Physiological Profile of National-Level Spanish Soccer Referees

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**ABSTRACT**

**Background:** Referees play a crucial role in soccer, although relevant key aspects of their physiological performance remain uncertain. **Research question:** To describe the physiological profile of national-level Spanish soccer referees. **Type of study:** Descriptive study. **Methods:** Twenty-two male referees (age: 26.0 ± 4.9 years; height: 1.76 ± 0.08 m; body mass: 76.3 ± 13.1 kg; body mass index: 24.4 ± 2.8 kg·m⁻²) were the participants of the study. Referees were subjected to a medical examination to determine their basal cardiovascular, haematological, pulmonary function and echocardiographical profile. Complementarily, the referees carried out an incremental maximal treadmill test and two field tests: a repeated sprint (6 x 40 m/90 s recovery) and a running test (fastest time to complete 2000 m). **Results:** The left ventricular mass index averaged 122.3 ± 23.6 g·m⁻². Mean oxygen uptake (VO₂max) averaged 48.7 ± 4.3 ml·kg·min⁻¹. Mean time during the repeated sprint test was 5.53 ± 0.21 s, while mean time to complete the endurance test was 7 min 43 s. **Conclusion:** The physiological profile of national-level Spanish soccer referees reveals moderate aerobic cardiac adaptations to training and match officiating. As match demands are relative to the standard of competition, the referees should increase their physiological parameters to be able to cope with the demands imposed by the players. **Keywords:** officials; football; physical performance; echocardiographic, fitness tests, soccer.

**INTRODUCTION**

The physiological profile of elite sportspeople has been studied in depth during the recent years, providing information about their physical fitness and response to training workloads. In the case of soccer, research has focused on the players’ profile (1-3), with less attention being paid to the physiological characteristics of those responsible for the fulfilment of the laws of the game, namely, the refereeing team.

Referees play a crucial role in modern soccer and the importance of their decisions during match-play can be critical for the final score of the match. Time-motion analysis has revealed that referees, on average, cover around 10-12 km during a match, with 4 - 18% of this match-distance covered at speeds faster than 13-15 km·h⁻¹ (4-9). Specifically, this amount of high-intensity running performed during a match appears to be the best physical performance indicator, as it has been related to the standard of competition (8-10). Mean heart rate during a 90min match averages 85% HRmax which represents an exercise intensity close to the anaerobic threshold (8,11). Altogether, these data suggest that the cardiovascular system of referees is taxed in the course of a soccer game.

The physical fitness of officials has also been reported in different studies, concluding that referees possess VO₂max values in the range of 44 - 50 ml·kg·min⁻¹ (4). From these studies it has been suggested the planning, and evaluation of the sport-specific physical preparation be directed to football referees. Furthermore, as referees are now considered professional officials in some top-class European leagues, it appears essential to carry out indepth medical examinations of their baseline parameters. To these authors’ knowledge, only Rontoyannis et al., (18) and Galanti et al., (12) have echocardiographically assessed the referees’ cardiovascular status, while this issue remains uncertain in Spanish officials. It would be expected that, as
Refereeing is considered a high-intensity intermittent exercise, referees should develop specific cardiac adaptations as an increased left ventricular mass index. Therefore the medical, morphological and functional evaluation of referees might allow establishing physical performance or talent detection criteria. Thus the aim of this study was to examine the physiological profile of national level Spanish referees.

METHODS
Subjects
Twenty-two male, national-level Spanish referees (26.2 ± 5.0 years) took part in this present study during the 2007/2008 season. All the officials had at least 5 years of experience as referees at national level and followed a habitual weekly training routine. Moreover, they were all familiar with carrying out laboratory and field physical tests, which are an annual requirement to renew their federal licenses. Informed consent was obtained from all the referees, which included a document signed by both the project’s director and each subject, according to the ethic regulations in the 2004 Declaration of Helsinki for research on human beings.

Laboratory tests
Biometric data related to height and body weight (BW) were used to calculate the body mass index (BMI) and the body surface area (BSA). Basal parameters of the cardiovascular system, such as the heart rate (HR) and the systolic (SAP) and diastolic (DAP) arterial pressure were also registered. Basal blood tests were used for biochemical and haematological checks in order to determine the hematocrit (HMC), haemoglobin (Hb), iron, ferritin and transferrin concentrations, and the transferrin’s saturation index, as well as the red blood cell concentrations. A simple and forced basic pulmonary function test (Microlab 3300, England) allowed the determination of the forced vital capacity (FVC), the maximal expiratory volume per second (MEVs) and the Tiffenau’s index or expiratory capacity per second (ECs), as basal indicators of the pulmonary system.

