VALIDITY OF CARMINATTI'S TEST TO DETERMINE PHYSIOLOGICAL INDICES OF AEROBIC POWER AND CAPACITY IN SOCCER AND FUTSAL PLAYERS

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ABSTRACT

Dittrich, N, da Silva, JF, Castagna, C, de Lucas, RC, and Guglielmo, LGA. Validity of Carminatti's test to determine physiological indices of aerobic power and capacity in soccer and futsal players. *J Strength Cond Res* 25(11): 3099–3106, 2011—The aim of this study was to verify the validity of a new progressive distance and fixed time test (Carminatti's test [TCAR]) in estimating the main physiological indices of aerobic fitness in team-sport players. Thirty professional national level team-sport players ($n = 12$ futsal players and 18 soccer players) volunteered to participate in this study. The subjects performed the TCAR and a laboratory incremental treadmill test (ITT). The TCAR required subjects to complete repeated sets of 5×12-second shuttle-running bouts at progressive speed until volitional exhaustion. Each 12-second bout and series were separated by a 6- and 90-second recovery periods, respectively. The initial distance was set at 15 m and was progressively increased by 1 m each set. The ITT commenced at a velocity of 9.0 $km \cdot h^{-1}$ and was increased by 1.2 $km \cdot h^{-1}$ each 3 minutes until volitional exhaustion. Peak TCAR running velocity resulted not significantly ($p > 0.05$) different from speed at $\dot{V}O_2max$ ($v\dot{V}O_2max$) during ITT. Peak TCAR running velocity was significantly correlated ($p < 0.01$) with $v\dot{V}O_2max$ ($r = 0.55$) and $\dot{V}O_2max$ ($r = 0.51$). No significant differences were found ($p > 0.05$) among the mean values of velocity and heart rate at the anaerobic threshold, estimated in the TCAR test and measured in the ITT. In light of this study results, the TCAR can be considered as a viable field test to estimate aerobic power and capacity in team-sports players. The limited devices and space required by TCAR warrant consideration for those strength and conditioning professionals who deal with team sports.

KEY WORDS field test, aerobic, team sports

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INTRODUCTION

Aerobic fitness is considered as a physiological determinant of team-sports performance (1). The physiological response during intermittent exercise modes with change of direction has been extensively studied in recent decades in several team sports such as soccer, futsal, handball, and basketball (4,10,14,20). Although crucial action during the game are the results of anaerobically supported movements (kicking, sprinting, changing direction), recent studies have shown that the aerobic pathway during soccer and futsal is greatly solicited (3,14,26).

Indeed recent studies reported that during competitive and training games professional soccer players play at 75% of their maximal oxygen uptake ($\dot{V}O_2max$) with an operational heart rate (HR) that attains the 90% of the individual maximal (19). Furthermore, the average $\dot{V}O_2$ demands of competitive professional futsal were reported to be of 48 $ml \cdot kg^{-1} \cdot min^{-1}$ with peak values close to 99% of $\dot{V}O_2max$ (14).

The importance of aerobic fitness in professional soccer and futsal players was further supported by the individual levels of $\dot{V}O_2max$ and ventilatory threshold found in well-trained players (3,14,35). Additionally, $\dot{V}O_2max$ possessed construct validity in futsal and soccer with values higher the higher the competitive level of players. Thus, aerobic fitness (i.e., $\dot{V}O_2max$ and anaerobic threshold [AT]) may be assumed as affecting soccer and futsal performance (35).

The maximal lactate steady state (MLSS) has been considered the gold standard to evaluate the AT, representing the higher exercise intensity that can be maintained over time without continued lactate accumulation (7,9). Nevertheless, the assessment of MLSS may cause disruption of the usual training schedule requiring on part of athletes several visits to the laboratory. Consequently, indirect methods emerged as alternatives to predict the AT (8,16,25) in a single incremental test.

