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Validity and reliability of a new field test (Carminatti’s test) for soccer players compared with laboratory-based measures

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Abstract
The aim of this study was to assess the validity (Study 1) and reliability (Study 2) of a novel intermittent running test (Carminatti’s test) for physiological assessment of soccer players. In Study 1, 28 players performed Carminatti’s test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti’s test twice within 72 h to determine test–retest reliability. Carminatti’s test required the participants to complete repeated bouts of 5 × 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s). The repeated sprint ability test required the participants to perform 7 × 34.2 m maximal effort sprints separated by 25 s recovery. During the intermittent treadmill test, the initial velocity of 9.0 km·h⁻¹ was increased by 1.2 km·h⁻¹ every 3 min until volitional exhaustion. No significant difference (P > 0.05) was observed between Carminatti’s test peak running velocity and speed at VO₂max (v-VO₂max). Peak running velocity in Carminatti’s test was strongly correlated with v-VO₂max (r = 0.74, P < 0.01), and highly associated with velocity at the onset of blood lactate accumulation (r = 0.63, P < 0.01). Mean sprint time was strongly associated with peak running velocity in Carminatti’s test (r = −0.71, P < 0.01). The intraclass correlation was 0.94 with a coefficient of variation of 1.4%. In conclusion, Carminatti’s test appears to be a valid and reliable measure of physical fitness and of the ability to perform intermittent high-intensity exercise in soccer players.

Keywords: Assessment, aerobic power, fitness performance, repeated sprint ability

Introduction
Physiological assessment of athletes has become common practice over the last few decades. While laboratory-based testing can provide valuable information about the physiological and performance characteristics of athletes (Billat et al., 1999; Noakes, 1988), their cost in terms of time generally excludes their use with large groups of team sport athletes. In addition, traditional laboratory test protocols often lack ecological validity and fail to replicate the specific movement patterns associated with team sport events. Indeed, these protocols do not involve any eccentric muscle actions, such as changing direction, which occurs during match-play (Currell & Jeukendrup, 2008).

To overcome some of the issues associated with laboratory testing, coaches and researchers have developed field-based test procedures that more closely replicate the intermittent nature of the sports themselves. Various tests have been proposed (Carminatti et al., 2004; Krustrup et al., 2003; Léger & Lambert, 1982), which seek to increase the degree of specificity in the assessment of physiological indices during intermittent activities. These tests aim to reproduce the movement patterns associated with team sports while also making it possible to evaluate a large number of athletes simultaneously and at low cost (Ahmaidi et al., 1992; Álvarez & Álvarez, 2003; Carminatti et al., 2004; Krustrup et al., 2003). The tests most often used for assessment of team sport athletes are the multi-stage fitness test (Léger & Lambert, 1982) and the Yo-Yo intermittent recovery test (Bangsbo, 1994). Theses tests have been used extensively to study physiological responses to intermittent exercise that involves changes
of direction, including soccer, futsal, handball, and basketball (Bangsbo, 1994; Bangsbo, Iaia, & Krustrup, 2008; Bradley et al., 2010; Castagna, Impellizzeri, Rampinini, D’Ottavio, & Manzi, 2008; Castagna, D’Ottavio, Granda-Vera, & Barbero Alvarez, 2009).

Carminatti et al. (2004) thus devised a new field-based test for use with soccer players. In contrast to previously proposed shuttle running tests, which are performed over a fixed distance (20 m) (Krustrup et al., 2003; Léger & Lambert, 1982), Carminatti’s test (the T-CAR) requires participants to perform repeated bouts of 5 × 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s).

Carminatti et al. (2004) claimed that this new test has several advantages over previous tests. The test more closely replicates the stop–start nature of a typical game and includes a range of distances (rather than a single fixed distance) associated with movements of players during competitive matchplay. In addition, the greater distances covered during the later stages of Carminatti’s test provides the athlete with more ground to accelerate over and reach higher peak running velocities compared with shorter fixed-distance protocols. However, published studies on the concurrent validity of Carminatti’s test for assessing physiological indices are currently lacking. Furthermore, there is no published information on the test–retest reliability of Carminatti’s test. This information is critical for coaches who want to use the test to monitor changes in players’ fitness and guide training prescription.

Therefore, the aims of the current study were: (a) to examine the association between physiological indices determined in an incremental intermittent laboratory test and in Carminatti’s test; (b) to investigate the association between Carminatti’s test and the performance indices obtained in a repeated sprint ability test; and (c) to determine the test–retest reliability of performance using Carminatti’s test.

