaluation of vital data such as HR and blood pressure (BP). It is worth noting that there was concern in selecting an appropriate cuff size to the arm girth of the volunteer evaluated. Also, everyone had their heart rate and breathing auscultated through a technique widely reported in the literature[17,18].

For the evaluation and registration of resting HR, we used a Polar S810™ frequency meter. After remaining 5 min in the supine position in a heated room with temperature maintained between 23° C and 25° C and relative humidity kept between 60.0% and 70.0%, volunteers had their heart rates recorded for 10 min. From the analysis of a report made by Polar Precision Performance™, we obtained the average HR for the period of 10 min of heartbeat recording. It should be emphasized that all study procedures were conducted between 03:00 p.m. and 05:00 p.m..

Exercise protocol application method (cardiorespiratory exercise evaluation)

All volunteers underwent a continuously increasing symptom-limited exercise protocol. The protocol was conducted on a treadmill (Inbrasport™ Super ATL) with initial velocity of 2.0 km/h, held for two minutes, followed by increases of 0.5 km/h every minute thereafter. Throughout the test, there was no treadmill inclination, avoiding thus overloading the volunteers and potential unintended orthopedic consequences, preventing complications to MO pre-adolescents.

Following completion of the test, the treadmill speed was progressively reduced until it reached a speed of 2.0 km/h, and remained so for two minutes. After that, the volunteers were seated and given fluid replacement.

Method for detection of heart rate variability threshold (HRVt)

During the exercise protocol, the RR intervals (iRR) were recorded using the Polar S810i™ frequency meter with sampling frequency of 1000 Hz The artifacts were eliminated with the use of very strong filter selected in the options allowed by the software, and these exclusions were confirmed by visual inspection done on the computer screen.

For the analysis to detect the HRVt, the record of the heartbeats extracted from the incremental test was divided into intervals of one minute, being arranged on the computer screen simultaneously with the relevant SD1 value presented by the software (Figure 1).

As the test progressed and the treadmill speed increased, the SD1 value was decreasing until, at a given point, the value of 3 m/s was reached, this point being referred to as the HRVt. Therefore, the first exercise intensity at which the HRV (SD1) had reached a value of 3 m/s was considered responsible for the appearance of the HRVt.