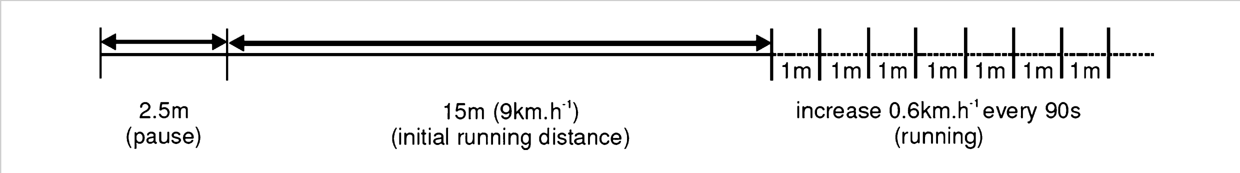

Figure 1. Visual representation of the Carminatti's test (TCAR) test.

The method proposed by Heck et al. (25) that uses a fixed value of 3.5 m·moL^{-1} to predict the MLSS has proved to be a viable option in different groups (18,23,24) and is the most frequently used method in sport science researches (21). The use of individual kinetic lactate curve in the incremental test has also been presented as an alternative method for determining the AT, because of the individual variations of blood lactate curve (8,16).

The component of aerobic fitness can be accurately assessed in a laboratory setup with valid and reliable protocols. However, these procedures require expensive equipment, trained personnel, and are time consuming as being conducted on individual base. Furthermore, laboratory test protocols involve exercise modes (i.e., line running and cycling) that are not team-sport relevant limiting test specificity and players' ability and motivation. As a consequence of that, field testing may constitute a viable method to assess aerobic fitness in team-sport players.

A number of field tests were proposed with the aim to assess aerobic fitness using team sport–specific exercise modes (i.e., continuous or intermittent shuttle running) (5,10,33). These tests showed to be valid and reliable surrogate of laboratory testing enabling mass evaluation within a limited amount of time (1,2,12,29).

Recently, Carminatti et al. (13) proposed a progressive distance intermittent shuttle-running test (TCAR–Carminatti's test) aiming to evaluate maximal aerobic power and aerobic capacity in team sports. Like other field tests involving shuttle running, the TCAR is guided by audio cues (i.e., beeps) diffused with a CD or MP3 player (6). However, differently from the previously proposed shuttle-running test, the TCAR requires players to intermittently run back and forward between 2 line set at progressive distance (i.e., from 15 m with 1-m increments until exhaustion) within a set time interval (i.e., 6 seconds) observing a 6-second recovery after 12 seconds of exercise. In addition, the larger distances covered during the later stages of the TCAR test allows the athlete to have more distance to accelerate and reach higher peak running velocities compared to shorter fixed distance protocols (1). The interest of this test lies in the constant stress imposed on the change of direction abilities of players and in the limited apparatus required.

Despite the interest of this novel test and its growing popularity, no study addressed TCAR validity. Therefore, the aim of this study was to verify the validity of the TCAR in estimating the main physiological indices of aerobic fitness in team-sport players.

Methods

Experimental Approach to the Problem

In this study was assessed the criterion-related validity of a novel test developed with the aim to estimate aerobic fitness in team-sport players using a progressive distance intermittent shuttle-running protocol. Convergent validity was assessed assuming as criterion variables of aerobic fitness maximal aerobic power ($\dot{V}O_2$max), treadmill maximal aerobic

Table 1. Peak physiological values during field and treadmill test protocols*.

	TCAR		ITT			
$n = 30$	HRmax (b·min^{-1})	PV (km·h^{-1})	HRmax (b·min^{-1})	PV (km·h^{-1})	$\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	$v\dot{V}O_2$max (km·h^{-1})
Mean	193	16.4†	193	17.1	59.9	16.7
DP	9.0	0.9	8.0	0.9	5.2	1.0

*TCAR = Carminatti's test; ITT = incremental treadmill test; HRmax = maximal heart rate; PV = peak velocity; $\dot{V}O_2$max = maximal oxygen uptake; $v\dot{V}O_2$max = velocity related to the $\dot{V}O_2$max; DP = deflection point.

†$p < 0.05$ related to the ITT PV.

