



Physiological Responses During the Time Limit at 100% of the Peak Velocity in the Carminatti's Test in Futsal Players

by

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The aim of this study was to investigate the physiological responses during the time limit at the intensity of the peak velocity of the Carminatti's test (T-CAR). Ten professional futsal players (age, 27.4 ± 5.8 years, body mass, 78.8 ± 8.5 kg, body height, 175.8 ± 6.8 cm, body fat mass, $14.1 \pm 2.6\%$) took part in the study. The players performed three tests, with an interval of at least 48 hours, as follows: the T-CAR to determine the peak velocity and the maximal heart rate; an incremental treadmill protocol to determine the maximal physiological responses; and a time limit running test at the peak velocity reached in the T-CAR. During the last two tests, a portable gas analyzer was used for direct measurement of cardiorespiratory variables. It was shown that the peak velocity was not significantly different from the maximal aerobic speed achieved in the laboratory ($p = 0.213$). All athletes reached their maximum oxygen uptake during the time limit test. The maximum oxygen uptake achieved during the time limit test was not different from that observed in the laboratory condition (51.1 ± 4.7 vs. 49.6 ± 4.7 ml·kg⁻¹·min⁻¹, respectively, $p = 0.100$). In addition, Bland and Altman plots evidenced acceptable agreement between them. On average, athletes took ~140 s to achieve maximum oxygen uptake and maintained it for ~180 s. Therefore, the peak velocity intensity can be used as an indicator of maximal aerobic power of futsal athletes and the time limit can be used as a reference for training prescription.

Key words: intermittent field test, peak velocity, maximal aerobic power, time limit.

Introduction

Futsal is an intermittent, high intensity team sport (5-a-side indoor soccer). Due to the court dimensions (40 x 20 m), an unlimited number of substitutions, as well as constant attacking and defensive tasks, futsal players are required to perform high-intensity activities such as sprints, accelerations, decelerations and changes of directions, stressing both the aerobic and anaerobic metabolism (Caetano et al., 2009, 2015). The most decisive periods of a futsal match are preceded by fast and high-intensity runs with a movement pattern varying, on average, every 3.3 s (Barbero-Alvarez et al., 2008; Dogramaci et

al., 2011). Professional futsal players spend about 5% and 12% of the match time performing sprinting and high-intensity running (> 15 km·h⁻¹), respectively (Barbero-Alvarez et al., 2008; Castagna et al., 2009). Furthermore, the athlete's ability to perform intense exercise (Barbero-Alvarez et al., 2008) and neuromuscular performance (Dal Pupo et al., 2014) are deteriorated towards the end of futsal matches, highlighting the importance of intermittent endurance performance to sustain high-intensity interval activities throughout training sessions and match play (Castagna et al., 2009).

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Based on time-motion analysis (Barbero-Alvarez et al., 2008; Dogramaci et al., 2011), the development of maximum aerobic power is an important prerequisite for physical performance, mainly due to the effective participation of the aerobic metabolism during the recovery periods between high-intensity efforts (Tomlin and Wenger, 2001). Moreover, maximal aerobic power plays a key role in determining the magnitude of individual's perceived exertion during futsal training sessions (Milanez et al., 2011). Thus, the use of the peak velocity (PV) from intermittent field tests with varied distances and direction change has been an interesting alternative to evaluate aerobic power in team sports (Dittrich et al., 2011) and it has been used for the prescription of interval training (Da Silva et al., 2015). Besides its applicability, practicality, low financial cost and high ecological validity (Svensson and Drust, 2005), PV is also associated with maximum aerobic speed (MAS) and repeated sprint ability (Da Silva et al., 2011).

