ABSTRACT

Crisp AH, Verlengia R, Sindorf MAG, Germano MD, Cesar MC, Lopes, CR. Time to Exhaustion at VO₂ Max Velocity in Basketball and Soccer Athletes. JEPonline 2013;16(3):82-91. The purpose of study was to compare the maximum distance traveled (Dmax) and time to exhaustion (Tlim) at the minimal velocity that elicits VO₂ max (vVO₂ max) in basketball and soccer athletes. Twenty-six basketball and 27 soccer players performed a maximal cardiopulmonary exercise test (CPETmax) to determine maximal oxygen uptake (VO₂ max), the first ventilatory threshold (VT1), velocity of VT1 (vVT1) and vVO₂ max, the time to exhaustion at vVO₂ max to determine Tlim and Dmax, and the kinetics of blood lactate removal at pre, 0 (immediate), 3, 6, 9, 15, and 20 min after time to exhaustion at vVO₂ max test. The findings indicate that the variables of CPETmax were significantly superior (P<0.05) for soccer athletes. On the other hand, the Tlim was significantly higher (P<0.05) for basketball athletes (318.0 ± 98.9 sec) versus the soccer athletes (255.3 ± 86.6 sec). There was no significant difference for the variable Dmax (basketball: 1344.7 ± 415.4 m; soccer: 1228.3 ± 369.6 m). There was no significant difference between the groups on the kinetics of blood lactate removal and peak blood lactate value. There was a moderate correlation of Tlim with VO₂ max (r = -0.44), vVO₂ max (r = -0.55), vLV1 (r = -0.43), and peak lactate (r = 0.47) only for soccer athletes. The findings suggest that these differences are likely to be due to physiological characteristics inherent in each sports modality. Soccer athletes had superior physiological parameters of aerobic metabolism while the basketball athletes had higher Tlim.

Key Words: Running Performance; VO₂ Max Velocity, Exhaustion
INTRODUCTION

During physical exercise, the main function of the cardiorespiratory system is to supply a continuous flow of oxygen and nutrients to the skeletal muscles and to remove metabolic products of cellular respiration (22). These physiologic responses are very important for athletic endurance performance, especially when running a long distance is an integral part of the sport.

Aside from being used as a prognostic tool for cardiac and/or respiratory limitations (1,19), maximal oxygen uptake (VO\textsubscript{2} max) is a commonly known physiological parameter that characterizes aerobic (or cardiorespiratory) fitness. Yet, VO\textsubscript{2} max by itself cannot discriminate in running performance between athletes (15,18).

Other variables such as ventilatory threshold and running economy are used in conjunction with VO\textsubscript{2} max to increase the prediction of endurance performance in athletes (1). Besides these variables, the minimal velocity that elicits VO\textsubscript{2} max (vVO\textsubscript{2} max) has been extensively investigated due to the fact that athletes who have similar VO\textsubscript{2} max may have different values in vVO\textsubscript{2} max. This explains in part the difference in running performance among athletes (8).

The vVO\textsubscript{2} max is also used to determine time to exhaustion (Tlim) (8), which is a physiological parameter correlated with lactate threshold expressed as percentage of VO\textsubscript{2} max (5,6) and anaerobic capacity (16,24). In addition, maximum strength training can be a very effective methodology for improving Tlim in runners (26) and cyclists (28). This suggests that Tlim at vVO\textsubscript{2} max may be related to anaerobic metabolism and/or neuromuscular factors.

Studies report mean values between 2.5 min (9) and 10 min (14) for Tlim at vVO\textsubscript{2} max, demonstrating great variability even among trained individuals (6). Based on this principle, Billat et al. (9) evaluated the Tlim at vVO\textsubscript{2} max in different sports modalities (cycling, kayaking, swimming, and running) that require aerobic adaptations, obtained different VO\textsubscript{2} max values by using ergometers specialized for each of the four types of athletes. They reported significant differences for Tlim at VO\textsubscript{2} max between cyclist (222 sec) and kayak paddlers (376 sec), which confirms the results depend on sports modality evaluated.

