Identification and Concordance of the Heart Rate Deflection Point and Heart Rate Variability Threshold Determined by Different Parameters in the 20 m Multi-Stage Fitness Test

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ABSTRACT

Nascimento VB, Osiecki R, Redkva PE, Gomes EB, Salgueirosa FM, Daros LB, Osiecki AC, Kaminagakura EI. JEPonline 2012;15(2):55-63. The purpose of this study was to identify the variability threshold determined by different parameters and the Conconi Threshold (HRDP) in a 20 m Shuttle Run Test, describing the concordance between these aerobic indexes. The subjects consisted of professional soccer players. The 20 m shuttle run test was used. The criteria for determining the heart rate variability threshold (HRVT) were the breaking of linearity SD1; breaking of linearity in SD1/SD2; first stage in the curve decrease in which the difference between the SD1 in two consecutive stages is less than 1 ms; breaking of linearity HFpeak x HFms². The HRDP was determined by the breaking of linearity in the heart rate curve. All criteria of HRVT demonstrated a moderately significant correlation with HRDP ($r=0.73$). However, only the HRVTSD1 presented concordance with HRDP (bias=0.24 km·h⁻¹, $P=0.245$). The main finding of this study was the demonstration of association between the non-invasive determination of anaerobic threshold in a field test as well as the evidence of agreement between the method HRVTSD1 with the HRDP in soccer players.

Key Words: Heart Rate Variability, Heart Rate Variability Threshold, Conconi Threshold, Soccer
INTRODUCTION

The evaluation of the aerobic condition through the maximum consumption of oxygen (VO$_2$ max) and Anaerobic Threshold (AT) through different methodologies is one of the main measurements in batch evaluations of athletes (7). Evaluation protocols that take into account the specificity of the modality must be considered (19).

Leger and Gadoury's (13) 20 m multi-stage fitness test is an indirect estimate of VO$_2$ max to evaluate the aerobic power of schoolchildren, healthy adults, and athletes. Popularly known as the Beep test, it consists of multiple progressive stages. The test is stopped if the subject fails to reach the line for two consecutive ends. It is widely used due to the low cost material in its application.

The heart rate deflection point (HRDP) identifies the AT through the breaking of the heart rate linearity in relation to intensity in progressive exercise (5). Despite the controversy in some studies by describing a linear relationship between heart rate (HR) and intensity in progressive exercise (10), and by reporting that it overestimates the values of the lactate threshold (22), HRDP can be used as part of the aerobic assessment (2).

The autonomous nervous system modulates the triggering rate of the sino-atrial node (19) during the exercise with progressive loads, and the increase in HR during the initial phase is due to the withdrawal of the vagal activity. Then, with the increase in the intensity of the workload, there is an increase in the sympathetic activity that is ultimately responsible for the HR response (8). The identification of the heart rate variability threshold (HRVT) determined by different criteria can be considered an index of aerobic capacity (9,15,16). However, since it is a recent method of indexing aerobic capacity, its identification in progressive field tests such as those of shuttle run has not been established in literature.

Thus, the objective of the present study was to identify HRVT determined by different parameters and HRDP in shuttle run field tests and to describe the concordance between these aerobic indexes.

METHODS

Subjects
The subjects in this study consisted of 21 professional soccer players, age 24.08±3.43 yrs old, body mass 78.13±8.19 kg, height 1.78±7.37 m, and %Fat 11.56±2.00; all subjects participated in the first division of the 2011 Brazilian Championship. Prior to the testing, each subject was familiarized with the experimental procedure and was informed of the risks associated with the protocol. All subjects gave their written voluntary informed consent.

Procedures
20 m Shuttle Run
Leger and Gadoury’s (13) 20 m shuttle run with speed starting at 8 km·h$^{-1}$ when subjects run a distance of 20 m coming and going, which is increased 1 km·h$^{-1}$ every minute (controlled by a sound signal). The test was stopped if the subject failed to reach the line (within 2 meters) for two consecutive ends. When the subjects were not able to complete the stage, the speed used was corrected according to the work of Kuipers and colleagues (12).

Heart Rate Variability Threshold (HRVT)
The RR intervals were registered with the use of a POLAR model RS800 heart monitor, which were transferred to the Polar ProTrainer 5 software and later analyzed by Kubius HRV software.
(http://kubios.uku.fi/KubiosHRV/) in order to have the heart rate variability parameters, SD1, SD1 of Pointcaré plot, HF peak, and HF ms² as obtained from 1 min samples in progressive test. The criteria for determining HRVT were the breaking of linearity SD1, ratio SD1/SD2 (21,20), first stage in the decrease of the curve where the difference between SD1 of two consecutive stages was lower than 1 ms (20), and the breaking of linearity HFpeak x HFms² (6).

Heart Rate Deflection Point (HRDP)
The HRDP was determined by the breaking in linearity of the HR curve along the time (5,22) using statistical analysis by piecewise linear regression.