The time limit (Tlim) maintained at this intensity and the time needed to achieve maximal oxygen uptake (TAVO₂max) have been used as a tool to calibrate the intensity and volume of high-intensity intermittent training sessions (Buchheit and Laursen, 2013; Caputo and Denadai, 2008). However, this model was designed primarily based on laboratory tests (Hill et al., 2003), aiming at training of endurance athletes. In light of these applications, Fernandes da Silva et al. (2015) reported the effectiveness of maximal aerobic power training prescription from the PV reached in the Carminatti's Test (PVT-CAR) using set duration (4 x 4 min) according to the traditional model (Helgerud et al., 2001), without the sets being individualized by the athlete's Tlim. Considering that precision in training prescription is one of the main aspects that can modify metabolic responses of trained athletes (Buchheit and Laursen, 2013), it is fundamental to identify physiological responses in the Tlim to individualize aerobic power training of futsal players.

In addition, VO₂ kinetics can also provide important information related to the physiological effects of training sessions. For example, a reduced oxygen deficit as a result of reduction of energy supply from the substrate level of phosphorylation and a lower accumulation of

fatigue-related metabolites (e.g., H⁺ and Pi) are expected after a period of training and these effects could be observed following VO₂ kinetics (Bailey et al., 2009; Dupont et al., 2010). Some authors also found significant relationships between VO₂ kinetics and the ability to perform high-intensity efforts (Dupont et al., 2005, 2010; Rampinini et al., 2009). Thus, information related to VO₂ kinetics such as the TAVO₂max and time maintained in VO₂max (TMVO₂max) during the execution of the Tlim at PVT-CAR intensity may have practical implications for aerobic training prescription. These variables can be used as a parameter to calibrate stimulus duration in high-intensity training sessions in team sport athletes (Buchheit and Laursen, 2013). However, physiological responses related to dynamics of VO₂max, VO₂ kinetics, a heart rate (HR) and lactate concentration during the Tlim at PVT-CAR are still unknown. It has not been investigated yet if this sort of a test is efficient to measure such responses. Therefore, the aim of the present study was to determine the physiological responses (VO₂max, HR, lactate) during the Tlim at PVT-CAR intensity as well as to analyze VO₂ kinetics during the Tlim in professional futsal players.

Material and Methods

Subjects

Ten professional national-level futsal players (age, 27.4 ± 5.8 years, body mass, 78.8 ± 8.5 kg, body height, 175.8 ± 6.8 cm, body fat mass, 14.1 ± 2.6%) competing in the first division of the Brazilian National League volunteered for the present study. The subjects had a minimum of four years of previous experience in high-level competition. All procedures were approved by the ethics committee of the Federal University of Santa Catarina, Florianópolis, Brazil (number 798/10).

Procedures

During the laboratory tests, air temperature and humidity were kept constant (i.e. 23–24 °C, 50–60% humidity). All tests were performed during the pre-season at the same time of the day (08.00–11.00 a.m.) to avoid the influence of circadian rhythms. The first experimental session consisted of anthropometric measurements (body mass, stature and skinfold measures to estimate the percentage of body fat) followed by an intermittent field test (T-CAR) to

determine PV_{T-CAR} and the HR_{max} . On the second visit, the athletes performed a maximal incremental treadmill test to determine their VO_{2max} , HR_{max} , MAS and peak lactate ($[La]_{peak}$). On the following visit the athletes completed a test to define the time limit at the intensity corresponding to the PV_{T-CAR} . Each participant was verbally encouraged to make maximum effort until volitional exhaustion in all the tests. It is important to highlight that the field tests were performed on the official futsal courts during a pre-season training period. Players recovered at least 48 h between each testing session to minimize residual fatigue.

Respiratory gases (VO_2 and VE) were measured breath by breath (K4 b2, Cosmed, Rome, Italy) during the incremental and time limit tests. The equipment was calibrated according to the manufacturer's recommendation before each test. During all test procedures the HR was monitored using the Polar system (Polar Electro Oy, Kempele, Finland). Capillary blood samples (25 μ l) from the ear lobe were obtained to measure blood lactate concentration ($[La]$). The analysis of lactate was performed using an electrochemical analyzer (YSI 2700 STAT, Yellow Springs, OH, USA), calibrated according to the manufacturer's recommendations before each test.