On the other hand, basketball and soccer are performed using intermittent movements that requires metabolic interaction between the aerobic and anaerobic pathways, which may promote specific responses on Tlim at vVO\textsubscript{2} max. To our knowledge, no study has determined the maximum distance traveled (Dmax) and Tlim at vVO\textsubscript{2} max in basketball and soccer athletes. Such information should provide a better understanding of the specific physiological adaptations and endurance capacity in aerobic athletes, since running is an important physical activity for these sports modalities. Investigation of variables related to endurance performance among sports modalities should provide relevant information and insight for coaches to help them design physical training programs in accordance to the requirements of the sport. Thus, the purpose of this study was to compare the Dmax and Tlim at vVO\textsubscript{2} max among basketball and soccer athletes. Additionally, the relationship of Tlim with the variables VO\textsubscript{2} max, vVO\textsubscript{2} max, first ventilatory threshold (VT1), velocity of first ventilatory threshold (vVT), and peak blood lactate were determined.

METHODS

Subjects

The subjects consisted of 26 basketball and 27 soccer players (goalkeepers were excluded) between 18 and 23 yrs of age. All subjects were athletes who were involved in regular physical training
sessions (5 to 10 sessions·wk⁻¹). They participated in state-level competitions of which the inclusion / exclusion criteria were: (a) at least 2 yrs of athletic experience in state-level competitions; (b) familiarity with treadmill running; and (c) no injury for at least 1 mth prior to the study. All subjects completed a questionnaire to assess health status and signed a free- and informed-consent form after being informed about the research and experimental protocol. This study was approved by the Research Ethics Committee of the Methodist University of Piracicaba (Protocol No: 86/12).

**Procedures**

This study was cross-sectional. Each subject visited the laboratory twice, with a minimum of 24 hrs between visits. During the first visit, a maximal cardiopulmonary exercise test (CPETmax) was conducted to determine the following parameters: VO₂ max, VT1, vVT1, vVO₂ max, and maximum heart rate (HR max). During the second visit, the athletes underwent a time to exhaustion at vVO₂ max test to determine Tlim and Dmax parameters. In addition, at the end of the time to exhaustion at vVO₂ max test, kinetics of blood lactate removal test was performed to determine the metabolic response at the following times: 0 (immediate), 3, 6, 9, 15, and 20 min, with pre (baseline) blood having been collected beforehand. During the experiments, training load on the subjects (athletes) was reduced. The subjects were also asked to participate in the tests rested, fed, and hydrated. They were verbally encouraged and motivated to make maximum efforts during the tests, which were performed at the same time with variation of ±3 hrs.

**Maximal Cardiopulmonary Exercise Testing (CPETmax)**

The subjects performed the CPETmax on a motorized treadmill (ATL Inbrasport, Porto Alegre, Brazil) at 1% incline using a continuous protocol that consisted of a warm-up of 8 km·h⁻¹ for 3 min followed by an incremental load of 1 km·h⁻¹ every minute until voluntary exhaustion. The expired gases were measured using a metabolic gas analyzer (VO2000 - Medical Graphics, St. Paul, MN, USA). The highest value of oxygen consumption achieved during the CPETmax was considered to be VO₂ max, while VT1 was determined by the ventilatory method (20). The additional exhaustion criteria were respiratory exchange ratio (RER) = 1.1 and = 10 beats·min⁻¹ of age predicted maximum. Equipment was calibrated for every evaluation according to the manufacturer’s recommendations. Heart rate was measured every 60 sec with a heart rate monitoring (Polar Vantage NV, Kempele, Finland). The vVO₂ max was considered to be the minimal velocity that elicited VO₂ max. If the velocity stage could not be maintained for 1 min, the velocity of the previous stage was defined as vVO₂ max (4).

**Time to Exhaustion at vVO₂ Max Test**

Prior to this test, the subjects performed a warm-up of 5-min at an intensity of 1 km·h⁻¹ below vVT1. After a 2-min rest, the time to exhaustion at vVO₂ max test was started. From the moment that the treadmill reached the vVO₂ max speed (between 8 to 10 sec) a manual chronometer was activated (Timex®, model 85103). The test was ended when the subject reached voluntary exhaustion (inability to maintain the required velocity). The Tlim was considered to be the total time of effort maintained in vVO₂ max, expressed in sec. The Dmax was determined by the multiplication of vVO₂ max (m·sec⁻¹) by Tlim (in sec) and was expressed in m.