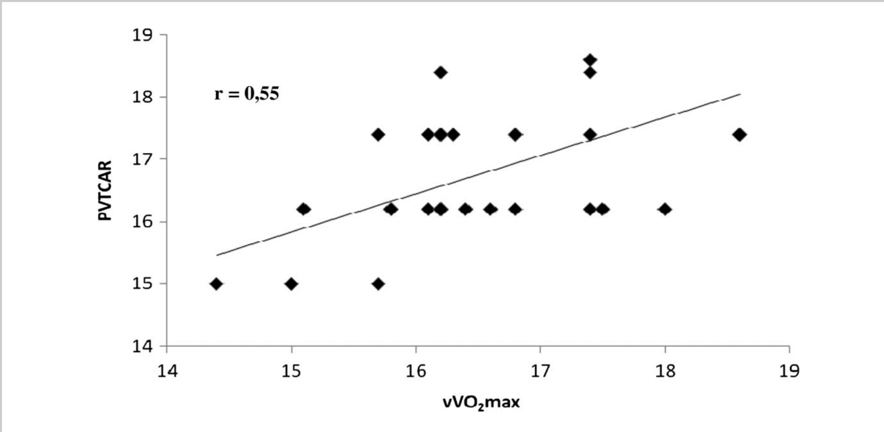

Figure 2. Relationship between PV_{TCAR} and $v\dot{V}O_2max$ (PV = peak velocity).

The TCAR being devised to test team-sport players, a population of randomly selected professional soccer and futsal players (outfield players) was considered in this descriptive research design (i.e., stratified randomization). The population homogeneity (i.e., court and pitch footballers) was assumed to challenge the association between individual level of aerobic fitness and TCAR performance (37). The professional status of players was understood as guarantee of training and athletic lifestyle status. The sample size was assumed considering power of 0.80 and a confidence level of 5% for reaching a Pearson correlation coefficient of 0.52.

speed ($v\dot{V}O_2max$), and ATs. Lactate thresholds were calculated using 3 constructs when analyzing the data collected during the treadmill test for $\dot{V}O_2max$ determination. Constructs for AT determination were assumed as follows: (a) as the running speed ($V_{3.5}$) and heart rate ($HR_{3.5}$) corresponding to blood lactate concentration of 3.5 $mmol \cdot L^{-1}$ as the $HR_{3.5}$ (25); (b) by linear interpolation from the minor relationship between the blood lactate and the velocity of exercise added by 1.5 $mmol \cdot L^{-1}$ to identify the lactate threshold speed ($V_{+1.5}$) and HR ($HR_{+1.5}$) according to Berg et al. (8); and (c) using the *D*max technique to assess the corresponding speed (V_{DMAX}) and HR (HR_{DMAX}) according to Cheng et al. (16).

However, as the literature presents different methods based on the individual lactate curve, the method proposed by Heck et al. (25) was set as the gold standard for aerobic capacity evaluation in this study.

Subjects

Thirty professional national-level team-sport players ($n = 12$ futsal players and 18 soccer players) volunteered to participate in this study. Mean age, height, body mass, and % body fat of futsal and soccer players were 23.3 ± 4.1 and 18.5 ± 1.2 years, 177.1 ± 6.7 and 177.8 ± 6.0 cm, 75.4 ± 8.6 and 74.2 ± 6.4 kg, and 9.9 ± 3.2 and 9.80 ± 1.3%, respectively. The players were assessed in the first week of the preseason. All tests were performed at the same hour of the day (i.e., 9–11 AM) to avoid circadian variation in performance output.

To avoid undue fatigue before testing, players refrained from heavy training during the preceding 24 hours. Players were advised to maintain a regular diet during the day before testing (i.e., 60, 25, and 15% of carbohydrates, fat, and protein,

Table 2. Descriptive values of the physiological variables related to the aerobic capacity.*

	TCAR			ITT		
$n = 30$	$V_{HRDP\text{-}V}$ ($km \cdot h^{-1}$)	$V_{HRDP\text{-}M}$ ($km \cdot h^{-1}$)	$V_{80.4}$ ($km \cdot h^{-1}$)	$V_{+1.5}$ ($km \cdot h^{-1}$)	V_{DMAX} ($km \cdot h^{-1}$)	$V_{3.5}$ ($km \cdot h^{-1}$)
Mean	13.4	13.3	13.2	13.4	13.5	13.6
SD	0.8	1.3	0.8	0.6	0.7	0.8
%PV	81.6	81.0	80.4	78.4	78.9	79.2

*PV = peak velocity; $V_{HRDP\text{-}V}$ = velocity corresponding at heart rate deflection point–visual method; $V_{HRDP\text{-}M}$ = velocity corresponding at heart rate deflection point mathematical method; $V_{80.4}$ = fixed percentage of 80.4 of PV_{TCAR}; $V_{+1.5}$ = velocity of exercise added by 1.5 $mmol \cdot L^{-1}$ to identify the lactate threshold speed; V_{DMAX} = Dmax technique to identify the anaerobic threshold speed; $V_{3.5}$ = running speed corresponding to blood lactate concentration of 3.5 $mmol \cdot L^{-1}$.