Incremental Treadmill Test (ITT)

Athletes' VO_{2max} was assessed using an incremental treadmill protocol on a motorized treadmill (Imbramed Millenium Super ATL, 10.200, Brazil). The initial treadmill speed was set at $9.0 \text{ km}\cdot\text{h}^{-1}$ (1% grade) with increments of $0.6 \text{ km}\cdot\text{h}^{-1}$ every minute until voluntary exhaustion. The VO_2 and HR were reduced to 15 s mean values. VO_{2max} and HR_{max} were considered as the highest value obtained during this interval time. Attainment of VO_{2max} was confirmed if the athlete met any two of the following criteria: (i) a respiratory exchange ratio (RER) ≥ 1.15 ; (ii) the HR within 10% of the age-predicted maximum; (iii) peak blood $[La] \geq 8 \text{ mM}$; (iv) a plateau in oxygen uptake despite increased exercise intensity or volitional exhaustion (Bassett and Howley, 2000). The MAS was identified as the lowest running speed where the VO_{2max} occurred as described previously (Billat and Koralsztein, 1996). To measure peak La concentration, blood samples were obtained 1, 3 and 5 minutes after the end of the test.

T-CAR test

The test consisted of intermittent shuttle runs of 12 s performed between 2 lines set at progressive distances with a 6 s recovery period between each run and a total stage time of 90 s. The protocol had a starting velocity of $9 \text{ km}\cdot\text{h}^{-1}$ over a running distance of 30 m (15 m out and back). The length in a single direction was increased progressively by 1 m at every level. Each stage consisted of 5 repetitions with a 6 s walking period between 2 lines set 2.5 m from the starting line. From eight to ten athletes were evaluated simultaneously with the running pace dictated by a pre-recorded audio system (Da Silva et al., 2011). The test ended when participants failed to follow the audio cues on the front line for 2 successive repetitions (objective criteria determined by observers). PV_{T-CAR} was calculated from the distance of the last set completed by the athlete divided by the time to complete the stage repetition. When an incomplete set occurred, peak velocity was interpolated using the equation: $PV = v + (ns/10)*0.6$, where "v" is the velocity of the last fully completed stage and "ns" = the number of repetitions completed in the partially completed stage.

Time limit (100% of PV_{T-CAR}) and VO_2 uptake kinetics

All athletes were asked to perform a run until exhaustion at the speed corresponding to the PV_{T-CAR} based on the same dynamics as the T-CAR. Prior to the test, the athletes performed a 5 min warm-up of general stretching exercises and a 5 min warm-up of intermittent runs at an intensity corresponding to 70% of PV_{T-CAR} (distance in meters from each subject).

The warm-up was followed by a passive recovery period lasting three minutes and at the end of the third minute athletes' blood samples were taken to measure the La concentration prior to the Tlim. The distance was adjusted to the intensity corresponding to 100% of PV_{T-CAR} (with the possibility of an adjustment of $0.1 \text{ km}\cdot\text{h}^{-1}$). The Tlim was considered as the total time between the first audio cue (test start) and the voluntary withdrawal of the athlete. Blood samples were collected 1, 3 and 5 min after the end of the test to determine the peak La concentration.

In order to determine the time needed to achieve VO_{2max} , mathematical adjustments were made to analyze VO_2 kinetics during the Tlim

using mono-exponential functions as suggested by Jones et al. (2008) and described in the following equation:

$$VO_2(t) = VO_{2base} + Amp \times [1 - e^{-t/\tau}]$$

where $VO_2(t)$ is oxygen uptake at time t , VO_{2base} is the 30 s prior to the exercise, Amp is the asymptotic amplitude, and τ is the time constant of VO_2 kinetics that represents the time required to attain 63% of the amplitude and is denominated as mean response time (MRT), since the adjustment is made from the initial to the end of the load without considering the delay time (Jones et al., 2008). For each test, $TAVO_{2max}$ was defined as $4.6 \times MRT$ s. Time maintained at VO_{2max} ($TMVO_{2max}$) was determined by subtraction of the $TAVO_{2max}$ from the $Tlim$ (Caputo and Denadai, 2008).

