



Determination of Aerobic Performance in Youth Soccer Players: Effect of Direct And Indirect Methods

by

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This study was conducted to correlate and compare values for variables determined in indirect tests with the values determined directly in youth soccer players. The study subjects were 27 youth soccer players (age 16.77 ± 0.75 years; body mass 63.29 ± 7.37 kg; body height 174.14 ± 8.46 cm) playing in the basic categories of a first division team at the regional level of Brazilian soccer. Each subject was evaluated with the following tests: a) a treadmill test to directly determine values of VO_{2max} and V_{amax} (Treadmill); b) an indirect Shuttle Run Test (SRT); c) an indirect Carminatti's test (TCar). VO_{2max} showed significantly different values in the Treadmill and the SRT (59.21 ± 5.88 and 50.67 ± 3.58 ml·kg⁻¹·min⁻¹, respectively). Similarly, values obtained for V_{Peak} in the treadmill test and for V_{amax} in TCar were different from values for SRT V_{Peak} (15.01 ± 1.10 , 14.92 ± 0.87 and 12.64 ± 0.62 km·h⁻¹, respectively). A correlation analysis showed a moderate relationship between values for V_{Peak} TCar and VO_{2max} determined on a treadmill ($r = 0.46$) and V_{amax} determined on a treadmill ($r = 0.54$). The analysis also showed a high correlation between values of VO_{2max} determined on the treadmill and VO_{2max} evaluated in the SRT ($r = 0.69$), as well as V_{Peak} determined in the SRT and VO_{2max} tested on the treadmill ($r = 0.71$), as well as between V_{Peak} determined in the SRT and VO_{2max} evaluated on the treadmill ($r = 0.77$). We concluded that the SRT underestimated values of VO_{2max} and V_{amax} . Additionally, V_{peak} TCar showed no difference compared to V_{amax} , although it did show a low correlation with it. In addition the SRT, even with high correlations, did not seem to be a great predictor of aerobic fitness in youth soccer players.

Key words: treadmill test, shuttle run test, Carminatti's test, maximal oxygen uptake, youth soccer.

Introduction

The complexity of soccer, especially from a physiological point of view, can be fully appreciated when one considers the main actions performed by players during a game. Di Salvo et al. (2007) reported that during a match, soccer players experienced short and intense periods of great effort characterized by periods of anaerobic metabolism; however, aerobic metabolism predominated during the recovery periods.

The value of VO_{2max} is the index most widely used for measuring aerobic fitness of soccer players, and can be determined in both laboratory and field tests. However, since soccer involves intermittent and sudden changes in a player's direction, the nature of tests used to determine VO_{2max} in the laboratory conditions can be quite different from the actions observed during actual play (Drust et al., 2007).

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For this reason, several field tests have been suggested to verify aerobic fitness of soccer players. Among the most widely used field tests, we studied those which required continuous activities such as the Shuttle Run Test (SRT) suggested by Léger and Lambert (1982), and also tests requiring intermittent exercise such as the Carminatti's test (TCar) proposed by Carminatti et al. (2004).

Reports concerning correlations between the results of the SRT and TCar tests and the results of laboratory tests, as well as the variables measured in the two types of tests (field and laboratory) are scarce and controversial (Aziz et al., 2005; Denadai et al., 2002; Silva et al., 2011; St Clair Gibson et al., 1998). Thus, we performed the present study to correlate and compare the results of variables measured in indirect and field tests (SRT and TCar) with the results of the same variables evaluated in laboratory tests in a group of youth soccer players.

Material and Methods

Subjects

This study included 27 healthy youth male soccer players (age 16.77 ± 0.75 years) who were members of a first division team playing at the regional level of Brazilian soccer. All study participants had been systematically training for at least one year. The study protocol was approved by the Ethics Committee for Research at the Catholic University Center Salesian Auxilium (protocol - 452/2012). All participants and their parents were fully informed about the study's procedures and potential risks, and they provided a signed informed consent form.