TABLE 3. Correlation values among the velocities of the aerobic capacity.*

$n = 30$	$V_{80.4}$	$V_{HRDP\text{-}V}$	$V_{HRDP\text{-}M}$	$V_{+1.5}$	V_{DMAX}
$V_{80.4}$					
$V_{HRDP\text{-}V}$	0.36†				
$V_{HRDP\text{-}M}$	0.18	0.84‡			
$V_{+1.5}$	0.45†	0.46†	0.23		
V_{DMAX}	0.38†	0.23	−0.06	0.62‡	
$V_{3.5}$	0.51‡	0.53‡	0.31	0.80‡	0.57‡

*$V_{HRDP\text{-}V}$ = velocity corresponding at heart rate deflection point–visual method; $V_{HRDP\text{-}M}$ = velocity corresponding at heart rate deflection point mathematical method; $V_{80.4}$ = fixed percentage of 80.4 of PV_{TCAR}; $V_{+1.5}$ = velocity of exercise added by 1.5 mmol·L^{-1} to identify the lactate threshold speed; V_{DMAX} = *D*max technique to identify the anaerobic threshold speed, $V_{3.5}$ = running speed corresponding to blood lactate concentration of 3.5 mmol·L^{-1}.

†Significant value to $p < 0.05$.

‡Significant value to $p < 0.01$.

respectively) and to refrain from smoking and caffeinated drinks during the 2 hours preceding testing. To avoid hypohydration, players were allowed to drink fluids "ad libitum."

Written informed consent was received from all participants and legal guardians of underaged players after a brief but detailed explanation about the aims, benefits, and risks involved with this investigation. Participants were told they were free to withdraw from the study at any time without penalty. All procedures were approved by the ethics committee of the Federal University of Santa Catarina, Florianópolis, Brazil (number 224/08).

Procedures

Players were tested on separate occasions (i.e., at least 48 apart) and in random order in laboratory and field conditions. Laboratory and field testing procedures included anthropometric evaluation and an incremental test on a treadmill to determine aerobic fitness and TCAR respectively.

All the subjects were assessed for body mass (kg), height (cm) and, 4 skinfolds (suprailliac, abdomen, triceps, subscapular) to estimate body fat percentage (22).

Players' $\dot{V}O_2max$ was assessed using an incremental treadmill protocol (ITT) to exhaustion on an inclined (i.e., 1.0%) motorized treadmill (Imbramed Millenium Super Atl, 10.200, Porto Alegre, Brazil). The initial treadmill speed was set at 9.0 km·h^{-1} (1% grade) with increments of 1.2 km·h^{-1} every 3 minutes interspersed with 30-second recovery (i.e., to allow earlobe blood sampling) until voluntary exhaustion. During the ITT, each subject was verbally encouraged to undertake maximum effort.

Oxygen consumption ($\dot{V}O_2$) was measured breath by breath using a gas analyzer (Quark PFT Ergo, Cosmed, Rome, Italy), which was calibrated according to manufacturer's recommendation before each test. Data were reduced to 15-second mean values, and $\dot{V}O_2max$ was considered as the highest value obtained in a 15-second interval. The attainment of $\dot{V}O_2max$ was defined using the criteria proposed by Lacour et al. (31). The $v\dot{V}O_2max$ was considered as the lower speed where $\dot{V}O_2max$ occurred and maintained for at least 1 minute.

Lactate thresholds were determined using the $\dot{V}O_2max$ protocol taking earlobe blood samples every 3 minutes. Blood lactate concentrations were assessed using an electrochemical analyzer (YSI 2700 STAT, Yellow Springs, OH, USA), calibrated according to the manufacturer's recommendations before each analysis.