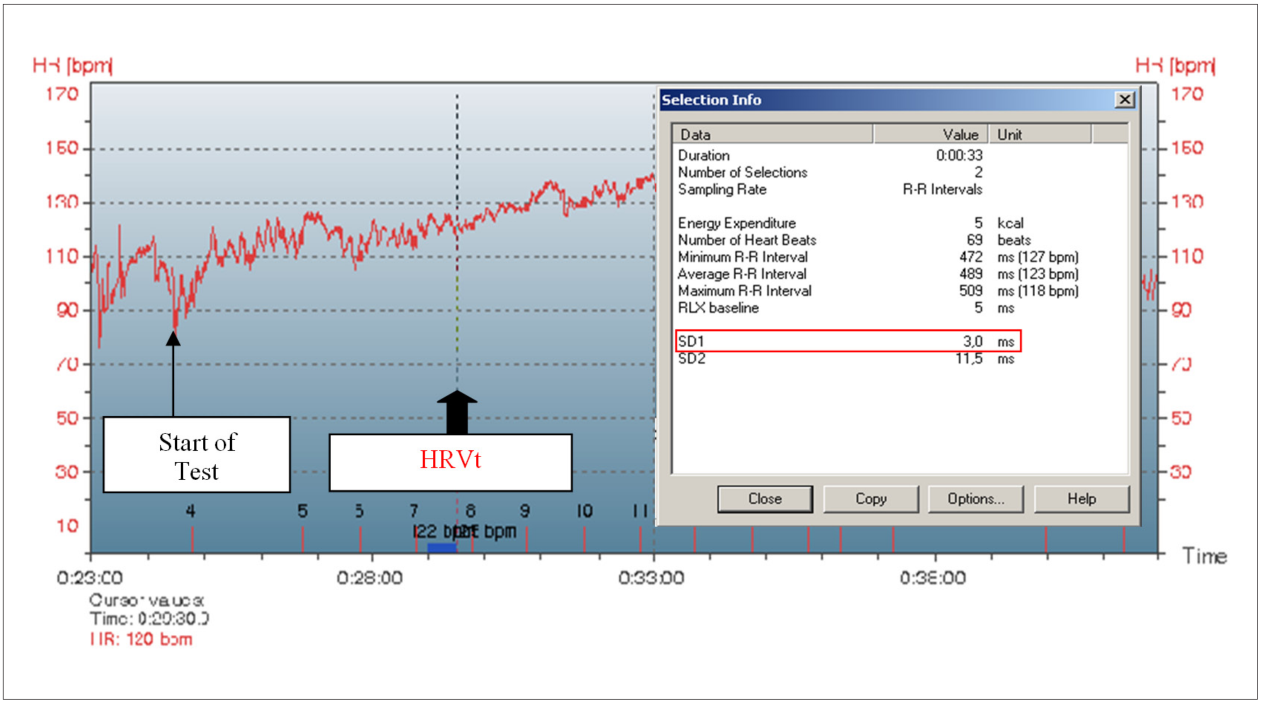

Figure 1 - Illustration of a computer screen depicting the anaerobic threshold (threshold 1) obtained by analysis of heart rate variability (HRVt) on a morbidly obese (MO) volunteer during stress protocol. The figure illustrates the HR response during the test, the way it is presented on the computer screen, highlighting the HRVt moment. It should be emphasized that for the detection of HRVt, the record was observed and analyzed minute by minute. HR - heart rate; SD - standard deviation.

The values of the variables of interest were recorded at the HRVt moment and were later used for comparison of CRC between groups.

Calculation of oxygen consumption (VO_2) at the HRVt time

For the calculation of VO_2, done indirectly, we used the metabolic equivalent values (MET) presented on the display of the treadmill obtained at the HRVt time. MET values were multiplied by 3.5; this value is equivalent to 1 MET. That is, 1 MET = 3.5 ml/O_2/kg/min.

Statistical analysis

Due to the non-normal distribution of age, anthropometric and clinical values, we applied the Mann Whitney U test. The data obtained at HRVt were compared by Kruskal-Wallis test followed by Dunn's multiple comparison test. The software used was *Graph-Pad Prism4.0™*, and in all procedures, we adopted the value 0.05 as the significance level.

Results

Anthropometric characteristics

Table 1 shows the anthropometric values obtained from the three groups studied. As we can see, the height was not the factor that promoted the difference between the groups, with their own body weight as the main factor for the BMI value to be statistically different between them.

Table 1 - **Mean age, anthropometric and clinical values of pre-adolescents**

	Non-obese group (n = 10)	Obese group (n = 10)	Morbidly obese group (n = 10)
Age (years)	9.4 ± 0.5	10 ± 0.6	9.9 ± 0.7
Body weight (kg)	33.5 ± 5.4	46.6 ± 5.9*	61.3 ± 15.2**
Height (cm)	140.0 ± 0.8	141.0 ± 0.0	145.0 ± 0.0
BMI (kg/m²)	16.8 ± 0.9	23.4 ± 1.1*	29.2 ± 4.7**
HR (bpm)	90.4 ± 8.0	101.8 ± 16.9*	100.1 ± 10.2#
SBP (mmHg)	109.8 ± 7.9	114.0 ± 8.7	119.3 ± 14.3
DBP (mmHg)	70.0 ± 7.8	72.6 ± 5.9	77.6 ± 9.0#

**p < 0.01 non-obese vs obese group; **p < 0.01 non-obese vs morbidly obese group; # p < 0.05 non-obese vs morbidly obese group.*

Figure 2 shows the relative VO_2 values. Respectively, for groups NO, O and MO, the median values were 30.1; 12.0 and 10.8 ml/O_2/kg/min; and differed as shown in the figure.

Figure 3 shows the values of the distance traveled by volunteers since the beginning of the exercise protocol up to the HRVt moment. Respectively, for groups NO, O and MO, the median values were 1.117,0; 487.5 and 358.3 meters, differing as shown in the figure.

The average speed (km/h) at the HRVt moment were: NO = 8.1 ± 1.5; O = 4.9 ± 2.1, and MO = 4.6 ± 1.0 $p < 0.05$ for NO compared to the other groups. Mean time of exposure to the protocol (min) from rest to HRVt were, respectively, for NO, O and MO, 14.3 ± 3.1, 7.9 ± 4.3 and 7.5 ± 2.1; with $p < 0.05$ between NO and MO. Mean values of metabolic equivalents (MET) at the HRVt moment were 7.8 ± 2.7 for NO, 3.7 ± 2.3 for O and 3.1 ± 0.5 for MO with $p < 0.05$ between NO and MO.

Figure 4 shows the HR values at rest and at the HRVt moment. We found a significant difference ($p < 0.05$) between HR medians for groups NO and MO in both situations compared.