Measures

Determination of body mass and body height

Each participant's height (H) was measured using a wall stadiometer (SUNNY®) with accuracy of 0.1 cm, and body mass (BM) was determined using a digital scale (TANITA TBF - 305®) with accuracy of 0.1 kg.

Determinations of VO_{2max} and V_{amax}

Values of VO_{2max} and V_{amax} were determined using an incremental and intermittent testing protocol involving the use of a motorized treadmill (Imbramed Millenium Super ATL) maintained at a 1% incline. After a warm-up, the test was initiated at a speed of $10 \text{ km}\cdot\text{h}^{-1}$, which was increased by $1 \text{ km}\cdot\text{h}^{-1}$ every 3 min

(corresponding to one stage) until volitional exhaustion.

Values of VO_{2max} were determined using a gas analyzer (METALYSER 3B - CORTEX®) which allowed data to be collected on a breath by breath basis. Values for the final 30 s of each stage were averaged. The highest VO_2 value obtained during the last 30 s of each stage was recorded as VO_{2max} . The velocity associated with VO_{2max} (V_{amax}) was the lowest exercise intensity at which VO_{2max} was obtained. If the intensity of VO_{2max} was not sustained for at least 1 min, the intensity at the previous stage was recorded as V_{amax} (Silva et al., 2011).

Shuttle Run Test (SRT)

The actual SRT was preceded by a standardized warm-up, stretching and familiarization with the protocol. The test was conducted on a soccer field which had two cones placed 20 m apart. The player was required to run back and forth continuously in the 20 m path. The player was prompted to change running speeds by an electronic device which emitted sounds at regular intervals and recorded the player's running speed. The initial running speed of $8.5 \text{ km}\cdot\text{h}^{-1}$ was increased by $0.5 \text{ km}\cdot\text{h}^{-1}$ every minute until the player voluntarily claimed exhaustion.

The player's speed during the final stage was used to calculate peak velocity (V_{Peak}) using the following equation (Denadai et al., 2002):

$$V_{Peak} = a + (0.5 \times b)/60$$

where a = the player's velocity during the last completed stage and b = the time achieved in the last completed stage.

The result obtained from the above calculation was used in the following equation to predict a value of VO_{2max} in units of $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Léger et al., 1988):

$$VO_{2max} (\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 31.025 + 3.238X - 3.248A + 0.1536AX$$

where X = peak velocity (V_{peak}) in $\text{km}\cdot\text{h}^{-1}$ and A = age in years.

Carminatti's test (TCar)

The TCar was preceded by familiarization with the protocol, a standardized warm-up and stretching. The TCar is a maximal incremental test

of a staggered intermittent type and has multiple stages of 90 s duration. The player performs 5 repetitions of shuttle run exercises consisting of 12 s of running (variable distances) interspersed with 6 s of walking (~ 5 m). The pace is dictated by an audio signal issued at regular intervals of 6 s. The signal determines the running speed to be attained during shifts between parallel lines marked on the ground and also marked by cones. The initial test speed of 9 km·h⁻¹ (initial distance of 15 m) is increased by 0.6 km·h⁻¹ at each stage until the participant voluntarily indicates exhaustion while attempting to complete successive stages 1 m greater than the initial distance (Carminatti et al., 2004).

Procedures

All testing procedures were performed in a two-week period during which the participants attended the laboratory, the athletic track and the soccer field of Physical Education Unisalesiano Lins four different times.

At first, the players attended the laboratory, where anthropometric measurements were recorded and an intermittent progressive treadmill test to voluntary exhaustion was performed. Additionally, each participant's height, body mass, aerobic power, VO_{2max} and speed associated with VO_{2max} (V_amax) were evaluated. The second and third rounds of testing were conducted outside the laboratory on a soccer field and performed in random order. During these visits, the volunteers completed the Shuttle Run Test (SRT) and Carminatti's Test (TCar).

