The Relationship Between Selected Blood Lactate Thresholds and Match Performance in Elite Soccer Referees

CARLO CASTAGNA,1 GRANT ABT,2 AND STEFANO D’OTTAVIO1

1Italian Soccer Federation (FIGC) and Italian Referees Association (AIA), Rome, Italy; 2St Martin’s College, Lancaster, UK.

ABSTRACT

The aim of this study was to examine the relationship between selected blood lactate thresholds and competitive match activities in elite soccer referees. Eight elite-level referees (mean age, 37.6 ± 3.4 years) were each observed during 2 Serie A matches (n = 16), and the mean of each match activity was used for analysis. Match activities were monitored using a technology similar to that reported by Ohashi and others (20). Blood lactate thresholds were assessed under field conditions during a progressive multistage protocol. Running velocities attained at selected lactate concentrations (2 and 4 mmol·L⁻¹, V2 and V4, respectively) were chosen because these are commonly used to assess endurance performance. Analyses of correlations were performed considering V2 and V4 values as independent variables and total distance, maximal velocity distance (runs performed at velocities faster than 24 km·h⁻¹) and high-intensity activity distance (runs performed at velocities faster than 18 km·h⁻¹) as dependent variables. Significance was set at *p* ≤ 0.05 for all measurements. The V2 and V4 values were 10.9 ± 1.8 km·h⁻¹ and 13.6 ± 1.4 km·h⁻¹ (10.5–15.0), respectively. Mean peak-lactate corresponded to 9.4 ± 1.6 mmol·L⁻¹. The V4 value correlated moderately with the total distance covered during the match (*r* = 0.73, *p* < 0.05). The results demonstrate the positive relationship of the running velocity attained at a blood lactate concentration of 4 mmol·L⁻¹ to the total amount of distance covered by a referee during a match.

Key Words: association football, running velocity, match analysis


Introduction

Recent studies have shown that refereeing is an intermittent exercise mode that relies heavily on oxidative metabolism for the supply of energy to working muscles (10, 19). This is supported by the finding that during friendly matches officials exercise at intensities that elicit approximately 68% of maximal oxygen uptake (VO₂max) (7). D’Ottavio and Castagna (11) reported that during first division matches elite-level Italian soccer referees attain, on average, 88% of maximal heart rate. Furthermore, during an average competitive match an elite-level referee covers about 9–11.5 km (9, 12, 19), of which 16% is performed running at speeds faster than 18 km·h⁻¹ (12). Given this involvement of oxidative metabolism in soccer refereeing, a well-developed VO₂max should prove useful in improving elite-level soccer referee’s match performance. In fact, Castagna and D’Ottavio (8) have shown that VO₂max is positively related to match physical performance in elite soccer referees. Because of this relationship, international governing bodies such as the Fédération Internationale de Football Association (FIFA) and the Union Européen de Football Association (UEFA) consider a high VO₂max as a requirement for good refereeing, probably because it allows the referee to be closer to the performing action, thereby providing the referee with an improved view (13, 17).

But endurance performance in its broadest sense is dependent on both VO₂max and the highest sustainable workrate, commonly described as the blood lactate or anaerobic threshold (21). Furthermore, the average physiological load imposed on the elite referee seems to be very close to what is usually reported for the blood lactate threshold (10, 26). In fact, Bangsbo and Lindquist (4) have shown that the oxygen uptake corresponding to a fixed blood lactate concentration of 3 mmol·L⁻¹ correlated with the total distance covered during a match involving Danish soccer players. Consequently, the blood lactate threshold may have potential as a good physiological predictor of the match physical performance of elite soccer referees.

But there is a debate whether the concept of a blood lactate or ‘anaerobic’ threshold is applicable to intermittent exercise and therefore, soccer refereeing.
Certainly, the variable intensity of play does mean that referees regularly exercise at an intensity above the lactate threshold (10), which may reduce the applicability of a threshold concept. To our knowledge, no study has examined the relationship between selected blood lactate thresholds and the match activities of elite-level soccer referees. The results of this study will be important for the development of referee-specific training programs and testing protocols.

