International Journal of
EXERCISE SCIENCE

Original Research

Can Heart Rate Variability Predict the Second Metabolic Threshold in Young Soccer Players?

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ABSTRACT

International Journal of Exercise Science 11(2): 1105-1111, 2018. Heart rate variability (HRV) is an effective method to assess the influence of the autonomic nervous system, which may be directly linked to metabolic demand. The aim of the study was to determine if the second metabolic threshold can be identified by HRV. Thirteen athletes were assessed in cardiopulmonary exercise test with concomitant gas analysis. The RR intervals (RRi) were plotted in a spreadsheet for graphics analysis and the point at which there was a shift in the RRi curve was determined as $RRiT_2$. The second ventilatory threshold (VT_2) was used as the gold standard technique. A positive correlation was found in the test time ($r = 0.84$), heart rate ($r = 0.97$) and VO_2 ($r = 0.97$) between the VT_2 and HRV second threshold ($RRiT_2$). All parameters identified by $RRiT_2$ were lower than predicted by VT_2 ($p < 0.05$).

KEY WORDS: Sports, anaerobic threshold, heart rate, athletes

INTRODUCTION

Metabolic transition zones, known as aerobic and anaerobic thresholds, are determinants for adequate prescription and control of training intensity (8). Analysis of gas exchange and blood lactate concentration are the main methods used to measure metabolic thresholds in cardiopulmonary exercise testing (CPET) (1). Although still there are disagreements about these nomenclatures, the second metabolic transition refers to the second ventilatory threshold (VT_2) and the lactate threshold (7, 8). Additionally, other methods were developed in an attempt to identify the catecholamine concentrations (18), electromyographic fatigue threshold (9), and salivary electrolytes composition (4) for cardiovascular exercise prescription. However, expensive equipment makes this techniques application unfeasible in amateur sports.

Interaction between physiological systems is observed through the metabolic (blood markers), neuroendocrine (catecholamine production), cardiopulmonary (heart rate, VO_2 and VCO_2) and neuromuscular (muscle activation) markers, all the responses being mediated by the autonomic nervous system (ANS). The heart rate is an alternative for this analysis due to its strong connection with oxygen uptake (VO_2). Conconi et al (5) proposed using the heart rate deflection point (HRDP) to identify anaerobic threshold, been criticized for the contradictory results in the anaerobic threshold identification (11).

Heart rate variability (HRV) is a widely used method to show the influence of ANS in exercise, mainly for being a non-invasive and a low-cost technique (19). The heart rate monitors (HRM) allow the registration of the RR intervals (RRi) for HRV analysis. Poincare plot standard deviation (SD1) showed promising results in determination of the first lactate threshold (13) and ventilatory threshold (2) among the different indexes for HRV. However, few studies have investigated the relationship between HRV and second metabolic transition. The aim of this study was to determine if the second metabolic threshold can be identified by HRV.

METHODS

Participants

Fifteen young male soccer players (under age 13) were evaluated during the competition season. All athletes were members of a Brazilian amateur soccer team. The baseline variables were measured on a mechanical height and weight scale. Body mass (BM) and height were utilized to determine body mass index (BMI). Table 1 shows the characteristics of the sample.

Table 1. Anthropometric characteristics of young soccer players.

n	Age (years)	BM (kg)	Height (cm)	BMI (kg/m²)
13	12.4 ± 0.5	48.8 ± 6.7	153.8 ± 6.7	20.6 ± 2.0

BM: body mass, BMI: body mass index. Values expressed as mean ± standard deviation.

Protocol

The athletes underwent CPET on the treadmill (Micromed, Brazil) with concomitant gas analysis breath-by-breath mode (Metalyzer 3B, cortex medical, Germany). A ramp protocol was applied with an initial velocity of 7 km/h and increments of 1 km/h every minute until exhaustion (7, 10).

The peak of oxygen uptake (VO_{2PEAK}) was determined at the point of the highest value of VO_2 attained on the CPET. The VT_2 was determined by two independent reviewers at the point where there was a systematic increase in the curve of oxygen (O_2) equivalent (VE/VO_2) without an increase in the carbon dioxide (CO_2) equivalent (VE/VCO_2) (1, 10). Authors reviewed the results with discrepancies greater than 5% (2).

The Polar F11 HRM (Polar Electro, Finland) was used to record the heart rate simultaneously to CPET. The RRi were determined by applying the equation: RRi = 60,000 / HR. The HRV second threshold ($RRiT_2$) was independently identified by two researchers at the point where there was a shift in the RRi curve.

This study was approved in the University's Ethics Committee in accordance with Resolution CNS 466/12 and the Declaration of Helsinki. All adolescents were able to choose whether or not to participate in the procedures, even after their parents signed the consent form.

Statistical analysis

Statistical analyses were performed in the GraphPad Prism 5 (San Diego, USA). Data are expressed as mean ± standard deviation (SD), level of significance was set at $p<0.05$. Shapiro-Wilk test was applied to verify the data normality, paired t-test and Pearson's correlation coefficient (r) were used to compare and test the dependent variables association.