Statistical Analysis
In order to determine the breaking in linearity between HRVT and HRDP, a segmented package (14) and the concordance methodology of Bland-Altman (1) were used (P=0.05). For all the analyses, free software R 2.13.2 (17) was used.

RESULTS
Data from the 20 m shuttle run test are shown in Table 1.

Table 1. Data Presented in Mean ± Standard Deviation Regarding Maximum Heart Rate, Speed Peak, Corrected Speed Peak and VO₂ max in the 20 m Shuttle Run Test.

<table>
<thead>
<tr>
<th>Variables</th>
<th>HR max (beats·min⁻¹)</th>
<th>SP (km·h⁻¹)</th>
<th>CSP (km·h⁻¹)</th>
<th>VO₂ max (mL·kg⁻¹·min⁻¹)</th>
</tr>
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<tbody>
<tr>
<td>Mean±SD</td>
<td>167±6.44</td>
<td>13.93±1.19</td>
<td>14.08±1.21</td>
<td>50.44±4.00</td>
</tr>
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*HR max: maximum heart rate; SP: speed peak; CSP: corrected speed peak.

The charts are the dispersion charts between HRDP and HRVT according to different methodologies.

(A) Chart 1. Dispersion chart between HRDP and HRVT Hfpeak x HFms². (B) Chart 2. Dispersion chart between HRDP and HRVT Diff 1 ms.
Concordance analyses between the different determination methodologies of HRVT with HRDP are presented in sequence.

Chart 5. Bland-Altman in relation to HRDP and HRVT SD1.

The results indicate concordance between the measures HRDP and HRVT, bias=0.24 km·h⁻¹, P=0.245.
These results did not show any concordance between the methods HRDP and HRVT SD1/SD2, bias=0.66 km·h⁻¹, P<0.05.

The same applies to the analysis developed between the methods HRDP and HRVT 1ms, bias=1.14 km·h⁻¹, P<0.05.
Likewise, in regards to concordance between methods HRDP and HRVT Hfpeak x HFms², bias = 0.92 km·h⁻¹, P<0.05.

**DISCUSSION**

For the measurements in the evaluation of aerobic condition, VO₂ max and AT are important for the monitoring and prescription of training in different sport modalities. In soccer, the aerobic resistance is highlighted as an important capacity for the recovery from motor actions (18).

Although this study had the sole objective of identifying HRVT, previous studies have shown good correlation between HRVT and lactate threshold and ventilation threshold (9,15,16). In a study performed with soccer players identifying HRVT through the Hfpeak x HFms² index, there was concordance between ventilation threshold and HRVT (6).

There was significant correlation between HRDP and HRVT determined by the different parameters, indicating certain consistency between these measures. Concordance between the HRDP and HRVT speeds determined by SD1 (bias=0.24 km·h⁻¹, P=0.245) was observed. However, the same concordance results were not observed between the HRDP and HRVT speeds determined by other indexes such as Hfpeak x HFms² (bias=0.92 km·h⁻¹, P<0.05), HRVT SD1/SD2 (bias=0.63 km·h⁻¹, P<0.05) and HRVT 1 ms (bias=1.14, P<0.05).

The identification of HRVT by a difference smaller than 1 ms (SD1) in two consecutive stages (18) was not possible in two subjects. However, in all indexes identified by the linearity break point, mathematically determined as Hfpeak x HFms², HRVT SD1/SD2, HRVT SD1, HRVT was identified. It was also possible to identify HRDP in all participants using the mathematical method of linearity break. Other papers, using the Dmax obtained similar results (9).

The relation between the HRDP and HRVT needs to be better elucidated. In the reviewed literature, we find the study of Buchheit et al. (4) that investigated the relationship between HRDP and HRVT
and showed similar responses in the HR and VO$_2$ of these methodologies regarding the ventilation threshold as well as strong correlation between the HRVT and HRDP, thus, suggesting similarities in the physiological development of both non-invasive methodologies for determining the AT of trained individuals. In agreement, this present study showed high determination coefficient ($r^2=0.73$) between HRVTSD1 and HRDP (Chart 4).

Additionally, various investigations have been designed to study the relation between HRVT and others possibilities at the determination of AT. Various investigations showed associations between HRVT and AT (3,4,6,8) and stabilization in 4 mM of lactate in constant running loads tests referring the HRVT (23). But, another study did not corroborate with association between HRVT and AT (3). Thus, we suggest further studies directed to understand the relationship and concordance between HRVT with AT determined either through lactate concentration ([La]), ventilation, HR or critical power in athletes or physically active people.

CONCLUSIONS

It was possible to identify HRVT using different parameters and HRDP in progressive 20 m shuttle run tests, with concordance between the measures only for SD1 criterion, nevertheless, its relation with gold standard measures needs to be determined in further studies.

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