Statistical analysis

Descriptive statistics are reported as means \pm standard deviations (SD), coefficients of variation (CV) and confidence intervals (95%). The criteria for the precision of the CV were adopted according to Hopkins (2000). The Shapiro-Wilk ($n < 50$) test verified that all data presented normal distribution, thus parametric statistics were used. The Student's t -test for paired samples was used to compare the mean values of the HR_{max} , MAS and PV_{T-CAR} derived from treadmill and T-CAR tests, and also to identify differences between VO_{2max} , HR_{max} , VE_{max} , RER_{max} and peak La concentration determined from incremental treadmill and Tlim tests. The agreement analysis for physiological variables determined from incremental, T-CAR and Tlim tests was assessed using Bland-Altman plots (bias \pm 95% limits of agreement) with variables difference bias tested for significance against the null hypothesis (difference = 0). Heteroscedasticity was tested according to Ludbrook (2010). Analyses were carried out using SPSS for Windows (SPSS v.15.0, Chicago, IL, USA). The level of statistical significance was set at $p < 0.05$.

Results

Table 1 presents the means and standard deviation (SD) of the physiological variables obtained in the incremental treadmill test and the T-CAR test.

No significant differences were found between the PV_{T-CAR} and the MAS reached in the

incremental test ($p = 0.21$). However, significant differences were found between HR_{max} values for both tests ($p = 0.04$). The bias 95% limits of agreement for the comparison between MAS vs. PV_{T-CAR} ($0.20 \pm 1.49\text{ km}\cdot\text{h}^{-1}$) and HR_{max} obtained from incremental and T-CAR tests ($-3.60 \pm 10.94\text{ bpm}$) are illustrated in Figures 1D and 1E, respectively.

The performance values ($Tlim$) and physiological indexes (VO_{2max} , VE_{max} , peak La, initial La, RER_{max} and HR_{max}) obtained during the constant workload exercise test at 100% of PV_{T-CAR} are presented in Table 2.

The peak La ($13.6 \pm 2.4\text{ mmol}\cdot\text{L}^{-1}$), RER_{max} (1.3 ± 0.14) and HR_{max} ($188 \pm 10\text{ bpm}$) during the Tlim presented maximal physiological responses. No significant differences were found in the values of VO_{2max} ($p = 0.10$), VE_{max} ($p = 0.73$) and HR_{max} ($p = 0.09$) when the values of the treadmill and Tlim tests were compared. In addition, Bland-Altman plots (bias \pm 95% limits of agreement) suggest acceptable agreement between VO_{2max} ($-1.47 \pm 6.61\text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), VE_{max} ($-2.46 \pm 16.27\text{ L}\cdot\text{min}^{-1}$) and HR_{max} ($-2.20 \pm 7.32\text{ bpm}$) derived from treadmill and Tlim tests (Figures 1A, 1B and 1C, respectively). It should be noted that there was no systematic error (heteroscedasticity) for agreement measures between the physiological variables determined in both tests. Moreover, the RER_{max} ($p = 0.005$) and posttest blood lactate ($p < 0.001$) values in the Tlim test were higher than those reached in the incremental treadmill test.

The physiological indices and VO_2 kinetics derived from mathematical mono-exponential adjustments are presented in Table 3.

It can be observed that during the Tlim at 100% of PV_{T-CAR} athletes took about 2.3 minutes to achieve VO_{2max} . It is also important to emphasize that VO_{2max} was sustained for $\sim 3\text{ min}$ during the Tlim, which demonstrates the effectiveness of this exercise model to estimate maximal aerobic power.