Methods

Participants

The investigation consisted of two studies involving a total of 52 Brazilian junior soccer players (mean ± s: age 17.9 ± 1.0 years; stature 179.0 ± 5.5 cm; body mass 73.6 ± 6.7 kg; body fat 11.3 ± 1.4%) from two teams competing in national junior competition. Prior written informed consent was obtained from all participants and all procedures were approved by the ethics committee of the Federal University of Santa Catarina, Brazil (#384/07).

Procedures

In Study 1, 28 soccer players (age 17.9 ± 1.0 years; stature 178.6 ± 5.0 cm; body mass 73.6 ± 6.6 kg; body fat 11.1 ± 1.3%) performed (1) a novel intermittent shuttle running test (Carminatti’s test), (2) an intermittent treadmill test for the assessment of peak treadmill velocity ($V_{PITT}$), maximum oxygen consumption ($VO_{2max}$), velocity at $VO_{2max}$ ($v$-$VO_{2max}$), and velocity at the onset of blood lactate accumulation ($v$-OBLA), and (3) a repeated sprint test. All tests were performed over a 2 week period, with a minimum of 48 h between tests.

In Study 2, 24 soccer players (age 17.6 ± 1.0 years; stature 179.4 ± 5.2 cm; body mass 73.6 ± 6.9 kg; body fat 11.5 ± 1.5%) completed Carminatti’s test on two separate occasions within 72 h to determine test–retest reliability. Test conditions were controlled for all tests. Specifically, field test sessions were performed in wind-free and similar environmental conditions (temperature 23–26°C, relative humidity 50–60%). Air temperature (23–24°C) and humidity (50–60%) were kept constant throughout all laboratory assessments. All tests were performed at the same time of day (i.e. 14.00–16.00 h) to avoid the influence of circadian rhythms. To avoid undue fatigue before testing, the players were asked to refrain from heavy training in the preceding 72 h.

Anthropometric measures included body mass (kg), stature (cm), and four skinfold thicknesses (suprailiac, abdomen, triceps, subscapular) to estimate percent body fat in accordance with the guidelines of Faulkner (1968).

Intermittent treadmill test

An intermittent treadmill exercise test was performed on a motorized treadmill (Imbramed Millenium Super, Porto Alegre, Brazil). The treadmill was set at a 1% gradient and an initial velocity of 9.0 km·h$^{-1}$; treadmill velocity was then increased by 1.2 km·h$^{-1}$ every 3 min until volitional exhaustion. There was a rest interval of 30 s between stages during which a 25 µL capillary blood sample was taken from an earlobe for analysis of blood lactate concentration. The analysis of lactate was performed using an electrochemical analyser (YSI 2700 STAT, Yellow Springs, OH, USA). $v$-OBLA was considered the velocity corresponding to a blood lactate concentration of 3.5 mmol·L$^{-1}$ (Heck et al., 1985).

Peak treadmill velocity ($PV_{ITT}$) was calculated according to the procedures of Kuipers and...
colleagues (Kuipers, Verstappen, & Keizer, 1985) using the following equation:

\[
\text{peak velocity} \left( \text{km} \cdot \text{h}^{-1} \right) = v + t/180,
\]

where \( v \) is velocity of the last fully completed stage, \( t \) is time (s) completed in a partially completed stage, and 180 is the time (s) of a completed stage.

Each participant was verbally encouraged to undertake maximum effort during the incremental test. Respiratory gases were measured breath by breath during the incremental test using a pre-calibrated online metabolic system (K4b2, Cosmed, Rome, Italy), and the data were reduced to 15 s averages. The attainment of \( \dot{VO}_2\text{max} \) was defined using the criteria proposed by Lacour and colleagues (Lacour, Padilla-Magunacelaya, Chataird, Arsac, & Barthelemy, 1991). The velocity at \( \dot{VO}_2\text{max} \) was considered the lowest speed where \( \dot{VO}_2\text{max} \) occurred and was maintained for at least 1 min.

**Carminatti's test**

Carminatti's test (the T-CAR) requires participants to perform repeated bouts of 5 × 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s) (Carminatti et al., 2004). The test protocol has an initial speed of 9 km·h\(^{-1}\) over a running distance of 30 m (15 m out and back). The stage length in a single direction was increased progressively by 1 m every set. Each stage consisted of five repetitions; between repetitions the participants performed a 6 s walk between two lines set 2.5 m from the start line (see Figure 1).