Methods

Experimental Approach to the Problem

Previous studies have examined the effect of $\dot{V}O_{2,max}$ on match performance in elite soccer players (5, 22, 23) and elite-level soccer referees (8). In those studies the influence of players’ cardiorespiratory fitness on the physical expressions of the game were reported as correlations ($r$ values) between distances performed during the match in a series of arbitrarily defined match categories and players’ $\dot{V}O_{2,max}$. Unlike with players, the analysis of the global distance covered by soccer referees is particularly useful because referees, during the course of the match, do not experience physical contact or perform other categories of activity that are not taken into account in the distance covered (tackling, heading, kicking, getting up from the ground etc. [2, 3]). Thus, distances and times spent in match activities may be representative of the physical involvement of the referees during the match.

In the present study only official first division matches were observed because soccer match intensity is competitive-level dependent (2, 3, 14). Because of the above-mentioned rationale, the individual levels of the blood lactate threshold were plotted against distances performed during the course of the match in a series of arbitrarily defined match categories and players’ $\dot{V}O_{2,max}$. Unlike with players, the analysis of the global distance covered by soccer referees is particularly useful because referees, during the course of the match, do not experience physical contact or perform other categories of activity that are not taken into account in the distance covered (tackling, heading, kicking, getting up from the ground etc. [2, 3]). Thus, distances and times spent in match activities may be representative of the physical involvement of the referees during the match.

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Subjects

All subjects ($N = 8$) were experienced elite-level referees enrolled in the Commissione Arbitri Nazionali (CAN) and thus officiating in the Serie A and B Italian championships. The Serie A is the highest level of soccer played in Italy and also regarded by many as the best domestic soccer competition in the world.

Each referee who took part in this study had no fewer than 20 years officiating experience, of which 5 years were spent at the first-division level (Serie A and B). Three of the officials were international level referees. At the time of the study, the subjects were in good health and were following a supervised physical training program, which consisted of running drills aimed for the development of aerobic capacity and speed endurance. Training sessions took place 4 times a week, and all the referees who participated in this study adhered to the above-mentioned training program during the 12 weeks preceding the start of this experimentation. The referees were able to overcome the fitness standards set by FIFA (13) throughout the study period. Written consent from all subjects was obtained before the study, after a detailed explanation regarding the nature of the research.

Each referee was observed during 2 regular season first division matches (Serie A). The matches ($n = 16$) were analyzed during the course of the 1995–1996 and 1996–1997 competitive seasons. Mean age, height, and weight of the referees were 37.6 ± 3.4 years (31–41), 182.9 ± 4.5 cm (179–190), and 77.6 ± 7 kg (69–90). Mean subjects’ relative $\dot{V}O_{2,max}$ were 49.30 ± 8.0 ml·kg$^{-1}$·min$^{-1}$ (8).

Match Analysis

Each referee was observed during the whole match by 2 cameras (Play Controller, Phromos, Città di Castello, Italy), each attached to a tripod equipped with encoders according to the method of Ohashi et al. (20). The cameras were set approximately 10 m away from 1 of the sidelines of the football pitch. Signals of angles obtained by the encoders were sequentially converted into digital data and recorded on a floppy disk for postmatch analysis (20). From the stored data, distances covered and time spent in each of the match categories were obtained by customized software.

Analysis of match activities was carried out taking into account the following categories: (a) high-intensity run (from 18.1 km·h$^{-1}$ to 24 km·h$^{-1}$), (b) maximal speed run (speeds higher than 24 km·h$^{-1}$), (c) high-intensity activity (HIA, sum of the activities performed at speeds faster than 18.1 km·h$^{-1}$), and (d) total distance covered.

Validity and reliability of the method for measuring the distances have been reported elsewhere (10). Z-tests were performed for each of the 11 match categories considered to verify if the match sample ($n = 16$) could be considered representative of a database of 96 Serie A matches collected and previously analyzed (12).