**Blood Lactate Analysis**

Blood samples (25 µl) were collected from the fingertips into heparinized capillary tubes and transferred to microtubes containing 50 µL of sodium fluoride at 1%. The lactate concentration was analyzed via an electro-enzymatic method with a lactate analyzer (YSI 2300 Stat Analyzer, Yellow Springs Instruments, Yellow Springs, OH, USA). Lactate concentrations in blood are expressed in mM.
**Statistical Analysis**
Data normality was assessed by Kolmorogov-Smirnov test. All data showed normal distribution, so the comparisons of means between the modalities (soccer and basketball) were performed by independent t test. One-way, repeated measures of analysis of variance (ANOVA) followed by a Turkey's post-hoc test were used for comparisons in kinetics of blood lactate removal values. The Pearson correlation coefficient was used to determine the level of correlation between selected variables. The level of significance was set at 5%. Data are expressed as mean ± standard derivation (SD). A study-power analysis suggested that a minimum of 18 subjects analyzed in each group and a 5% significance level (two-tailed) would yield at least 80% power for detecting differences for the variable Tlim.

**RESULTS**

**Anthropometric and Cardiopulmonary Values**
The anthropometric and cardiopulmonary variables for soccer and basketball athletes are described in Table 1. Age did not differ significantly (P>0.24) between groups, while significant differences were observed in body mass (P<0.01) and height (P<0.01) of the basketball athletes. Analysis of cardiopulmonary variables obtained by the CPETmax showed higher values in all parameters for soccer athletes when compared to basketball athletes: VO₂ max (P<0.01), vVO₂ max (P<0.01), VT1 (P<0.01), and vVT1 (P<0.01). There was no significant difference (P>0.07) for HRmax.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Basketball (n = 26)</th>
<th>Soccer (n = 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>18.9 ± 1.9</td>
<td>18.5 ± 0.9</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>82.8 ± 10.9*</td>
<td>71.4 ± 5.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>190.2 ± 7.4*</td>
<td>178.8 ± 6.7</td>
</tr>
<tr>
<td>VO₂ max (mL·kg⁻¹·min⁻¹)</td>
<td>50.0 ± 3.1</td>
<td>58.3 ± 4.2*</td>
</tr>
<tr>
<td>vVO₂ max (km·h⁻¹)</td>
<td>15.3 ± 1.1</td>
<td>17.5 ± 1.1*</td>
</tr>
<tr>
<td>VT1 (mL·kg⁻¹·min⁻¹)</td>
<td>35.9 ± 4.1</td>
<td>41.3 ± 4.1*</td>
</tr>
<tr>
<td>vVT1 (km·h⁻¹)</td>
<td>10.1 ± 1.1</td>
<td>12.1 ± 0.8*</td>
</tr>
<tr>
<td>HR max (beats·min⁻¹)</td>
<td>190.6 ± 7.6</td>
<td>194.8 ± 8.3</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD. VO₂ max: maximal oxygen uptake; vVO₂ max: velocity at maximal oxygen uptake; VT1: first ventilatory threshold; vVT1: velocity at first ventilatory threshold; HR max: heart rate maximum. *Significant difference between groups.

**Dmax and Tlim at vVO₂ Max Test**
Figure 1 shows the data obtained in the time to exhaustion at vVO₂ max test, which includes time (sec) and maximum distance (m) categorized according to the type of athlete. Tlim was significantly
higher ($P<0.02$) for the basketball athletes (318.0 ± 98.9 sec) compared with the soccer athletes (255.3 ± 86.6 sec). However, no significant difference was observed ($P>0.28$) between groups for the variable Dmax (basketball: 1344.7 ± 415.4 m; soccer: 1228.2 ± 369.6 m).

**Figure 1.** (a) Values of time to exhaustion (Tlim) in seconds obtained by time to exhaustion at the velocity at maximal oxygen uptake ($vVO_2$ max) test for basketball and soccer groups; (b) Values of maximum distance traveled (Dmax) in meters obtained by time to exhaustion at $vVO_2$ max test for basketball and soccer groups. *Significant difference between groups. Data are expressed as mean ± SD.

**Blood Lactate**

Analysis of kinetics of blood lactate removal showed significant changes ($P<0.01$) until 20 min after the $vVO_2$ max test compared to the pre-test values for both groups (Figure 2). However, no significant interaction between groups was observed ($P>0.05$). In addition, the peak blood lactate concentration did not differ significantly between groups ($P>0.05$), with mean values of 14.4 ± 4.1 mM and 13.8 ± 3.0 mM for basketball and soccer athletes, respectively.