Discussion

One of the parameters most commonly used for determination of physical capacity and proper aerobic training intensity in healthy and sick pre-adolescents in the rehabilitation process is the AT[8,10,19,20]. To determine this, a new non-invasive method has been studied due to evidence of good correlation with both the lactate threshold[13] and with the so-called product-moment with respect to the values of VO_2 in incremental testing[14]. This is the HRVt, which allows the detection of the precise AT occurrence timing (threshold 1) for the development of continuously increasing exercise protocols and to support this new proposal, it has been demonstrated that nonlinear methods aimed at analysis of HRVt in physical exertion can also provide consistent results on the cardiac autonomic modulation[13,15,21-23].

Lima and Kiss[13] reported that during incremental exercise, the progressive decrease of SD1 (standard deviation of

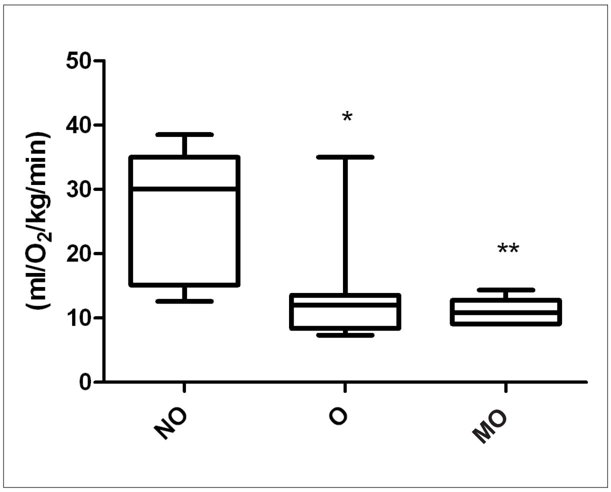

*Figure 2 - Median Values of oxygen consumption (VO_2) calculated at the time of heart rate variability threshold (HRVt), compared between non-obese (NO; n = 10), obese (O; n = 10) and morbidly obese groups (MO; n = 10). *p < 0.05 = NO vs O; **p < 0.05 = NO vs MO.*

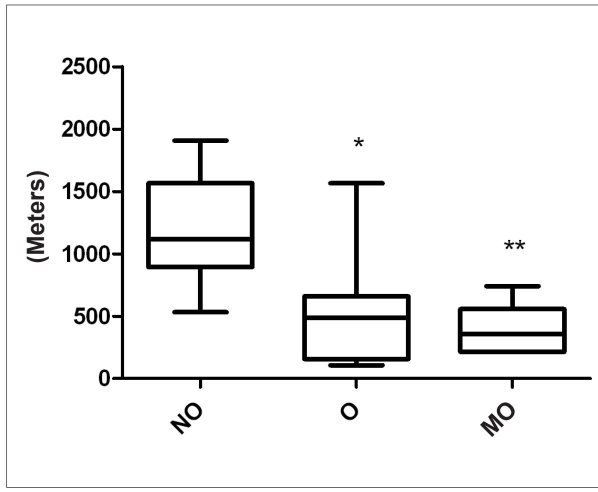

*Figure 3 - Median values of the distances traveled since the beginning of the exercise protocol until the time of heart rate variability threshold (HRVt) of non-obese (NO; n = 10), obese (O; n = 10) and morbidly obese groups (MO; n = 10). *p < 0.05 = NO vs O; **p < 0.05 = NO vs MO.*