To avoid fatigue, the visits were scheduled with a 2 day interval between following tests. Additionally, the players were advised not to engage in strenuous physical activities or ingest alcoholic or caffeinated beverages at least 24 hours before each testing period. They were also required to get a good night's sleep and to consume a light meal at least 2 h prior to testing.

Prior to all physical tests, the participants performed a standardized warm-up and stretching which lasted ~ 10 min. The first 5 min were used for the warm-up at 50-60% of the participant's maximum heart rate (HR_{max}) as determined by the Karvonen formula (Camarda et al., 2008). The second 5 min consisted of stretching the main muscle groups to be utilized in the test.

Statistical Analysis

Data were analyzed using descriptive

statistics and results are expressed as mean ± standard deviation (SD). The normal distribution of data was tested using the Shapiro-Wilk test. Normally distributed data were analyzed as follows: a) the Student's t test was used to compare values obtained for VO_{2max} as determined directly using the treadmill test with VO_{2max} values determined indirectly with the Shuttle Run Test, b) analysis of variance (one-way ANOVA) with the Tukey's post-hoc test was used to compare peak velocities determined using the treadmill and Shuttle Run Tests (SRT) with those determined using the Caminatti's Test (TCar), c) the Pearson's product moment coefficient was used to verify possible correlations between values determined using indirect tests with those measured directly using laboratory tests. All statistical analyses were performed using SPSS Version 19 and *p*-values < 0.05 were considered statistically significant.

Results

The variables examined in this study, including their means, SD and coefficients of variation are shown in Table 1.

The results of VO_{2max} are presented in Table 1, and indicate significant differences between values obtained in the SRT and those in the treadmill test.

The values for speeds and maximal heart rate achieved in the direct and indirect tests are shown in Figures 2 and 3, respectively. There were significant differences between the values obtained from treadmill tests and those obtained from the TCar with respect to peak velocity in the SRT. There were also significant differences between the values obtained in all the tests with respect to the maximal heart rate.

Figures 4 and 5 indicate that almost all values obtained from indirect and field tests showed moderate to high correlations with values determined in laboratory conditions.

Discussion

The main objective of this study was to determine correlations between values of different variables obtained using indirect field tests specific to soccer and corresponding values obtained directly in laboratory conditions. We found differences in the values of VO_{2max} as determined directly and indirectly (SRT), as well

as lower peak velocities in the SRT compared to peak velocities in the treadmill test and TCar. We also found moderate to high correlations between values determined in the SRT and TCar, respectively, with corresponding values determined directly in the treadmill test. Reilly et al. (2000) reported that VO_{2max} was one of the

variables most often used to physiologically characterize soccer players and this variable showed values ranging between 55 and 68 $ml \cdot kg^{-1} \cdot min^{-1}$. This variation is primarily due to inherent differences in the tactical positions taken during a match (Reilly et al., 2000) and the fitness level of the player (Wells et al., 2012).

Table 1: Characteristics of study participants: mean value, standard deviation (SD) and coefficient of variation (CV in %).

	Average	SD	CV
Age (years)	16.77	0.75	4.47
Body mass (kg)	63.29	7.37	11.64
Body height (cm)	174.14	8.46	4.86
VO_{2max} Treadmill ($ml \cdot kg^{-1} \cdot min^{-1}$)	59.21	5.88	9.93
V_{amax} Treadmill ($km \cdot h^{-1}$)	15.01	1.10	7.36
VO_{2max} SRT ($ml \cdot kg^{-1} \cdot min^{-1}$)	50.67	3.58	7.08
V_{Peak} SRT ($km \cdot h^{-1}$)	12.64	0.62	4.96
V_{Peak} TCar ($km \cdot h^{-1}$)	14.92	0.87	5.83

SD = standard deviation; *CV* = coefficient of variation; *VO_{2max} Treadmill* = maximum oxygen uptake determined on a treadmill; *V_{amax} Treadmill* = velocity associated with maximal oxygen uptake; *SRT VO_{2max}* = maximum oxygen uptake determined indirectly in the Shuttle Run Test; *V_{Peak} SRT* = maximum speed achieved in the Shuttle Run Test; *V_{Peak} TCar* = maximum speed achieved in Carminatti's Test.