During the test, 8–10 athletes were evaluated simultaneously with running pace dictated by pre-recorded audio cues (beeps) that determined the running speed to be performed between the start and finish lines. The test ended when the participant failed to keep in time with the audio cues for two successive repetitions (objective criteria), or a perceived inability on behalf of the participant to cover more distance at the attained level (subjective criteria). Peak running velocity in Carminatti’s test (PVT-CAR) was calculated from the distance of the last set completed by the athlete divided by the time to complete the stage repetition. In the case of an incomplete set, peak velocity was interpolated using the equation:

\[
\text{peak velocity} = v + \left( \frac{ns}{10} \right) \times 0.6
\]

where \( v \) is velocity of the last fully completed stage and \( ns \) is the number of repetitions completed in the partially completed stage. Heart rate was monitored at 5 s intervals throughout all the tests with a commercially available telemetry system (Polar S610; Polar Electro Oy, Kempele, Finland).

Plots of running velocity versus heart rate for Carminatti’s test were used to determine the heart rate deflection point and its corresponding speed. The heart rate deflection point was estimated in accordance with the methods of Kara and colleagues (Kara, Gökbel, & Bediz, 1996). Briefly, the heart rate–velocity relationship was fitted with a third-order polynomial curve and a linear plot was fitted between the lowest and highest heart rate from Carminatti’s test. The heart rate deflection point (HRDP) was determined as the greatest distance between the linear and the polynomial curve fit. The heart rate deflection point was used because studies in our laboratory have shown it to be a good method to predict maximal lactate steady state (unpublished data).

To determine test–retest reliability of Carminatti’s test, 24 participants performed the test on two occasions within a 72 h period. The procedure for the test was identical to that previously described.

**Repeated sprint ability test**

Before the repeated sprint ability test, each athlete performed 20 min of stretching and warm-up, followed by a 5-min rest (Abrantes, Macaé, & Sampaio, 2004). The repeated sprint ability test involved seven maximal sprints of 34.2 m. Each sprint involved changes of direction, with 25 s of recovery between sprints, and the athlete readying for a new start in accordance with the protocol of Bangsbo (1994). The duration of each sprint was measured by a photocell system (CEFISE® – Speed Test 4.0, São Paulo, Brazil) and the same equipment controlled the recovery interval, via the emission of an audio signal. The test was performed on natural grass and all participants wore soccer shoes and were familiarized with the test by performing one trial.
before the test. Performance variables calculated from the repeated sprint ability test included fastest sprint time, mean sprint time, and fatigue index (FI) over the seven sprints (Fernandes da Silva, Guglielmo, & Bishop, 2010).

**Statistical analyses**

Analyses were carried out using the SPSS for Windows (SPSS v.13.5, Chicago, IL, USA). Descriptive statistics are reported as means ± standard deviations (s). A Shapiro-Wilk test was used to verify the normality of the data. A one-way analysis of variance (ANOVA) with Tukey’s post hoc tests was used to determine any significant differences between physiological and performance variables. Pearson’s product–moment correlations were used to determine the strength of relationships between physiological and performance variables. The magnitude of effects was qualitatively assessed according to Hopkins (2008) 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 $r = 1$. Multiple stepwise regression analysis was performed to determine the strength of relationships between single and multiple variables and performance. Intraclass correlation coefficients (ICC), coefficients of variation (CV), and their 95% confidence intervals (95% CI) were estimated for the association between the two Carminatti tests in accordance with the recommendations of Hopkins (2000). Bland and Altman plots (described by Nevill & Atkinson, 1997) were used to verify the agreement of Carminatti’s test with laboratory measures, and reproducibility of peak velocity of Carminatti’s test (test and retest). Statistical significance was set at $P < 0.05$.

**Results**

A summary of the physiological and performance test results for the laboratory incremental test, Carminatti’s test, and the repeated sprint ability test is shown in Table I. There was no significant difference ($P > 0.05$) between peak running velocity in Carminatti’s test and $v$-VO$_{2\text{max}}$ measured on the treadmill. A strong correlation ($r = 0.62$, $P = 0.0004$) was between maximum heart rate established on the treadmill and peak heart rate obtained in Carminatti’s test. Figure 2B shows the Bland-Altman plot of $v$-VO$_{2\text{max}}$ on the treadmill versus peak velocity of Carminatti’s test, while Figure 2C shows the Bland-Altman plot of maximum heart rate on the treadmill versus maximum heart rate on Carminatti’s test. In addition, there were no significant differences between velocity and heart rate at the onset of blood lactate accumulation in the treadmill test, and velocity and heart rate at the estimated deflection point in Carminatti’s test.