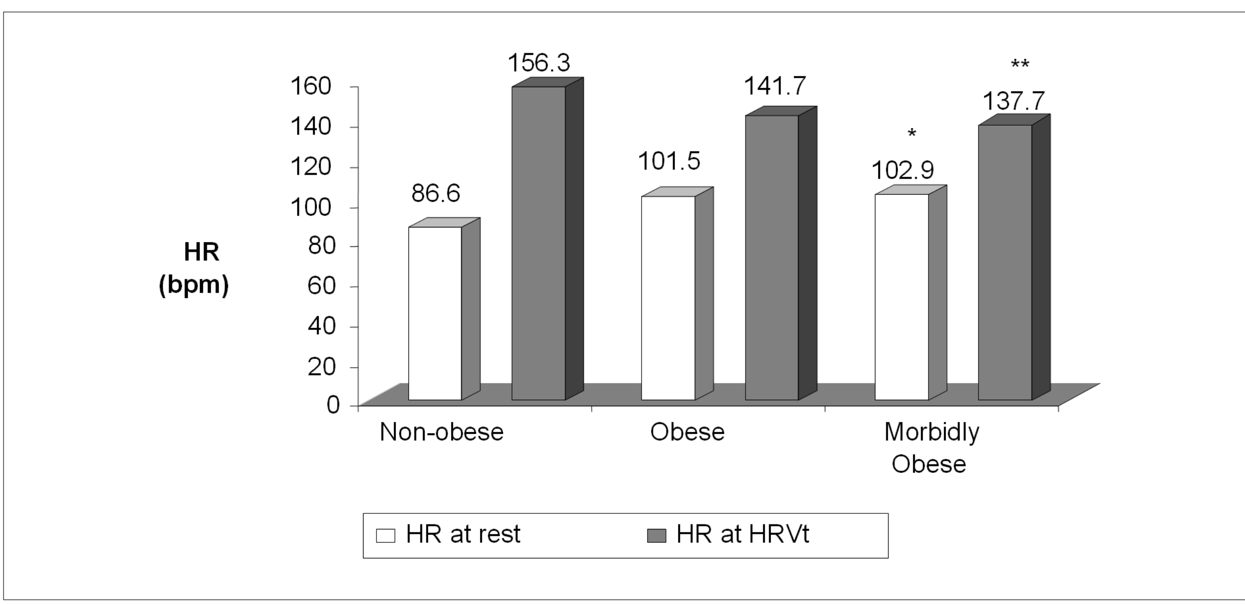

*Figure 4 - Median values of initial HR and at HRVt. HR - heart rate; HRVt - heart rate variability threshold; *p < 0.05 non-obese vs morbidly obese; **p < 0.05 non-obese vs morbidly obese.*

instantaneous variability, beat to beat) of the Poincaré plot stops when it reaches values equal to and/or smaller than 3 m/s, suggesting that this point identifies HRVt.

However, Brunetto et al[14] considered the hasty application of this method as an alternative to the detection of AT by the ventilatory method (threshold 1), claiming to have shown no statistically significant correlation in proportionate values of peak VO_2 during exercise stress tests.

As a counter-argument, it should be noted that in Brunetto et al[14] study, there are two important differences with respect to this research. The first is that the protocol used by these authors was modified Bruce, with stages lasting three minutes and treadmill inclinations, while ours was done in increments of 0.5 km/h every minute and no inclination. The second difference is that the volunteers of Brunetto et al[14] study were adolescents aged between 14 and 18, different from our volunteers, aged between 9 and 11 years.

Aside from these arguments, we emphasize that the main objective of this study was not to compare the HRVt detection method with any other, but to use it as a parameter for evaluating the CRC of three groups of pre-adolescents. With respect to demographics and clinical features of this sample, it is worth noting that the value of volunteers' height was not different between groups. This aspect is relevant in studies that use the treadmill as an evaluation tool, because people tend to run earlier in incremental tests, which can interfere in the evaluation of results.

With respect to data obtained at HRVt, there are strong indications that the factor responsible for lower performance presented by the groups O and MO was limited mobility due to increased body weight of these volunteers[24,25].

According to Birrer and Levine[26], there is evidence that motor skill may be jeopardized by factors such as adiposity, reducing the performance of obese children subjected to incremental tests. Other studies such as those by Rowland[27], Zanconato et al[28], Huttunen and Paavilainen[29] also showed higher values of VO_{2max} in normal children compared to obese children. Also for Goran et al[25], when there is more fat mass in obese children in proportion to the amount of fat mass in normal children, it is reasonable to think that this factor has limited functional capacity of obese children, as this aspect did not contributed to the study being conducted, which would increase the limitation of obese children.

In contrast, according to some authors[25,30], when there is standardization for differences in body size, obese people have VO_{2max} values similar to those of normal weight individuals. However, when it comes to measurements in submaximal efforts, such as those regarding the HRVt zone, there is greater consensus on the existence of major differences between obese and non-obese individuals because the former present, in these conditions of stress, higher HR values, respiratory rate and VO_{2max}[25] percentage. For example, in a study[31] in which obese children were subjected to hikes with non-obese children, they used 57.0% of VO_{2max}, while the normal children used only 36.0% of VO_{2max}. More recently, it has been documented that obese children have used 44.0% of VO_{2max} against 37.0% used by non-obese children when performing activities considered mild moderate[25].

In this study, considering VO_2 values at HRVt, it was found that O and MO pre-adolescents showed 47.8% and 40.1% respectively of the value presented by the children from the NO group.