Discussion

The main finding of the present study was that the peak velocity reached in the T-CAR can be considered an indicator of maximal aerobic power in professional futsal players, since during a high-intensity intermittent exercise (100% of the PV_{T-CAR}) maximum oxygen uptake was achieved ($TMVO_{2max} \sim 181\text{ s}$).

Table 1*Descriptive values of the physiological variables related to the treadmill and T-CAR tests*

	Mean \pm SD	CV	95% CI	
			Lower	Upper
Incremental treadmill test				
PV (km·h ⁻¹)	16.4 \pm 1.4	8.8	15.5	17.2
VO _{2max} (ml·kg·min ⁻¹)	49.6 \pm 4.7	9.4	46.7	52.5
VO _{2max} (L·min ⁻¹)	3.9 \pm 0.5	12.8	3.6	4.2
MAS (km·h ⁻¹)	16.0 \pm 1.4	8.7	15.1	16.9
VE _{max} (L·min ⁻¹)	143.1 \pm 17.7	12.3	132.2	154.1
La peak (mmol·L ⁻¹)	8.5 \pm 2.1	25.1	7.2	9.9
RER _{max}	1.2 \pm 0.2	15.2	1.1	1.3
HR _{max} (bpm)	185 \pm 11	6	179	192
T-CAR				
PV (km·h ⁻¹)	15.8 \pm 1.0	6.2	15.1	16.5
HR _{max} (bpm)	189 \pm 9	4.7	182	195

PV = peak velocity VO_{2max} = maximal oxygen uptake, vVO_{2max} = velocity related to VO_{2max}, MAS = maximal aerobic speed, VE_{max} = maximal ventilation, RER_{max} = maximal respiratory exchange ratio. HR_{max} = maximal heart rate.

Table 2

Descriptive values of performance and physiological variables obtained in the time limit test (100%PV_{T-CAR})

	Mean \pm SD	CV	95% CI	
			Lower	Upper
Time limit (s)	321.4 \pm 48.8	16.0	283.8	346.2
VO _{2max} (ml·kg·min ⁻¹)	51.1 \pm 4.7	9.1	48.2	54.0
VO _{2max} (L·min ⁻¹)	4.0 \pm 0.4	11.0	3.7	4.3
VE _{max} (L·min ⁻¹)	145.6 \pm 13.2	9.0	137.4	153.8
Lactate post warming (mmol·L ⁻¹)	2.1 \pm 0.4	20.4	1.5	2.8
Lactate peak (mmol·L ⁻¹)	13.6 \pm 2.4	17.4	11.9	15.2
RER _{max}	1.3 \pm 0.1	11.0	1.2	1.4
HR _{max} (bpm)	188 \pm 10	5	182	194

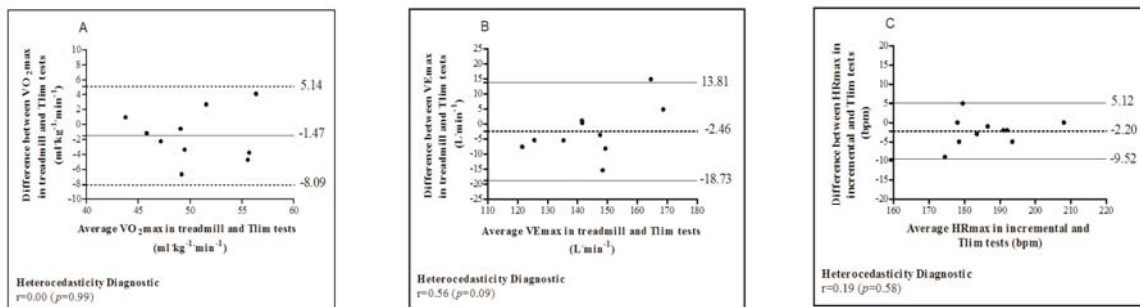
Time limit = time that the athlete sustained at PV_{T-CAR}.