**Figure 2.** Blood lactate concentrations (means ± SD) at times: pre (baseline), 0 (immediately), 3, 6, 9, 15, and 20 min after time to exhaustion at the velocity at maximal oxygen uptake ($vVO_2$ max) test for the basketball and soccer groups. *Significant difference ($P<0.01$) compared to pre values (basketball and soccer athletes).
Correlation with the Variable Tlim

Significant correlation was observed between Tlim and VO$_2$ max, vVO$_2$ max, vVT1, and peak blood lactate in the soccer athletes. No significant correlation was observed among any of the variables in the basketball athletes (Table 2).

Table 2. Pearson Correlation Coefficient Between Time Limit (Tlim) with Maximum Oxygen Uptake (VO$_2$ max), Velocity at Maximal Oxygen Uptake (vVO$_2$ max), First Ventilatory Threshold (VT1), Velocity at First Ventilatory Threshold (vVT1), and Lactate Peak.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Basketball (n = 26)</th>
<th>Soccer (n = 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tlim x VO$_2$ max</td>
<td>r = -0.27</td>
<td>r = -0.44</td>
</tr>
<tr>
<td></td>
<td>P = 0.18</td>
<td>P = 0.02*</td>
</tr>
<tr>
<td>Tlim x vVO$_2$ max</td>
<td>r = -0.29</td>
<td>r = -0.55</td>
</tr>
<tr>
<td></td>
<td>P = 0.15</td>
<td>P = 0.01*</td>
</tr>
<tr>
<td>Tlim x VT1</td>
<td>r = -0.59</td>
<td>r = -0.24</td>
</tr>
<tr>
<td></td>
<td>P = 0.77</td>
<td>P = 0.23</td>
</tr>
<tr>
<td>Tlim x vVT1</td>
<td>r = 0.14</td>
<td>r = -0.43</td>
</tr>
<tr>
<td></td>
<td>P = 0.51</td>
<td>P = 0.02*</td>
</tr>
<tr>
<td>Tlim x Lactate Peak</td>
<td>r = 0.17</td>
<td>r = 0.47</td>
</tr>
<tr>
<td></td>
<td>P = 0.41</td>
<td>P = 0.01*</td>
</tr>
</tbody>
</table>

VO$_2$ max: maximum oxygen uptake; vVO$_2$ max: velocity at maximal oxygen uptake; VT1: first ventilatory threshold; vVT1: velocity at ventilatory threshold. * Significant correlation.

DISCUSSION

The purpose of this study was to compare cardiopulmonary variables and performance on time to exhaustion of vVO$_2$ max tests among basketball and soccer athletes. The main findings were: (a) all cardiopulmonary variables analyzed in CPETmax were superior for soccer athletes; (b) the Tlim in vVO$_2$ max was higher for basketball athletes; (c) there was no significant difference in Dmax in vVO$_2$ max between sports modalities; and (d) the variables VO$_2$ max, vVO$_2$ max, vVT1, and blood lactate peak were moderately associated with Tlim for soccer athletes.

Aerobic power represents the maximum uptake rate of molecular oxygen from the environment and its transport and use by the mitochondria for cellular respiration during physical exercise (20,23). The VO$_2$ max values obtained in this study were in agreement with the values reported by da Silva et al. (13) for soccer athletes (between 55 to 68 mL·kg$^{-1}$·min$^{-1}$) and with those reported by Ziv and Lidor (29) for basketball athletes (between 50 to 60 mL·kg$^{-1}$·min$^{-1}$). However, when the groups in this study were compared to each other, the values of VO$_2$ max were 14% higher for the soccer athletes (Table 1). These findings are consistent with the training adaptations that are necessary to accommodate different levels of metabolic demand between sports modalities.
Despite both soccer and basketball requiring intermittent cardiovascular effort, with decisive muscle actions being supplied by anaerobic metabolism (2,29), aerobic power is a variable that promotes better physiological recovery between high-intensity muscle actions and maintenance of sports performance (27). Therefore, higher values of VO$_2$ max for soccer athletes were expected, due to the fact that distance covered during a match is higher for soccer players (10000 to 12000 m) (25) compared with basketball players (4404 to 7558 m) (3,16).