The stress caused by obesity also caused the O and MO volunteers to reach, from the rest to HRVt, a distance of only 42.1% and 33.4% respectively, of the distance reached by NO. At the same time, the speed reached by NO children was 39.6% higher than that achieved by O children at HRVt, and 43.3% higher than that of OM children in the same condition.

One last aspect has shown the best CRC of NO pre-adolescents. Figure 4 displays the median values of initial HR and at HRVt. In general, low values of resting HR, such as the one shown by NO, reflects a good functional status associated with a better fitness level[32,33], while high values, such as those presented by O and OM, are related to various physiological disorders and predisposition to certain types of cardiovascular diseases[33,34].

Studies on the alterations in cardiac autonomic function and therefore on the value of resting HR in the presence of obesity in children and adolescents present some inconsistencies. They reveal: reduced parasympathetic activity; high sympathetic activity associated with decreased parasympathetic activity; and reduction of both sympathetic and parasympathetic activity[1,14,35-37]. Regardless of the mechanism responsible for changes in resting HR, it is known that a lower value of this variable relates to a greater ability of chronotropic reserve, which means that there is a greater amount of heartbeats which can be used during exercise, influencing therefore the cardiac output and performance[38].

It was found that the variation (delta) of HR in NO volunteers from rest to HRVt, was 69.7 bpm and 40.2 bpm and 34.8 bpm respectively for O and MO. This greater variation in HR of NO is a fact that reflected a higher CRC in these children at HRVt.

A limitation of this study was the absence of a parallel study done with the same volunteers subjected to the same protocol, but with AT being assessed by spirometry, as we could ensure greater reliability for the HRVt method for assessment of CRC in children and pre-adolescents.

Conclusion

It can be concluded that this study reached its objective by showing the application of a new AT detection tool for evaluating CRC in children, which led to confirmation of a higher CRC in the NO group. Also, it was found that the HRVt method requires further comparisons with the models traditionally used for detecting AT in order to extend its degree of efficiency and credibility, because its input can be very significant in several procedures for evaluating and controlling development of treatment due to its smaller cost and easy access.

Potential Conflict of Interest

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

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any post-graduation program.