Table 3
Descriptive values of physiological variables related to oxygen uptake obtained during the time limit test (100% PV_{T-CAR}).

	Mean ± SD	95% CI	
		Lower	Upper
VO _{2base} (ml/min)	731.4 ± 83.2	598.0	849.3
Amp (ml/min)	3058.5 ± 361.2	2595.1	3890.9
VO ₂ total (ml/min)	3789.8 ± 393.0	3283.0	4687.9
MRT (s)	30.4 ± 5.3	22.0	42.0
TAVO _{2max} (s)	140.0 ± 24.5	101.1	193.4
TMVO _{2max} (s)	181.4 ± 64.4	64.6	267.6

VO_{2base} = maximal oxygen uptake on the initial load; Amp = VO₂ amplitude; VO₂ total = VO₂ load; MRT = mean response time; TAVO_{2max} = time to achieve VO_{2max}; TMVO_{2max} = time maintained at VO_{2max}.

Incremental treadmill test vs. Tlim test



Incremental treadmill test vs. T-CAR

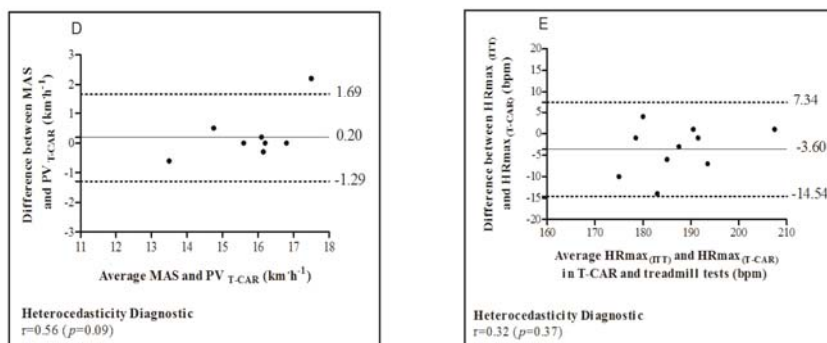


Figure 1

Bland-Altman plots between variables obtained from incremental treadmill and Tlim tests (upper panels: VO_{2max} [A], VEmax [B] and HR_{max} [C]), and variables derived from the incremental treadmill test and the T-CAR (lower panels: MAS vs. PV_{T-CAR} [D] and HR_{max} [E]). Solid lines represent the bias and dashed lines denote the lower and upper 95% limits of agreement (±1.96 SD).

The PVT-CAR might be a useful physiological marker to plan individualized intermittent running training sessions in which the objective is exercising for a long time at a high percentage of VO_{2max} . In addition, player's exercise tolerance (i.e. T_{lim}) at maximal intermittent efforts and $TAVO_{2max}$ has also been considered key parameters to individualize the stimulus duration in each set in aerobic training sessions (Buchheit and Laursen, 2013; Hill and Rowell, 1997). Based on our findings, it may be suggested that the minimum volume load for prescribing high-intensity training should be equal to or higher than 100% $TAVO_{2max}$ (i.e., ~140 s), which represents about 43% of the T_{lim} in this model (100% PVT-CAR) for futsal players. Previous studies have already shown that efforts lasting ≈ 2 to 4 min at an intensity near to maximal or maximal (e.g. 100%PVT-CAR) are capable to induce a high cardiovascular demand (Da Silva et al., 2015; Ferrari Bravo et al., 2008; Helgerud et al., 2001; Laursen et al., 2004), being an effective approach to improve the cardiorespiratory and metabolic function, and, in turn, to enhance the athletes physical performance (Ferrari Bravo et al., 2008; Helgerud et al., 2001; Impellizzeri et al., 2006).