Blood Lactate Threshold Testing Protocol

Participants ($n = 8$) were evaluated with a progressive multistage protocol conducted under field conditions. The subjects performed the test running on an athletic track marked with cones every 20 m. After a brief warm-up carried out on an individual basis, subjects ran at 8 km·h$^{-1}$ for 2 minutes. Thereafter the speed was increased every 2 minutes by 2 km·h$^{-1}$ until exhaustion. The pace was set with the help of an audio player broadcasting prerecorded beeps of an audiocassette. The beep indicated the moment when the subjects had to pass near a cone to maintain a constant speed. At the end of each stage, the subjects were stopped to allow blood sampling (30 s).
felt more motivated under field conditions than in lab conditions, thus obtaining more reliable results. Field tests were used because referees felt more motivated under field conditions than in lab conditions, thus obtaining more reliable results. Furthermore, we believed that velocities obtained under field conditions were more closely related to match situations than those usually assessed during laboratory testing.

**Validity and Reliability of the Test Protocol**

The test protocol was a modified version of the Montreal Track Test (18) with the same stage duration but faster speed increments to reduce test time. Subjects with this protocol usually become exhausted within 10–12 minutes of exercise. Validity studies performed before this research began revealed that the test results were not different from the lab results (n = 18, p > 0.05). Reliability analysis showed a 0.93 intraclass R (p < 0.01). Field tests were used because referees felt more motivated under field conditions than in lab conditions, thus obtaining more reliable results.

**Statistical Analyses**

Data are presented as means and standard deviation. Mean values for match activities were compared using analysis of variance for repeated measures. Post hoc analyses were performed using Tukey’s HSD test (24). Z-tests were performed for all match categories, comparing the sample means (16 matches) with those of a database of 96 Serie A matches previously collected. Relationships between variables were analyzed using the Pearson correlation coefficient (r). Statistical power ranged from 0.70 to 0.80 for the sample size used with the variables measured in this study. The alpha level of significance was set at 5% (p ≤ 0.05) a priori.

Correlations were performed considering total distance, maximal velocity distance and HIA as dependent variables, and V2 and V4 as independent variables. The 3 match variables were used for computations because they were considered as meaningful measures of referee’s match physical performance (10–12).

**Results**

**Z-Score Analysis**

The results showed that the mean value of all match categories could be considered as having been randomly drawn from the 96 matches previously collected and analyzed (8) (p > 0.05).

**Match Activities**

Distances covered during the match in the game-related categories are given in Table 1.

**Subjects’ Blood Lactate Threshold Values**

Mean velocities attained at 2 and 4 mmol·L⁻¹ blood lactate concentrations were 10.9 ± 1.8 km·h⁻¹ and 13.6 ± 1.4 km·h⁻¹, respectively. Mean peak-lactate corresponded to 9.4 ± 1.6 mmol·L⁻¹.

**Blood Lactate Thresholds Vs. Match Activities**

The global mobility of the referees, defined as the total distance covered during the match, was moderately correlated with V4 (r = 0.73, p < 0.05). No other relationships were found between independent and dependent variables.

**Discussion**

The results of the present study show that the running velocity attained at a blood lactate concentration of 4 mmol·L⁻¹ was positively related to the global match coverage of elite referees. This particular blood lactate threshold may be useful in the assessment of endurance fitness for elite soccer referees. Bangsbo and Lindquist (4) reported that the VO₂ max corresponding to a fixed blood lactate concentration of 3 mmol·L⁻¹ related significantly to match distance, although the

### Table 1. Distances covered during the match in game-related categories.

<table>
<thead>
<tr>
<th>Variable</th>
<th>First half (m)</th>
<th>Second half (m)</th>
<th>Whole match (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High intensity run</td>
<td>717 ± 222</td>
<td>719 ± 238</td>
<td>1436 ± 449</td>
</tr>
<tr>
<td>Maximal speed run</td>
<td>251 ± 241</td>
<td>226 ± 203</td>
<td>477 ± 141</td>
</tr>
<tr>
<td>High-intensity activity</td>
<td>969 ± 424</td>
<td>944 ± 408</td>
<td>1913 ± 821</td>
</tr>
<tr>
<td>Total distance</td>
<td>5977 ± 468</td>
<td>5606 ± 584*</td>
<td>11584 ± 1017</td>
</tr>
</tbody>
</table>

* Significantly different from the first half (p ≤ 0.05).
relationship was not as strong as that of \( \text{VO}_2\text{max} \) and match distance \( (r = 0.58 \text{ vs. } 0.64, \text{ respectively}) \).