Peak velocity in Carminatti’s test was strongly correlated with peak running velocity ($r = 0.73$, very large; $P = 0.0009$), VO$_{2\text{max}}$ ($r = 0.52$, moderate; $P = 0.004$), $v$-VO$_{2\text{max}}$ ($r = 0.74$, very large; $P = 0.0008$) (Figure 3A), and $v$-OBLA ($r = 0.65$, large; $P = 0.0003$ (Figure 3B) in the incremental exercise test. Large and very large correlations were also found between peak velocity in Carminatti’s test and the fastest sprint time ($r = -0.51$, $P = 0.005$) and mean sprint time ($r = -0.71$; $P = 0.0002$) (Figure 3C), respectively. Correlations between peak treadmill velocity and $v$-VO$_{2\text{max}}$ with mean time in the repeated sprint ability test were moderate ($r = -0.42$, $P = 0.027$; $r = -0.43$, $P = 0.021$, respectively).

Multiple regression analysis showed that a combination of VO$_{2\text{max}}$ and $v$-VO$_{2\text{max}}$ from the treadmill test and mean time from the repeated sprint ability test explained ~78% of the variance in peak running velocity in Carminatti’s test (Table II). The intraclass correlation and coefficient of variation for Carminatti’s test was 0.94 (95% CI = 0.89–0.97) and 1.4% (Figure 3D), respectively.

**Discussion**

The aim of the current study was to assess the concurrent validity and reliability of a novel field-based intermittent running test (Carminatti’s test) for use with soccer players. The main findings indicate that peak running velocity in Carminatti’s test was correlated with VO$_{2\text{max}}$ (moderate),

Table I. Physiological and performance variables determined from the treadmill, Carminatti, and repeated sprint ability tests ($n = 28$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean</th>
<th>$s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treadmill test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO$_{2\text{max}}$ (mL·kg$^{-1}$·min$^{-1}$)</td>
<td>63.0</td>
<td>5.0</td>
</tr>
<tr>
<td>$v$-OBLA (km·h$^{-1}$)</td>
<td>13.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Heart rate at OBLA (beats·min$^{-1}$)</td>
<td>174</td>
<td>8</td>
</tr>
<tr>
<td>$v$-VO$_{2\text{max}}$ (km·h$^{-1}$)</td>
<td>16.8</td>
<td>1.1</td>
</tr>
<tr>
<td>PV$_{\text{TIT}}$ (km·h$^{-1}$)</td>
<td>17.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Maximum heart rate (beats·min$^{-1}$)</td>
<td>197</td>
<td>7</td>
</tr>
<tr>
<td>Carminatti’s test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV$_{\text{T-CAR}}$ (km·h$^{-1}$)</td>
<td>16.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Peak heart rate (beats·min$^{-1}$)</td>
<td>197</td>
<td>6</td>
</tr>
<tr>
<td>$v$-HR$_{\text{DP}}$ (km·h$^{-1}$)</td>
<td>13.1</td>
<td>1.5</td>
</tr>
<tr>
<td>HR$_{\text{DP}}$ (beats·min$^{-1}$)</td>
<td>173</td>
<td>9</td>
</tr>
<tr>
<td>RSA test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean time (s)</td>
<td>6.56</td>
<td>0.23</td>
</tr>
<tr>
<td>Fastest time (s)</td>
<td>6.30</td>
<td>0.24</td>
</tr>
<tr>
<td>Fatigue index (%)</td>
<td>4.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Peak lactate concentration (mmol·L$^{-1}$)</td>
<td>15.4</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Note: HR$_{\text{DP}}$ = heart rate at deflection point.

*Significantly different to peak velocity determined in Carminatti’s test ($P \leq 0.05$).
VO2max (very large), and peak treadmill velocity (very large) obtained during a laboratory-based incremental treadmill test. Bland-Altman limits of agreement (peak velocity of Carminatti’s test and VO2max) showed that individual differences were about +8.5% (confidence interval = 95%) of the actual value (Figure 2B). Thus Carminatti’s test is a good means of individually estimating maximal aerobic velocity.

There were also strong correlations (large) between laboratory-based and field-based estimates of the OBLA exercise intensity. Furthermore, Carminatti’s test showed very good relative (i.e. intraclass correlation) and absolute (i.e. coefficient of variation) short-term test test reliability.