References

1. Paschoal MA, Trevizan PF, Scodeler NF. Heart rate variability, blood lipids and physical capacity of obese and non-obese children. Arq Bras Cardiol. 2009;93(3):239-46.
2. Giuliano ICB, Caramelli B, Duncan BB, Pellanda LC. Children with adult hearts. Arq Bras Cardiol. 2009;93(3):211-2.
3. Sekine M, Izumi I, Yamagami T, Kagamimori S. Obesity and cardiac autonomic nerve activity in healthy children: results of the Toyama Birth Cohort Study. Environm Health Prev Med. 2001;6(3):149-53.
4. Gutin B, Barbeau P, Litaker MS, Ferguson M, Owens S. Heart rate variability in obese children: relations to total body and visceral adiposity, and changes with physical training and detraining. Obes Res. 2000;8(1):12-9.
5. Willians DP, Going SB, Lohman TG, Harsha DW, Srinivasan SR, Webber LS, et al. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. Am J Public Health. 1992;82(3):358-63.
6. Goran MI, Reynolds KD, Lindquist CH. Role of physical activity in the prevention of obesity in children. Int J Obes Relat Metab Disord. 1999;23(Suppl 3):S18-33.
7. Paschoal MA. Capacidade funcional. In: Pulz C, Guizilini S, Peres PAT. Fisioterapia em cardiologia: aspectos práticos. São Paulo:Atheneu;2006.p.23-38.
8. Wasserman K, Beaver WL, Whipp BJ. Gas exchange theory and the lactic acidosis (anaerobic) threshold. Circulation. 1990;81(1Suppl):II14-30.
9. Wasserman K, Hansen JE, Sue DY, Lasaburi R, Whipp BP. Principles of exercise testing & interpretation: including pathophysiology and clinical applications. 3rd ed. Philadelphia:Lippincott Williams & Wilkins;1999.
10. Davis JA. Anaerobic threshold: review of the concept and directions for future research. Med Sci Sports Exerc. 1985;17(1):6-21.
11. Brooks GA. Current concepts in lactate exchange. Med Sci Sports Exerc. 1991;23(8):859-906.
12. Fronchetti L, Nakamura FY, Aguiar CA, Oliveira FR. Regulação autonômica em repouso e durante exercício progressivo: aplicação do limiar de variabilidade da freqüência cardíaca. Rev Port Cien Desp. 2006;6(1):21-8.
13. Lima JRP, Kiss MAP. Limiar de variabilidade da freqüência cardíaca. Rev Bras Ativ Fis Saúde. 1999;4(1):29-38.
14. Brunetto AF, Silva BM, Roseguini BT, Hirai DM, Guedes DP. Limiar ventilatório e variabilidade da freqüência cardíaca em adolescentes. Rev Bras Med Esporte. 2005;11(1):22-7.
15. Nakamura Y, Yamamoto Y, Muraoka I. Autonomic control of heart rate during physical exercise and fractal dimension of heart rate variability. J Appl Physiol. 1993;74(2):875-81.
16. National Center for Chronic Disease Prevention and Health Promotion and National Center for Health Statistics, 2000. [Cited in 2010 Dec 10]. Available from http://www.cdc.gov/growthcharts.
17. Koch VH. Casual blood pressure and ambulatory blood pressure measurement in children. São Paulo Med J. 2003;121(2):85-9.
18. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics. 2004;114(2 Suppl 4th Report):555-76.
19. Wasserman K, McIlroy MB. Detecting the threshold of anaerobic metabolism in cardiac patients during exercise. Am J Cardiol. 1964;14:844-52.
20. Wasserman K, Whipp BJ, Koyal SN, Beaver WL. Anaerobic threshold and respiratory gas exchange during exercise. J Appl Physiol. 1973;35(2):236-43.
21. Anosov O, Patzak A, Kononovich Y, Persson PB. High-frequency oscillations of the heart rate during ramp load reflect the human anaerobic threshold. Eur J Appl Physiol. 2000;83(4-5):388-94.
22. Hautala AJ, Mäkikallio TH, Seppänen T, Huikuri HV, Tulppo MP. Short-term correlation properties of R-R interval dynamics at different exercise intensity levels. Clin Physiol Funct Imaging. 2003;23(4):215-23.
23. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation. 1996;93(5):1043-65.
24. Wearing SC, Hennig EM, Byrne NM, Steele JR, Hills AP. The biomechanics of restricted movement in adult obesity. Obes Rev. 2006;7(1):13-24.
25. Goran MI, Fields DA, Hunter GR, Herd SL, Weinsier RL. Total body fat does not influence maximal aerobic capacity. Int J Obes. 2000;24(7):841-8.
26. Birrer RB, Levine R. Performance parameters in children and adolescent athletes. Sports Med. 1987;4(3):211-27.
27. Rowland TW. Effects of obesity on aerobic fitness in adolescent females. Am J Dis Child. 1991;145(7):764-8.
28. Zanconato S, Baraldi E, Santuz P, Rigon F, Vido L, Da Dalt L, et al. Gas exchange during exercise in obese children. Eur J Pediatr. 1989;148(7):614-7.
29. Huttunen NP, Paavilainen T. Physical activity and fitness in obese children. Int J Obes. 1986;10(6):519-25.
30. Maffeis C, Schutz Y, Schena F, Zaffanelo M, Pinelli L. Energy expenditure during walking and running in obese and nonobese prepubertal children. J Pediatr. 1993;123(2):193-9.
31. Mattson E, Larsson UE, Rossner S. Is walking for exercise too exhausting for obese women? Int J Obes. 1997;21(5):380-6.
32. Almeida MB, Araújo CGS. Effects of aerobic training on heart rate. Rev Bras Med Esporte. 2003;9(2):104-12.
33. Dixon EM, Kamath MV, McCartney N, Fallen EL. Neural regulation of heart rate variability in endurance athletes and sedentary controls. Cardiovasc Res. 1992;26(7):713-9.
34. Jeukendrup A, Van Diemen A. Heart rate monitoring during training and competition in cyclists. J Sports Sci. 1998;16(Suppl 1):S91-9.
35. Kenney WL. Parasympathetic control of resting heart rate: relationship to aerobic power. Med Sci Sports Exerc. 1985;17(4):451-5.
36. Rabbia F, Silke B, Conterno A, Grosso T, De Vito B, Rabbone I, et al. Assessment of cardiac autonomic modulation during adolescent obesity. Obes Res. 2003;11(4):541-8.
37. Yakinci C, Mungen B, Karabiber H, Tayfun M, Evereklioglu C. Autonomic nervous system functions in obese children. Brain Dev. 2000;22(3):151-3.
38. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate: a longitudinal study. Ann Med Exp Biol Fenn. 1957;35(3):307-15.