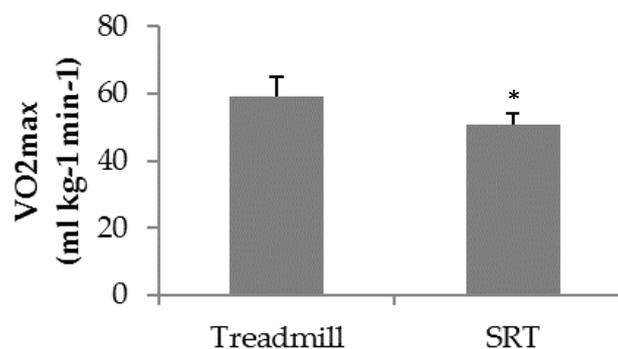


Figure 1: Maximal oxygen uptake (VO_{2max}) determined directly (Treadmill) and indirectly with the Shuttle Run Test (SRT). *Significant difference with respect to Treadmill results; $p \leq 0.05$.

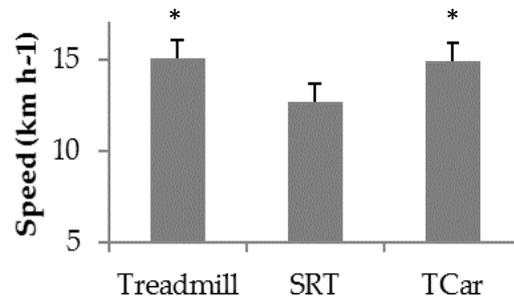


Figure 2: Maximum speeds achieved in direct tests (V_{\max}) and indirect tests (velocity peak in the Shuttle Run Test - V_{Peak} SRT and peak velocity in Carminatti's Test - V_{Peak} TCar). *Significant difference with respect to V_{peak} in the SRT; $p \leq 0.05$.

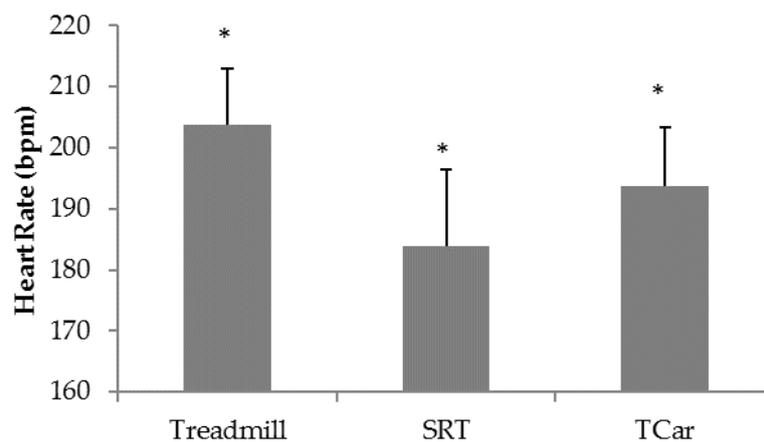


Figure 3: Maximum heart rate achieved in direct (treadmill) and indirect tests (Shuttle Run Test - SRT and Carminatti's Test - TCar). *Significant difference with respect to other tests; $p \leq 0.05$.