Despite the limitation of VO_{2max} for monitoring training adaptation in team sports, it appears to be related to player's exercise tolerance and recovery during repeated bouts of high-intensity intermittent exercise (Milanez et al., 2011; Tomlin and Wenger, 2001). VO_{2max} reached during the T_{lim} at PVT-CAR was similar to that obtained during the treadmill protocol, resulting in a mean difference (i.e. bias) considered as trivial/small ($-1.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). However, it is important to highlight that there may be an intraindividual variation of up to $\pm 6.61 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Figure 1A). This finding, showing no significant difference in VO_{2max} values between treadmill and T_{lim} tests, may be explained, at least in part, by the fact that exercises performed between 5 and 10% above the critical power (severe domain) are sufficient to induce instability in gas exchange and the metabolism (Hill et al., 2002), increasing VO_2 to its maximum values due to the slow component or as an effect of muscle fatigue and/or recruitment of additional motor units (less efficient fibers) (Caputo and Denadai, 2008). The

increased body temperature, circulating catecholamines and lactate metabolism are also factors that can influence the increase in oxygen uptake in exercises with intensity close to VO_{2max} (Hughson et al., 2001). Finally, the greater recruitment of type II fibers during a high-intensity activity increases the energy cost for the same rate of work due to a higher need for oxygen (Dupont et al., 2010).

Currently, several training programs are available in literature to be applied to team sport athletes (Iaia et al., 2009). Traditionally, the HR and peak velocity derived from intermittent field testing are the two most commonly measured physiological markers used for prescribing and controlling exercise intensity in the field conditions (Buchheit and Laursen, 2013). For instance, Fernandes da Silva et al. (2015) showed that training with and without direction change at the intensity of the 100%PVT-CAR was effective in improving aerobic power and capacity, and the ability to perform high-intensity intermittent activities in U-20 elite soccer players. Furthermore, Ferrari Bravo et al. (2008) and Helgerud et al. (2001) demonstrated that 4 sets of 4 min at 90-95% of the HR_{max} with 3 min of active recovery at 60-70% of the HR_{max} were efficient training stimuli to increase the cardiorespiratory function and soccer performance (e.g. distance covered and the number of sprints) in trained athletes. These studies give support to the inclusion of training sessions involving stimulus at the intensity of MAS (Buchheit and Laursen, 2013). It should be noted that, in the present study, the bias and limits of agreement between MAS and PVT-CAR ($0.20 \pm 1.49 \text{ km}\cdot\text{h}^{-1}$, Figure 1D) were similar to peak velocity values found in the T-CAR test ($0.08 \pm 1.62 \text{ km}\cdot\text{h}^{-1}$) and the 45-15 test ($-0.20 \pm 1.7 \text{ km}\cdot\text{h}^{-1}$) in soccer players (Castagna et al., 2014; Teixeira et al., 2014). Moreover, the bias $\pm 95\%$ limits of agreement between HR_{max} obtained from the incremental test and the T-CAR in our study ($-3.60 \pm 10.94 \text{ bpm}$, Figure 1E) were similar to those reported in previous studies (Castagna et al., 2014; Teixeira et al., 2014). From a practical point of view, our findings highlight acceptable agreements among these variables, supporting the relevance of using the HR and peak velocity as variables to control the internal and external training load, respectively. However, the Bland-

Altman plots indicate that if the MAS and HRmax determined in laboratory condition were estimated from PVT-CAR and the HRmax reached during the T-CAR, a variation of up to $\pm 1.49 \text{ km}\cdot\text{h}^{-1}$ and $\pm 10.94 \text{ bpm}$ could be expected. The interpretation of these data is of interest for coaches and fitness trainers, as they suggest that these individual differences should be taken into account during the individualization of training intensities.