The TCAR consists of progressive intermittent shuttle runs performed between 2 lines set at progressive distances (13). The test protocol considers a starting speed of 9 km·h^{-1} and a corresponding running base of 15 m, which is increased by 1 m every 90 seconds. Each distance stage (i.e., from 15 m to exhaustion) is composed of 5 repetitions of 12 second interspersed by a 6-second walk to be performed between 2 lines set 5 m apart from the starting line (see Figure 1). During

TABLE 4. Descriptive values of the HR (b·min^{-1}) in the velocity related to the aerobic capacity.*

	TCAR			ITT		
$n = 30$	$HR_{DP\text{-}V}$ (b·min^{-1})	$HR_{DP\text{-}M}$ (b·min^{-1})	$HR_{80.4}$ (b·min^{-1})	$HR_{+1,5}$ (b·min^{-1})	HR_{DMAX} (b·min^{-1})	$HR_{3.5}$ (b·min^{-1})
Mean	177	177	175	171	172	172
DP	10	11	11	9	12	9
%HR	91.8	91.6	90.9	88.9	89.2	89.4

*HR = heart rate; $HR_{DP\text{-}V}$ = heart rate deflection point–visual method; $HR_{DP\text{-}M}$ = heart rate deflection point–mathematical method; $HR_{80.4}$ = heart rate corresponding of fixed percentage of 80.4 of PV_{TCAR}; $HR_{+1.5}$ = heart rate corresponding of $V_{+1.5}$; HR_{DMAX} = heart rate corresponding of V_{DMAX}; $HR_{3.5}$ = heart rate corresponding to blood lactate concentration of 3.5 mmol·L^{-1}; ITT = incremental treadmill test; DP = deflection point.

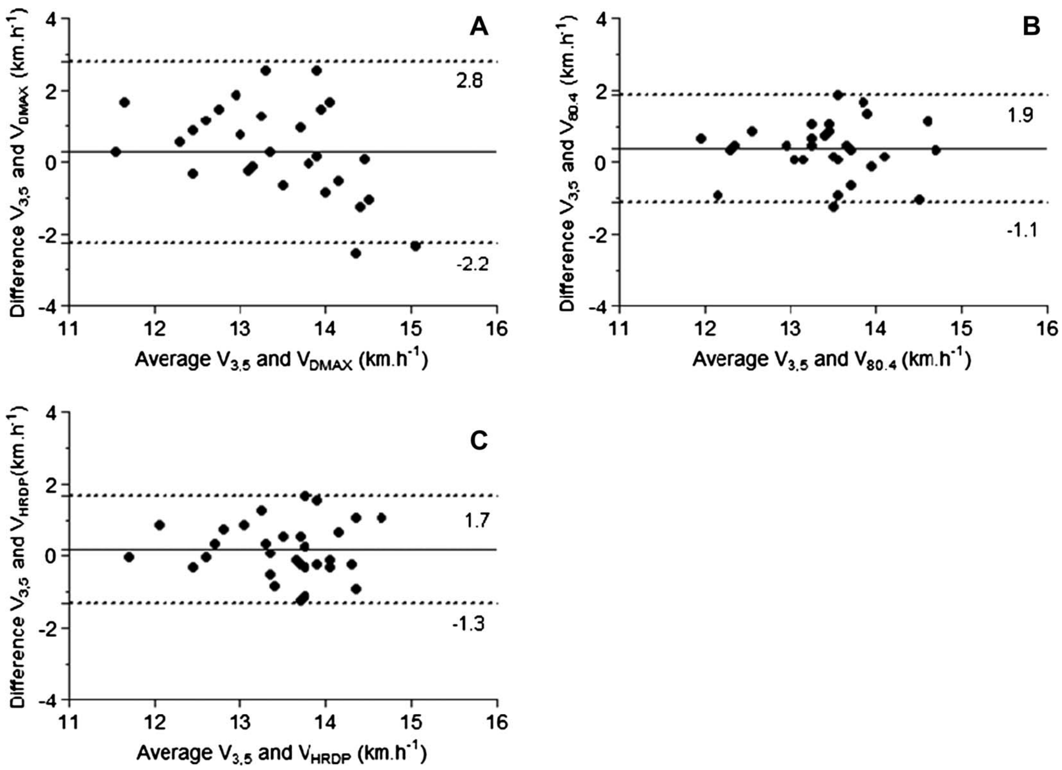

Figure 3. Analysis of Bland–Altman plot of $V_{3.5}$ with the estimated anaerobic threshold velocities obtained during Carminatti's test (TCAR; $V_{80.4}$, $V_{HRDP\text{-}V}$, $V_{HRDP\text{-}M}$).