Typically, the correlation coefficients observed between routinely measured blood lactate concentrations (such as 2 and 4 mmol\( \text{L}^{-1} \)) and endurance performance (such as distance running and cycling) are above 0.83, indicating a strong relationship (15, 16). But the relationship between \( V_4 \) and total match distance observed in the present study was 0.73. Given the findings reported by Bangsbo and Lindquist (4), this probably reflects the unique nature of refereeing compared with both soccer players and typical endurance exercise and probably places referees somewhere in between the 2 for the factors that influence their performance. Factors other than pure physiological measures (e.g., team tactics) contribute to the match physical performance of elite soccer referees, although not to the same extent as soccer players.

But the relationship between \( V_4 \) and total match distance observed in the present study is not as strong as that of \( \text{VO}_2\text{max} \) and total match distance reported by other authors (3). Castagna and D'Ottavio (8) reported a correlation coefficient of 0.87 for the relationship between \( \text{VO}_2\text{max} \) and total match distance in elite soccer referees. Furthermore, Castagna et al. (6) reported that the distance covered during a 12-minute run test correlated with the distance covered by elite referees at HIA and maximal speed \( (r = 0.51 \text{ and } r = 0.32, \text{ respectively}) \). Smaros (22) also reported a similar finding, in that \( \text{VO}_2\text{max} \) influenced the number of sprints attempted by players. Therefore, it appears that \( \text{VO}_2\text{max} \) is still a better predictor of referees match physical performance than are measures of blood lactate. Again, this highlights the unique nature of refereeing (and intermittent exercise per se) compared with typical endurance exercise because it is blood lactate measures that are more highly related to typical endurance performance than \( \text{VO}_2\text{max} \) (25).

Given the relationships between total distance covered, measures of blood lactate, and \( \text{VO}_2\text{max} \) in elite soccer referees, it is clear that the assessment of \( \text{VO}_2\text{max} \) is still the preferred test of potential match physical performance for elite soccer referees. But blood lactate measures such as \( V_4 \) may provide useful additional information regarding the fitness profile of elite soccer referees. The decision to use \( V_4 \) within a test battery is probably dependent on the availability of equipment, expertise, and time.

Although \( V_4 \) was related to the total match distance, it was not related to the distance covered at maximal velocity or HIA. Given that mean \( V_4 \) was 13.6 km\( \text{h}^{-1} \), and both maximal velocity and HIA were defined as running velocities above 18.1 km\( \text{h}^{-1} \), it is not surprising that there was no relationship between these variables. Other variables related to work capacity, that have not been considered here, could have influenced the level of activity performed at speeds faster than 18.1 km\( \text{h}^{-1} \).

**Practical Applications**

The results of the present study reveal a moderate relationship between measures of blood lactate (\( V_4 \)) and elite-level soccer referees' match physical performance. This finding supports the importance of developing the 2 components of aerobic fitness (\( \text{VO}_2\text{max} \) and blood lactate threshold/running economy, respectively) in determining both the amount of distance covered and exercise intensity during a game. But it is clear that \( \text{VO}_2\text{max} \) is more closely related to referee match physical performance and is therefore still the preferred measure of referee fitness. In light of the results of this study, good levels of running economy at 4 mmol\( \text{L}^{-1} \) blood lactate concentration might provide referees’ the opportunity to be more active and therefore closer to the performing action during the game, compared with a less well-trained counterpart. Thus, soccer referee fitness training should include training sessions aimed at improving the blood lactate threshold and running economy (together with, or independent of, \( \text{VO}_2\text{max} \)), possibly using drills that mimic the specific exercise intensity and movements the officials perform during a match (2).

**References**

12. D’Ottavio, S., and C. Castagna. Analysis of match activities


**Acknowledgments**

We are greatly indebted to Prof. Marcello Faina M.D. and his superb staff from the Institute of Sport Science of Rome for performing and collecting the physiological measurements.

Address correspondence to Prof. Carlo Castagna, casanti@tin.it.