Additionally, it is important that the conditioning coach also identifies exactly the time that each athlete requires to achieve VO_2max , as well as the time that the athlete maintains this intensity (Hill et al., 2002). In the present study, the TAVO $_2\text{max}$ and TMVO $_2\text{max}$ represented around 43.6% and 56.4% of the Tlim at PVT-CAR, respectively. Due to the variability of the TAVO $_2\text{max}$, training should be prescribed individually (Hill and Rowell, 1997). In light of the results found and specific training for futsal players, it should be emphasized that workloads with duration lower than 40% of the Tlim (i.e. < 2 min) are not sufficient to achieve VO_2max , and therefore induce physiological adaptations related to maximal aerobic power (Midgley et al., 2007). These findings are in line with those reported by Billat et al. (1999) and Laursen et al. (2004) who also suggest volumes of 50–70% of the Tlim as ideal duration for the development of high-intensity training programs, considering that this would be sufficient to reach VO_2max and maintain it for a longer time, especially during subsequent loads.

The Tlim at 100%PVT-CAR in our study is consistent with the values reported in the literature for the running model without pauses (Billat et al., 1994), even though it was previously reported that the Tlim in the intermittent model was superior to that in the continuous model (Demarie et al., 2000). It was found that 6 s pauses during the Tlim at 100%PVT-CAR, due to its short duration, did not affect the final values of VO_2max and lactate concentration. Probably, these findings may be related to the fact that the creatine phosphate resynthesizes needs at least 30 s to restore 50% of the initial concentration (McMahon and Jenkins, 2002). Thus, performing several sets of running at high intensity will result in a progressive decline of the creatine phosphate system and a greater demand for the glycolytic

system. In this way, it is reasonable to suggest that the Tlim at PVT-CAR can also be used as a variable for prescribing lactate tolerance training (Billat, 2001). Furthermore, intermittent activities with short recovery periods are able to maintain the exponential VO_2 behavior, and when applied at maximal intensity (or in the severe domain) the athletes sustain VO_2max for a certain period of time as observed in the present study (Rossiter, 2011).

Based on the findings of the present study, we suggest that the PVT-CAR can be used as a reference intensity for the MAS, whereas the Tlim and TAVO $_2\text{max}$ may be adopted to calibrate the volume for prescribing training aiming to develop maximal and submaximal aerobic functions. In sports training, it is also necessary to implement this information in the athlete's routine. Different study designs have aimed to explain how to obtain the best relationship between training volume and intensity in order to induce chronic metabolic adaptations (Billat et al., 1999). In accordance to previous studies in team sports (Ferrari Bravo et al., 2008; Helgerud et al., 2001; Impellizzeri et al., 2006), we suggest the inclusion of 1 to 2 times per week of high-intensity training using the variables described in this study as a means of achieving improvements in VO_2max and MAS of futsal players.

The combination of the practicality of performing a field test with several athletes simultaneously without high financial costs and the effectiveness of determining physiological variables that can support the professional practice in intermittent sports such as futsal was the practical focus of this research. Furthermore, this study provides volume and intensity criteria for the prescription of individualized training sessions for futsal players.

The main limitation of the present study is the determination of the VO_2 response variables using only one rest-exercise transition that can demonstrate low confidence in the variables. However, we found high coefficients of determination (unpublished data) for the estimation of MRT with one single repetition. Consequently, a single transition seems to provide practical realistic information of VO_2 kinetics.

Conclusion

In conclusion, our study demonstrated

that the peak velocity derived from the T-CAR might be considered a useful tool to estimate maximal aerobic power in professional futsal players. These findings enable conditioning coaches to monitor and evaluate the development and stability of the intermittent endurance running performance of futsal players during the pre- and in-season training period, respectively. Furthermore, the Tlim and TAVO₂max can be used as reference for adjusting the total volume in

training sessions, which is intended to enhance the aerobic power of futsal athletes. From a practical perspective, training sessions at 100%PVT-CAR intensity for futsal players could be based on total volume close to 15-21 min (e.g. 5-7 sets of 3 min) with a work:rest ratio equal to 1:1. Finally, we recommend that total training session volume in team sports should enable athletes to spend between \approx 3 to 5 min at VO₂max.

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