TCAR, running pace is dictated by a constant frequency (i.e., 6 seconds) audio cue (beep) which determines the running speed to be developed in displacement between the parallel lines demarcated in the ground and marked by cones. Test result considered is the total distance covered at exhaustion. The test ends when the subject fails to step on time with the audio cues on the front line for 2 successive occasions (objective criteria) or for perceived inability on the part of the subject to cover more distance at the attained speed level (i.e., subjective criteria).

The TCAR peak speed (PV_{TCAR} [PV: peak velocity]) was determined according to Kuipers et al. (30) for those not completing the last stage. To examine the estimating potential of TCAR over physiological traits of aerobic fitness, HR was monitored throughout all the test. The TCAR HR profile was used to detect the HR deflection points (HR_{DPs}) and corresponding speeds with the Kara et al. (28) ($HR_{DP\text{-}M}$ and $V_{HRDP\text{-}M}$) and Conconi et al. (17) ($HR_{DP\text{-}V}$ and $V_{HRDP\text{-}V}$) methods. The HR deflection variables were detected by visual inspection by 3 experienced researchers. Interrater reliability was assessed with intraclass correlation coefficient. The third adopted method to estimate the AT from TCAR was the use of fixed percentage of 80.4 of PV_{TCAR} (11).

During all test procedures, HR was monitored at 5-second intervals using the Polar S610i system (Polar Electro Oy, Kempele, Finland).

Efforts were provided to control environmental conditions across the testing sessions. Specifically, field testing sessions were performed in the absence of wind and similar environmental conditions (i.e., 23–26°C, 50–60% humidity). Laboratory assessments air temperature and humidity were kept constant throughout the test duration (i.e., 23–24°C, 50–60% humidity).

Statistical Analyses

Data are presented as mean ± *SD*. Normality was assessed by visual inspection and Shapiro–Wilk test. Comparisons between physiological variables were performed with 1-way analysis of variance. Post hoc tests were performed by the Bonferroni test.

Pearson's product–moment correlations were used to examine the relationships between field and laboratory tests. Magnitude of effects was qualitatively assessed according to Hopkins (27) as follows: trivial $r < 0.1$, small $0.1 < r < 0.3$, moderate $0.3 < r < 0.5$, large $0.5 < r < 0.7$, very large $0.7 < r < 0.9$, nearly perfect $r > 0.9$ and perfect $r = 1$. Correlation effect sizes were assessed with coefficient of determination (r^2). Measurement agreement was assessed using the Bland and Altman plots with variables difference bias tested for significance against the null hypothesis (difference = 0).

Analyses were carried out using the Statistical Package for Social Sciences for Windows® (SPSS Inc. version 13.5, Chicago, IL, USA) and Graph Pad Prism® (version 4.0, San Diego, CA, USA). The level of confidence was set at 5% for all calculations a priori.

Results

PV_{TCAR} was significantly lower than the PV obtained in the laboratory test ($p < 0.05$); however, it showed no significant difference with the $v\dot{V}O_2max$ obtained on the treadmill (Table 1). The PV_{TCAR} was also significantly correlated ($r = 0.55$, $p < 0.01$) with $v\dot{V}O_2max$ (Figure 2) and $\dot{V}O_2max$ ($r = 0.51$, $p < 0.01$) and showed no significant correlation with laboratory PV ($r = 0.11$).

Table 1 presents the means and *SD* of the HRmax values and the physiological variables of aerobic power obtained during the ITT and TCAR test.

Related to the submaximal indices, no significant differences were found ($p > 0.05$) among the mean values of velocity referent to the AT, estimated in the field test and measures directly in the laboratory (Table 2). Table 2 presents the means and *SD* of the physiological variables of aerobic capacity obtained in the ITT and TCAR test.