RESULTS

Table 2 shows the second metabolic threshold predicted by gas exchange (VT_2) and heart rate variability ($RRiT_2$) in amateur young male soccer players. A positive correlation was found in the test time ($r = 0.84$), HR ($r = 0.97$) and VO_2 ($r = 0.97$) corresponding to metabolic transition point between the VT_2 and $RRiT_2$. The anaerobic threshold occurred at 94 and 92% of the MHR and at 90 and 88% of the VO_{2PEAK} when predicted by VT_2 and $RRiT_2$, respectively. Table 2 shows that all parameters predict by $RRiT_2$ were lower than determined by VT_2.

Table 2. Second metabolic threshold predicted by gas exchange (VT_2) and heart rate variability ($RRiT_2$) in amateur young male soccer players.

Criteria	**Time (min)**	**HR (bpm)**	**VO_2 (ml.kg.min^{-1})**
VT_2	9.39 ± 1.71	180 ± 16	35.6 ± 4.4
$RRiT_2$	8.44 ± 1.67	177 ± 14	34.6 ± 4.8
	$p = 0.003$	$p = 0.013$	$p = 0.009$

HR, heart rate. VO_2, oxygen consumption. VT_2, second ventilatory threshold. $RRiT_2$, second heart rate variability threshold. Values expressed as mean and standard deviation.

The variation coefficient was moderate regarding in the time (18 and 20%) and VO_2 (13 and 14%), and low (9 and 8%) for HR when estimate by VT_2 and $RRiT_2$, respectively. All athletes trained 2-3 times per week (three hours week), they had 3.8 ± 1.6 years of experience and completed two games per month during the 5-month competitive season. The VO_{2PEAK} obtained on CPET was 38.7 ± 6.2 ml/kg/min. In two tests it was not possible to determine the thresholds: VT_2 in two subjects and $RRiT_2$ in one subject. Figure 1 shows the individual behavior of the analyzed parameters.

DISCUSSION

Our data indicate that $RRiT_2$ underestimates the second physiologic transition point identified by VT_2, refuting the hypothesis of similarity between the techniques. Although investigating different methods, Hallmark et al (11) observed that the HRDP underestimated the lactate threshold (136 ± 32.83 *vs* 150 ± 34.03 watts, $p = 0.015$) during an incremental test. The same authors have stated that HRDP may not be an effective marker for determining the training intensities. Opposing these findings, others studies have reported that the HRV matches with LT_2 and VT_2 in a more complex analysis (6, 3). Cottin et al (6) analyzed twelve professional soccer players of the French First League and observed similarities in running speeds correspondent to VT_2 and the second nonlinear increased in HFT_2 (high frequency power by high frequency peak) during the 20m Shuttle run test (12.6 ± 1.3 *vs* 12.6 ± 1.3 km/h).