Peak running velocity from laboratory-based incremental tests is a good indicator of an athlete’s physical fitness and is often used to assess changes in performance due to training or other interventions (Billat et al., 1999). In this study, we found that a novel intermittent test (Carminatti’s test) provided peak running velocities that were not significantly different from those of a laboratory-based test. Therefore, Carminatti’s test may provide a more practical alternative to laboratory performance tests when a large number of athletes (as in soccer) need to be monitored for changes in performance over a competitive season. In contrast to our findings, previous authors have reported that alternative intermittent tests do not provide a good assessment of peak velocity. Castagna et al. (2008) reported a significantly lower peak velocity in the Yo-Yo recovery (level 1) test compared with a standard treadmill protocol. Similarly, Ahmaidi et al. (1992) reported significantly lower peak velocity during a 20 m shuttle run test compared with a treadmill test.

The higher peak velocity obtainable in Carminatti’s test than the other tests is probably due to a combination of two factors. First, the rest periods between each repetition contribute to a higher obtainable velocity. Second, the greater distances (~30–32 m) covered by athletes during the final test stages, compared with other tests (20 m), reduce the time spent accelerating and decelerating after each turn. The constant changes in direction over a short distance (20 m) during other tests prevent athletes from reaching high speeds. The act of starting, speeding up, slowing down, stopping, and changing direction during the shuttle run tests involves numerous decelerations and accelerations and causes marked vertical displacement of the centre.

Table II. Multiple stepwise regression analysis to predict peak velocity in Carminatti’s test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>R²</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>t VO2max</td>
<td>0.54</td>
<td>0.69</td>
</tr>
<tr>
<td>t VO2max + mean time</td>
<td>0.73</td>
<td>0.54</td>
</tr>
<tr>
<td>t VO2max + mean time + VO2max</td>
<td>0.78</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Figure 2. (A) Analysis of Bland-Altman plot of Carminatti’s test and retest. Solid line = bias (0.260); dashed lines = 95% limits of agreement (−0.961 to 0.328). (B) Analysis of Bland-Altman plot of peak velocity of Carminatti’s test and VO2max. (C) Analysis of Bland-Altman plot of HRmax treadmill test and HRmax of Carminatti’s test.
of mass and lowers stride efficiency (Ahmaidi et al., 1992). Thus the correlations between peak running velocity in Carminatti’s test with \( v_{\text{VO}_2_{\text{max}}} \) and peak treadmill velocity (reference measure) support the concurrent validity of Carminatti’s test for estimating the velocity related to maximal aerobic power (Impellizzeri & Marcora, 2009). The direct analysis (i.e. use of portable gas analysers) of the involvement of the aerobic pathway in Carminatti’s test may be more helpful for training prescription and further studies are warranted (Castagna & Barbero Alvarez, 2010). Other advantages of Carminatti’s test are that it can be performed rapidly and at low cost (no treadmill, no gas exchange equipment). Thus, at least 10 athletes can be tested within 20 min.

The peak heart rates of field tests and maximum heart rates of laboratory tests were not significantly different (Table I), and had “very large” \( r \)-values. As a result, the peak heart rates measured during Carminatti’s test at exhaustion may be used as a surrogate of maximum heart rate. Bland-Altman limits of agreement showed that individual differences were about \( \pm 5.8\% \) (confidence interval = 95\%) of the actual value (Figure 2C). Thus, Carminatti’s test is a valid means to individually estimate maximum heart rate.

This is of practical value, as heart rate monitors are commonly used as a method to control and regulate training intensity in soccer (Stølen, Chamari, Castagna, & Wisloff, 2005). Krstrup and Bangsbo (2001) found maximum heart rates in the Yo-Yo recovery level 1 corresponding to 99 \( \pm \) 1.0\% of those obtained with a treadmill protocol. Dupont et al. (2009) also found no significant differences between maximum heart rate determined in the Yo-Yo recovery level 1 and the Montreal university track test (Léger & Boucher, 1980), which were highly correlated (\( r = 0.88, P \leq 0.001 \)). These findings demonstrate that Carminatti’s test has similar validity to other popular field tests already established in the literature.

The present study found no significant difference (\( P > 0.05 \)) between \( v_{\text{OBLA}} \) obtained in the laboratory test and the velocity at the heart rate deflection point (Table I) determined in Carminatti’s test, showing that this method can also be used to evaluate the intensity of exercise associated with the onset of blood lactate accumulation. In addition, peak running velocity in Carminatti’s test showed strong association with \( v_{\text{OBLA}} \) (Figure 3C). This result was similar to that reported by Castagna and colleagues (Castagna, Impellizzeri, Chamari, Carломagno, & Rampinini, 2006), who investigated the relationship between the velocity corresponding to the ventilatory threshold and the distance covered in Yo-Yo recovery level 1. This suggests that peak running velocity in Carminatti’s test is associated with aerobic capacity, which indicates the total
amount of energy that can be obtained by the aerobic metabolism in activities of long duration.