In addition, the major requirement of aerobic metabolism for soccer athletes was also confirmed by the data on ventilatory threshold (Table 1). The table shows its highest values at VT1 and vVT1 with the value for oxygen consumption at VT1, which represented 71% of VO$_2$ max for soccer athletes and 72% for basketball athletes. VT1, also described as the aerobic threshold, represents increased participation of glycolytic anaerobic metabolism during exercise while aerobic metabolism is still the primary source of energy (10,21).

The vVO$_2$ max is described as a variable that integrates VO$_2$ max and running economy in a single factor, thus explaining in part the difference in running performance among athletes (8). In this study, the data for vVO$_2$ max were higher for soccer athletes and were in agreement with those obtained by da Silva et al. (12). We found no data in the literature regarding basketball athletes.

As indicated by their Tlim scores, the soccer athletes had lower length of performance for the same relative intensity (vVO$_2$ max) compared to basketball athletes. However, no significant difference was observed for the variable Dmax. These data can be explained due to the fact that soccer athletes performed the test with higher velocity; a fact that allowed them to travel the same distance in a shorter time (Figure 4).

Similarly, Billat et al. (5) reported an inverse correlation between both VO$_2$ max and vVO$_2$ max and Tlim at vVO$_2$ max in elite half-marathon runners. In addition, bioenergetic analysis of long-distance recreational runners demonstrated that aerobic energy represents approximately 83% of total energy expenditure during the Tlim at vVO$_2$ max (4). Therefore, despite the metabolic prevalence during the time to exhaustion at vVO$_2$ max test, the aerobic metabolism does not seem to be a determining factor for improved Tlim performance for soccer athletes.

Likewise, we observe that the variables VO$_2$ max, vVO$_2$ max, and vVT1 were inversely correlated with Tlim for soccer athletes (Table 2). These data indicate that athletes who had better results in the CPETmax did not achieve better performance in the time to exhaustion at vVO$_2$ max test. On the other hand, the peak blood lactate concentration was positively associated with Tlim, thereby demonstrating that soccer athletes who had a greater magnitude of activation of glycolytic anaerobic metabolism were the subjects with better performance on the time to exhaustion at vVO$_2$ max test. Similarly, Renoux et al. (24) demonstrated that the Tlim was positively correlated with determination in runners of the maximum accumulated oxygen deficit (MAOD), methodology considered the gold standard for determining anaerobic capacity.

In contrast, although the basketball athletes scored better in the time to exhaustion during vVO$_2$ max test, the peak values and kinetics of blood lactate removal did not differ significantly when compared with soccer athletes (Figure 2). In addition, studies have reported that maximal strength training was effective for improving time to exhaustion at vVO$_2$ max in runners (26) and cyclists (28). Thus, these data suggest greater tolerance for efforts with high glycolytic demand and the neuromuscular performance required of basketball athletes, possibly a characteristic of the sports modality.
Conversely, no correlation analyses were significantly associated with Tlim for basketball athletes. Likewise, other studies have found no significant correlation between VO\textsubscript{2} max and vVO\textsubscript{2} max and Tlim (6,7,11). The literature has reported that Tlim has good reproducibility, but it exhibits a high coefficient of variation (6). Therefore, the difference between the studies may be explained due to the large variability between individuals in determining Tlim at vVO\textsubscript{2} max.

**CONCLUSIONS**

Soccer athletes had higher values in the parameters associated with aerobic metabolism (VO\textsubscript{2} max, vVO\textsubscript{2} max, VT1, and vVT1). However, determination of Tlim in vVO\textsubscript{2} max was higher for basketball athletes, and there was no significant difference for the variable Dmax. Therefore, these differences are due to physiological characteristics relevant to each sports modality. In addition, Tlim was moderately correlated with VO\textsubscript{2} max, vVO\textsubscript{2} max, VT1, and peak blood lactate, but only for the soccer athletes.

**ACKNOWLEDGMENTS**

The authors thank CAPES for the financial support and the master’s scholarships.

**Address for correspondence:** Rozangela Verlengia (PhD), Master in Physical Education – FACIS - UNIMEP - Campus Taquaral Rodovia do Açúcar, Km 156, s/n, Piracicaba -SP, Brazil. e-mail: rverleng@unimep.br

**REFERENCES**


**Disclaimer**

The opinions expressed in *JEPonline* are those of the authors and are not attributable to *JEPonline*, the editorial staff or the ASEP organization.