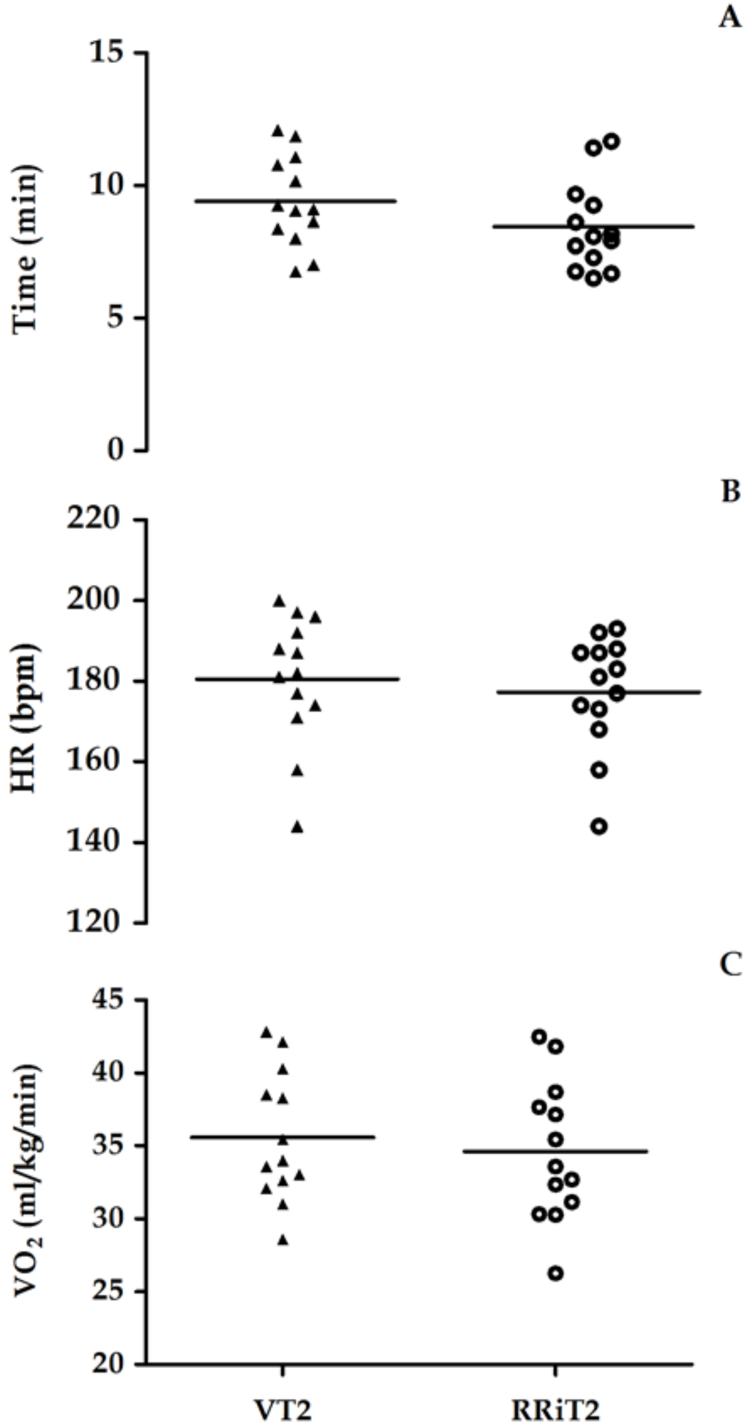

Figure 1. Individual CPET results. Time (A), heart rate (B) and oxygen uptake (C) related to second metabolic threshold.

In addition, Buchheit et al (3) compared the accuracy of the HRDP and HFT_2 to predict anaerobic threshold in seventy-two boys (age 13.3 ± 1.3 years). The authors observed similar VO_2 between VT_2 (47.6 ± 6.2 ml/kg/min), HRDP (48.2 ± 4.9 ml/kg/min) and HFT_2 (48.7 ± 5.4 ml/kg/min). The same occurs between HR and VT_2 (187 ± 9 bpm), HRDP (188 ± 7 bpm) and HFT_2 (189 ± 9 bpm). These works show a discrepancy in the determination of the threshold anaerobic by HRV. Some variables may lead to this contradiction, as the test protocol, HRV index and population used. An explanation for outcome of this study could be a possible early signaling of the ANS, considered the main modulator of metabolic responses (16). Thus, both $RRiT_2$ as HRDP could identify it. Our findings showed that the $RRiT_2$ variables were lower, although this theory has not been supported by other studies (2, 3, 6, 13).

During the incremental test, there was a gradual increased in workload, elevating hydrogen ions (H^+) and lactate concentrations as a result of the glycolytic pathway (12). The H^+ is rapidly buffered to CO_2 and H_2O, and the CO_2 is expired in the lungs (1). When this buffer system reaches maximum velocity, CO_2 and lactate concentrations increase exponentially determining the anaerobic threshold or respiratory compensation point, which can be determined by VT_2 and LL_2 respectively (17). In addition, CO_2 and pH blood levels would inhibit vagal ANS and the increase of noradrenaline and joint movement would activate sympathetic ANS, contradicting our findings. This sympathovagal change would be expected to respond to the byproducts cited above, and thus, $RRiT_2$ would tend to underestimate VT_2, and not underestimate overestimate it.

Regarding anaerobic threshold percentage, Cunha et al (7) cited that soccer players present VT_2 between 80-90% of maximum heart rate or 75-90% of the VO_{2PEAK}. Our data showed similarity to these values when related to VO_{2PEAK}, but when related to HR, presented a more pronounced percentage. This finding was not expected due to age and recreational training level of the sample. Anyway, it has already been shown that anaerobic threshold can decrease with maturation progression (8).

However, it is not possible to make this statement because the sexual maturation was not evaluated. A simple tool that could have been used without raising the costs of research is the pubertal status or age at peak height velocity (15), mainly because the effects of maturation on anaerobic thresholds are conflicting and need to be controlled (14). Even so, Cunha et al (8) were demonstrated that pre-pubescent, pubescent and post-pubescent individual presents similar VT_2 values when expressed as $\%VO_{2MAX}$. The same authors affirmed that maturation did not affect the VT_2 and VO_{2PEAK} when these measures are normalized (8). Indeed, a simple anthropometric measurement of the lower limb muscle or a more elaborate ultrasound assessment could provide more valuable data. Other limitations such as the absence of a familiarization test and evaluation of the anxiety and unrest levels of sample or small sample size may have influenced the results.

In conclusion, the anaerobic threshold is a performance marker in soccer. The loss of $RRiT_2$ linearity does not seem to be sensitive in correctly detecting the point of metabolic change. The

RRiT$_2$ underestimated the VT$_2$ in young soccer players. Therefore, others HRV indexes should be investigated and use of RRiT$_2$ should not be encouraged in young athletes.

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