Peak running velocity in Carminatti’s test was also correlated with mean time (very large; Figure 3B) and the fastest time (large), showing that peak running velocity in Carminatti’s test was associated with the athletes’ capacity to perform repeated runs at high intensity without reducing performance. Moderate correlations were found between both peak treadmill velocity and $v_{O2max}$ with mean time ($r = -0.42$, $P < 0.05$; $r = -0.43$, $P < 0.05$, respectively). Thus, the constant changes in direction and the pauses in the intermittent model (Carminatti’s test) reflect a greater anaerobic demand compared with the treadmill protocol. Moreover, no significant correlation was found between the fastest time and aerobic power indicators in the treadmill test. This suggests that the intermittent nature of Carminatti’s test enable the evaluation of anaerobic aspects, due to the relationship with the fastest time and mean time.

In a previous study, Aziz and colleagues (Aziz, Mukherjee, Chia, & The, 2007) found no association between the number of stages completed in the multi-stage fitness test and the variables derived from the repeated sprint ability test ($6 \times 20$ m; $20$ s recovery). These contradictory results might be related to the anaerobic protocol used in the study of Aziz et al. (2007), which was of a shorter duration. The number and length of the sprints may influence this relationship between the multi-stage fitness test and the variables derived from the repeated sprint ability test, by altering the contribution of the aerobic system (Fernandes da Silva et al., 2010). Moreover, the continuous nature of the multi-stage fitness test limits any comparison with our findings.

In the present study, multiple regression analysis showed that $78\%$ of peak running velocity in Carminatti’s test can be explained by $v_{O2max}$, mean time, and $V_{O2max}$ (Table II). Thus, it is possible that peak velocity obtained in this way allows evaluation of athletes’ physical fitness in intermittent modalities in an integrated way, by measuring simultaneously the aerobic fitness response ($V_{O2max}$, $v_{O2max}$) and repeated sprint ability (mean time, fastest time) in soccer players.

Another important finding that supports the use of Carminatti’s test was the high reproducibility of peak running velocity (ICC = 0.94, 95%CI = 0.89 – 0.97, $P < 0.01$; CV = 1.4%), as shown in Figure 3D. Thus, Carminatti’s test is more reliable than previous field based tests that had coefficients of variation of ~5%, making it better to detect the smallest worthwhile change in an athlete’s performance caused by training or other interventions (Krustrup et al., 2003). Furthermore, based on the bias and the limits of agreement ($\pm 1.96s$) for test–retest reliability of Carminatti’s test, we observed good concordance between them (Figure 2A) (Atkinson & Nevill, 1998).

In the present study, we only examined a population of well-trained soccer players. Thus although the nature of Carminatti’s test may suggest its use in other team sports, further study is warranted. Future research might address the specificity of Carminatti’s test, looking the relationship between Carminatti test variables and selected match activities in other team sports (Castagna & Barbero Alvarez, 2010).

**Conclusion**

The results of this study show that Carminatti’s test provides a reliable and valid estimate of the velocity that corresponds to maximal aerobic power and to the onset of blood lactate accumulation when used with soccer players. Carminatti’s test might also be used with other team sports such as futsal and handball, since the characteristics of these sports are similar. Consequently, further research of the applicability of Carminatti’s test to other team sports is warranted.

The test would prove useful to soccer coaches and strength and conditioning professionals who want regularly to assess changes in the intermittent high-intensity endurance of players across the competitive season. Further research examining the relationship between Carminatti’s test and soccer-match performance to evaluate test specificity is needed.

**Practical implications**

Carminatti’s test is a valid means to determine peak running velocity and to predict the $v$-OBLA in soccer players.

Based on the aerobic power and capacity indices obtained with Carminatti’s test, it is possible to prescribe exercise-mode specific (i.e. intermittent high-intensity shuttle running) training to soccer players. Specifically using these test variables, physical conditioning coaches may easily control training intensity by simply modifying the running distance according to the individual’s fitness using the same audio cues (12 s of effort; 6 s of recovery).

The high reliability of Carminatti’s test makes it suitable for monitoring training-induced performance changes in soccer players.

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