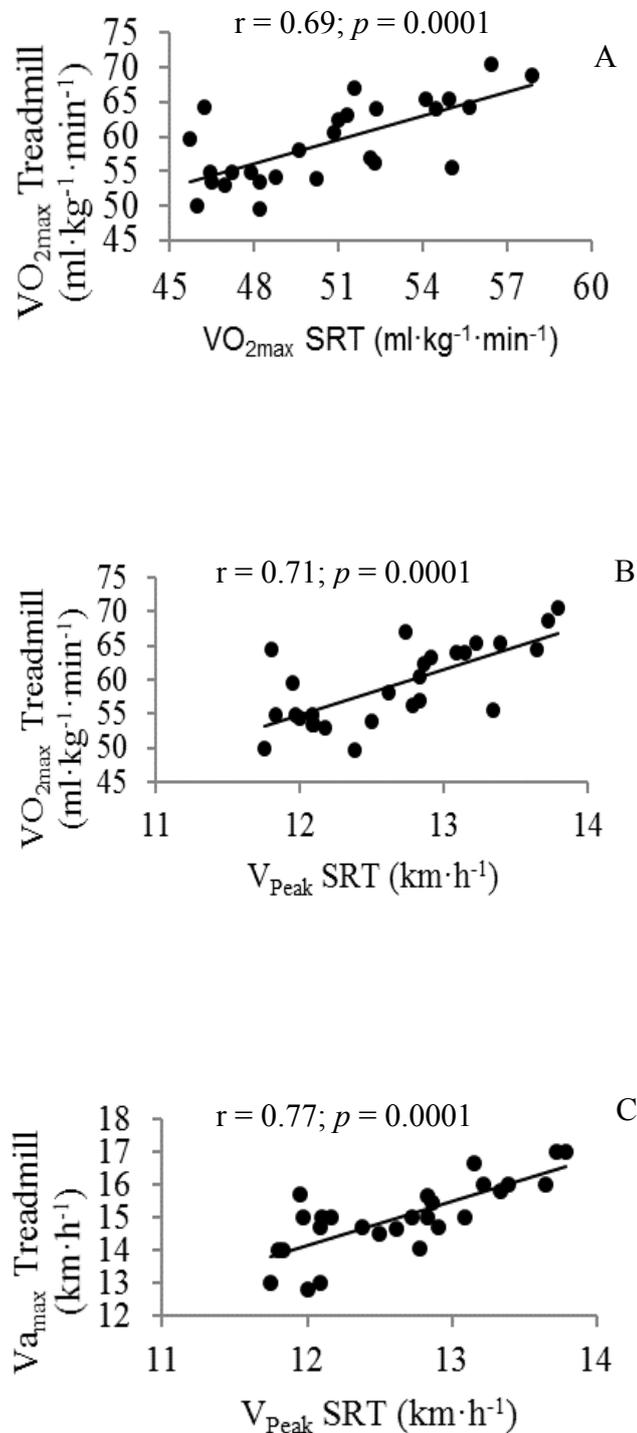


Figure 4: Correlation between maximum oxygen uptake determined directly on a treadmill (VO_{2max} Treadmill) and the value determined indirectly in the Shuttle Run Test (VO_{2max} SRT) (A). Correlation between VO_{2max} Treadmill and maximum speed in the Shuttle Run Test (V_{Peak} SRT) (B). Correlation between the velocity associated with VO_{2max} Treadmill (V_{amax} Treadmill) and V_{peak} eSRT (C); $p \leq 0.05$.