Table 3 presents the correlation values found between the aerobic capacity indicators obtained in the ITT and TCAR test, and among the 3 methods, the $V_{3.5}$ was the index that presented best correlation with $V_{HRDP\text{-}V}$ and $V_{80.4}$.

The HR values referring to the methods used to predict the AT presented no significant difference among them (Table 4).

Figure 3 presents the HR values found in the aerobic capacity intensity obtained in the ITT and TCAR test. Figure 3 depicts the Bland–Altman plot of $V_{3.5}$ with the estimated AT velocities obtained from HR response during TCAR ($V_{80.4}$, $V_{HRDP\text{-}V}$, $V_{HRDP\text{-}M}$).

Analyzing the limits of agreement, it is possible to observe that the $V_{80.4}$ and $V_{HRDP\text{-}V}$ showed better accuracy to estimate $V_{3.5}$, than $V_{HRDP\text{-}M}$.

Discussion

The purpose of this study was to verify the validity of TCAR examining the association between the physiological indices obtained in field condition with traditional laboratory test indices of aerobic fitness. The results of this study showed the existence of significant associations and similarities between TCAR physiological variables (PV_{TCAR}, $V_{80.4}$, $V_{HRDP\text{-}V}$, $V_{HRDP\text{-}M}$) and the indices of aerobic power (i.e., $v\dot{V}O_2max$) and aerobic capacity (i.e., $V_{3.5}$) obtained in the ITT.

The $\dot{V}O_2max$ values of our players (59.88 ± 5.23 $ml\cdot kg^{-1}\cdot min^{-1}$) are in agreement with those reported in the literature (2,15,26). The maximal HR found in the ITT (193 ± 8 $b\cdot min^{-1}$) and TCAR (193 ± 9 $b\cdot min^{-1}$) showed to be very largely associated ($r = 0.76$, $p \leq 0.01$) and not significantly different ($p < 0.05$). As a result, the peak HR measured during the TCAR at exhaustion may be used to estimate HRmax. This is of practical value because HR monitor was indicated as a viable method to control and regulate training in soccer and futsal.

No significant difference was found between the PV (16.42 ± 0.94 $km\cdot h^{-1}$) obtained in the TCAR and $v\dot{V}O_2max$ (16.71 ± 1.05 $km\cdot h^{-1}$) determined on the ITT. Additionally, a significantly large correlation was found between these indices ($r = 0.55$, $p < 0.01$).

Lacour et al. (31) studying a continuous incremental field test found that PV was significantly higher ($p < 0.03$) than the $v\dot{V}O_2max$ determined on a treadmill in 32 well-trained runners. However, these 2 variables were significantly correlated ($r = 0.92$). This confirms our observations that the constant directions change during the TCAR contributed to lower PV values than those determined on the treadmill, unlike the continuous field tests.

The gradual increase in velocity assured with added distance and the pauses during the TCAR (shuttle run) allow athletes to reach PV values that correspond to $v\dot{V}O_2max$ determined in ITT (straight line). In protocols with fixed distances (SHT20, YO-YO) low PV values have been found (1,15), underestimating the maximal aerobic velocity. The reasons for such differences are probably because of the nature of the shuttle-running tests (i.e., fixed vs. progressive distance) involving a higher stress during the fixed base condition (20 m). Indeed the reiterated use of starting, speeding up, slowing down, stopping, and changing direction during the shuttle test involves broken acceleration and causes marked vertical displacement of the center of mass and lower stride efficiency (1).

The different characteristics of the protocol on field and laboratory partly explain the lower values of PV_{TCAR} in relation to PV_{ITT} (Table 1). Castagna et al. (15) also found significant difference (1.4 $km\cdot h^{-1}$, $p = 0.002$) between the PV of the Yo-Yo recovery test (level 1) and the PV determined on a treadmill test. These differences might be explained by the constant direction changes, which contribute significantly to loss of movement economy. The protocol on the treadmill has 30-second pauses among stages for blood collection, a factor that can also contribute to delay fatigue and therefore increase the values of PV.