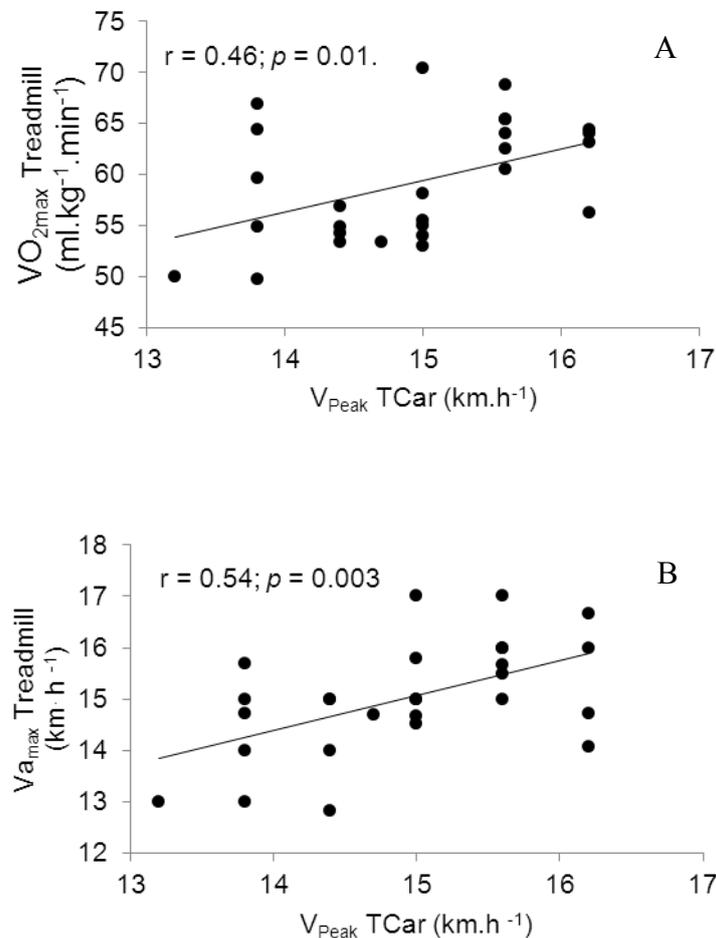


Figure 5: Correlation between maximum oxygen uptake determined directly on a treadmill (VO_{2max} Treadmill) and the maximum speed achieved in the Carminatti's Test (V_{Peak} TCar) (A). Correlation between the velocity associated with VO_{2max} Treadmill (V_{amax} Treadmill) and V_{Peak} TCar (B); $p \leq 0.05$.

The mean VO_{2max} values found in this study are in line with those previously reported in the literature. Rampinini et al. (2010) found that professional soccer players with different tactical roles had similar VO_{2max} values (mean value ~ 58.5 $ml \cdot kg^{-1} \cdot min^{-1}$). Additionally, Fornaziero et al. (2009) reported similar values for this variable in semi-professional players (59 $ml \cdot kg^{-1} \cdot min^{-1}$) and players in other basic categories of Brazilian soccer (56 $ml \cdot kg^{-1} \cdot min^{-1}$). Thus, the results of this study confirm the results of previous studies conducted with both semi-professional and well-

trained professional soccer players.

Although some studies have found no differences in values of VO_{2max} as determined in the SRT and in laboratory conditions (Aziz et al., 2005; Edwards et al., 2003), Grant et al. (1995) reported the underestimation of VO_{2max} values when determined using predictive formulas. According to Lamb and Rogers (2007), the predictive formulas developed for measuring VO_{2max} using the SRT are influenced by intrinsic factors such as the sample's size, degree of heterogeneity and other dependent variables used

in the regression model. In the current study, we used the predictive formula developed by Léger et al. (1988), which was intended for use in populations of students, healthy adults, academic practitioners and individuals practicing sports such as basketball.

Ahmaidi et al. (1992) reported that differences in VO_{2max} as determined in different tests may be related to biomechanical factors; for instance, correct body movements are more efficient regarding energy expenditure. Making more efficient movements increases the recruitment of muscle fibers by reducing the recruitment of type II fibers and increasing the recruitment of type I fibers (Mauger and Sculthorpe, 2012). The participants of the present study were much more accustomed to performing field tests specific to soccer compared to treadmill tests. Thus, the fact that they were more familiar with tests similar to the SRT may have led them to perform movements which required less energy expenditure and maximal heart rate. Furthermore, characteristics of the SRT, such as its sudden changes in speed, direction and acceleration may have led to greater voluntary anaerobic participation (Grant et al., 1995).