In this study, the $V_{3.5}$, set as the standard measure to predict the AT, presented no significant difference compared to the other methods. Denadai et al. (18) verified that the $V_{3.5}$ presented no significant difference related to the MLSS, whereas Pires et al. (34) compared the $V_{3.5}$ and V_{DMAX} and found no significant difference between the methods, besides that the authors verified a significant correlation between them ($r = 0.65$; $p < 0.05$). Corroborating with this finding, in this study, the method proposed by Cheng et al. (16) presented a very large correlation with other laboratory methods (Table 4), indicating the possibility of using this method to predict the AT.

The HRDP has been proposed as an alternative, indirect and noninvasive method to identify the AT intensity in laboratory and field tests. In TCAR, the AT was identified by 3 different methods, 2 being derived from HRDP. The HRDP is located between 85 and 95% of HRmax, and the percentages increase according to the fitness level of athletes (31,32). It can be observed that our findings are consistent with those suggested in the literature, with the AT of the assessed group being 91.8% of HRmax by visual inspection and 91.6% of HRmax by the mathematical method. Although no significant differences were found for $V_{HRDP\text{-}M}$ with the laboratory measures, the high limits of agreement (-2.2 to 2.81 $km \cdot h^{-1}$), and the low correlation coefficient makes this method questionable to predict the aerobic capacity.

Interestingly $V_{3.5}$ resulted in 79.2% of the ITT, which is very close to the value (i.e., 80.4%) proposed by Carminatti (11) to predict AT with TCAR. Furthermore, in this study, the $PV_{80.4}$ presented large correlations and good agreement (Bland and Altman plot) when compared to the method derived from the blood lactate response. Few studies that compared laboratory and field methods to estimate the same parameters used this statistical agreement method (Bland and Altman). Observing the bias and the limits of agreement calculated ($\pm 1.96SD$) for the comparison of $V_{3.5}$ with the indirect methods obtained in TCAR, we found that $V_{HRDP\text{-}V}$ and $V_{80.4}$ presented narrower limits of agreement related to $V_{HRDP\text{-}M}$, showing good concordance of these indices with those obtained from the blood lactate response in the laboratory testing.

Thus, according to the previously mentioned results, it is observed that the TCAR is a viable test to estimate aerobic power and capacity. The intermittent field model, ease of application, low cost, specificity, and the capability to simultaneously evaluate several athletes make TCAR an interesting alternative for the evaluation, prescription, and control training of team-sports players. Although in this study the TCAR was assessed for validity using a homogeneous population of professional players (i.e., court and pitch footballers), the information here provided can be extended to other teams players that present aerobic fitness similar to this study players (i.e., 59.88 ± 5.23 $ml \cdot kg^{-1} \cdot min^{-1}$). It should be considered that $\dot{V}O_2max$ values equal or higher than 60 $ml \cdot kg^{-1} \cdot min^{-1}$ are currently accepted as proof of a good aerobic power for professional team-sport players (16,35,36).

The TCAR positions in the group of shuttle-running tests that have been recently successfully proposed to assess aerobic fitness in team-sports players such as the Multistage fitness test, the Yo-Yo Intermittent and recovery and endurance test (i.e., levels 1 and 2). Differently from those tests that were extensively tested for the various aspects of validity, the TCAR possess limited information in this regard. As a result, the TCAR should be further studied for direct validity and sensitivity before being fully considered as an alternative to the existing shuttle-running test for endurance. Consequently, further study in this regard is warranted.

Practical Applications

Coaches and fitness trainers can determine $\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$) and lactate threshold from laboratory tests. However, laboratory test protocols involve exercise modes (i.e., line running and cycling) that are not relevant to team sports, limiting test specificity and player's ability, and motivation (7). As a consequence, the progressive distance intermittent shuttle-running test (TCAR–Carminatti's test) was proposed with the aim to assess aerobic fitness using specific exercise modes. This study showed that TCAR present physiological indices of aerobic power (PV) and aerobic capacity ($V_{80.4}$, $V_{HRDP\text{-}V}$) that are associated with the laboratory standard measures ($v\dot{V}O_2max$ and $V_{3.5}$, respectively). This way the results obtained can be used for a reasonably accurate aerobic-fitness assessment and training prescription in team-sport players that possess a physiological background similar to this study of soccer and futsal players. Further studies examining the TCAR potential for aerobic fitness assessment in team-sport players of different fitness levels and gender are warranted. The TCAR performance reported here may be used as normative for professional futsal and soccer players in the preseason period.

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