A previous study by Silva et al. (2011) may help explain the difference in values obtained for V_{Peak} in the SRT and when using the TCar and V_{amax} (Treadmill). Those authors evaluated soccer players similar to the participants of this study and found no significant differences between values of V_{Peak} in the TCar and V_{amax} as determined in a treadmill test. Moreover, Ahmaidi et al. (1992) and Galloti and Carminatti (2008) reported lower values for V_{Peak} in the SRT compared to V_{amax} determined on a treadmill, as well as for V_{Peak} evaluated in the TCar. Jones and Carter (2000) stated that the value of V_{Peak} in continuous tests was associated with V_{amax} as determined on a treadmill; however, the authors noted that this physiological index was influenced by anaerobic capacity, muscle strength and the neuromuscular ability to run at high speeds. Thus, it is likely that low values of VO_{2max} and V_{Peak} in the SRT are associated with a higher level of effort needed to complete an incremental test without pausing, coupled with low levels of power and anaerobic capacity; all leading to a lower level of tolerance towards exercise (Galloti and Carminatti, 2008; Grant et al., 1995).

In general, the SRT appears to be highly predictive for VO_{2max} (Lamb and Rogers, 2007). Although several studies have found a low correlation between the values of VO_{2max} determined in the SRT and those determined in laboratory tests (O'Gorman et al., 2000; St Clair Gibson et al., 1998), most studies have shown the opposite (McNaughton et al., 1998; Wilkinson et al., 1999). However, according to Drust and Svensson (2005), the estimated error introduced when determining VO_{2max} using a prediction formula may lead to inaccurate results. Similarly, V_{Peak} in the TCar correlates well with values of aerobic variables such as VO_{2max} and V_{amax} determined with a treadmill test (Silva et al., 2011). However, in the present study, the values of variables examined in the SRT and TCar showed strong and moderate correlations, respectively.

Castagna et al. (2006) suggested that a possible explanation for the low correlation between results of VO_{2max} and field tests designed for soccer was that the outcomes of field tests may be associated with factors other than aerobic power, such as the ability to accelerate, decelerate and quickly change directions. According to Pasquarelli et al. (2010), these abilities to some extent seem to be influenced by player's muscle power of the lower limbs, as training these abilities can positively influence player's acceleration capacity, which increases performance in progressive and multistage high intensity field tests such as the SRT and TCar test.

Although the values of VO_{2max} in our sample lie within normal values for young soccer players, the values of V_{amax} are below those reported in the literature (Silva et al., 2011). According to Silva et al. (2009), V_{amax} is the index that best describes the relationship between maximum aerobic power and running economy, as individuals with similar VO_{2max} values may have different V_{amax} values. This difference is explained by running economy that can be influenced by strength and anaerobic power of the athlete (Higino et al., 2011) and also has a significant effect on the outcome of our study.

Our results show that VO_{2max} determined by the formula proposed by Léger et al. (1988) underestimates values determined directly in laboratory conditions. Among the peak velocities determined in the SRT and TCar, only values of

V_{Peak} in the TCar showed no significant differences with respect to V_{max} determined on a treadmill. However, both variables determined in the SRT and TCar showed low correlations with those presented in the literature. This leads us to believe that factors other than maximum aerobic power determine the outcomes of field trials such as the SRT and TCar performed with youth soccer players.

Practical Implications

Thus, as practical implications for the use of the SRT and TCar tests, it is suggested that these tests should be used with great caution with

regard to the evaluation of aerobic fitness of youth soccer players. The fact that athletes are more

familiar with tests similar to the SRT may lead them to perform movements requiring less energy expenditure and maximal heart rate. Furthermore, characteristics of the SRT, such as sudden changes in speed, direction and acceleration, may also induce greater voluntary anaerobic participation (Grant et al., 1995), associated with a higher level of effort needed to complete an incremental test without pausing, coupled with low levels of power and anaerobic capacity; all leading to a lower level of tolerance towards exercise (Galloti and Carminatti, 2008; Grant et al., 1995).

Although the SRT and TCar tests are specific to soccer, they should not be considered good tools for assessing aerobic capacity of youth soccer players as they are influenced by factors other than cardiorespiratory fitness.

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