The echocardiographic evaluation (Toshiba Sonolayer SSH-140A, Toshiba Medical System Inc, Japan) provided data from the diastolic diameter of the left ventricle (DDLV), the systolic diameter of the left ventricle (SDLV), the interventricular septum thickness (IST), the left ventricular posterior wall thickness (LVPW), and the left atrium diameter (LAD). With these measures, it was possible to determine the left ventricular mass (LVM), the left ventricular mass index (LVMI), the asymmetrical septum index (ASI), and the left ventricle concentric hypertrophy index (LVCHI). Devereux and Reichek (13) and Devereux’s (14) formulas were applied for the calculation of the left ventricular mass (LVM).

All the subjects carried out an ergonometric test on a Jaeger treadmill (Viasys Healthcare, Germany) after a standardised warmup at 8 km·h⁻¹. The treadmill speed was set at 8 km·h⁻¹ during the first 2min of the test and increased by 2 km·h⁻¹ every minute until 14 km·h⁻¹ was reached. At this stage the subjects ran for 4 min at 14 km·h⁻¹ and 2 more minutes at the same speed at an 8 % gradient. At this point, the speed was increased 1 km·h⁻¹ per minute until reaching exhaustion. Measurements of composition and volumes of the exhaled air were carried out with a Jaeger Oxicon Pro® (Viasys Healthcare, Germany) gas analyser. The oxygen analysis was based on the differential paramagnetic principle, whereas the carbon dioxide analysis was based on the infrared absorption principle; the speed of the sampling was 100ml·s⁻¹ for both gases. The transducer volume was digital bidirectional (Triple V®) of low dead space and endurance, fulfilling the ATS (American Thoracic Society) and ECCS (European Communities Chemistry Society) regulations. The analyser was connected to a computer desktop with which all the data processing was carried out with the Software LabManager v4.52.i. The gas analyser was provided with an auto-calibration system with variations of ± 2%.
with respect to the standardized values. This gas analysis computerized system has been validated when applying diverse exercise intensities. During this test the maximum heart rate (HR\textsubscript{max}), the maximum respiratory rate (RR\textsubscript{max}), the maximum oxygen uptake (VO2\textsubscript{max}) and the heart rate found in the second ventilatory threshold (HRVT\textsubscript{2}) were recorded for further analysis. The second ventilatory threshold was calculated according to the method of Foster et al., and Lucia et al., and defined as the point where there was an abrupt increase in the ventilatory equivalent for oxygen and carbon dioxide together, with a decrease in the end-tidal pressure of carbon dioxide.

Field tests
The field tests applied to the sample of study followed the protocol established by the Federation International de Football Association (FIFA) since 2006. In the first test, the referees had to sprint 6 times over 40 m with a 90 s recovery between exercise bouts. All the sprints had to be completed in less than 6.4 s. Time was calculated with the use of photoelectric beams (Ergo Tester, Globus, Codognè, Italy) and the starting position was 0.5 m behind the first photocells’ gates. The second test required the referees to complete 2000 m in less than 8 min. Both the tests were carried on a 400 m athletic track following a standardised warm-up carried out by the referees’ fitness coach.

Data analysis
All the statistical analyses were carried out with SPSS 15.0 (SPSS, Inc., Chicago, IL) software. Normal Gaussian distribution of data was verified by the Shapiro-Wilk test and homoscedasticity by a modified Levene test. Inter-individual relationships were studied using Pearson’s correlation coefficient (r). The correlation’s coefficients were interpreted in accordance with the scale of magnitude proposed by Hopkins. All data are presented in the text as means and standard deviation. The statistical level of significance was set at $p < 0.05$.

RESULTS
Laboratory tests
Table 1 shows the anthropometric and basal cardiovascular parameters of the subjects. The blood laboratory tests allowed determining the referees’ basic haematological and biochemical parameters, such as hematocrit (41.0 ± 1.7%), haemoglobin (14.9 ± 0.6g·dl\textsuperscript{-1}), iron (87.5 ± 34.5μg·dl\textsuperscript{-1}), ferritin (85.1 ± 59.8ng·dl\textsuperscript{-1}), transferrin (276.3 ± 36.8mg·dl\textsuperscript{-1}), transferrin saturation index (32.2 ± 15.0%) and red cells (4.9 ± 0.3 x 10^6μl). Complementarily, the pulmonary function data revealed that the referees’ forced vital capacity averaged 4.5 ± 0.8l, the maximal expiratory volume per second 4.1 ± 0.7s and the Tiffenau’s index or expiratory capacity per second 92.0 ± 7.0%.

Table 1: Anthropometric and cardiovascular basal parameters of the referees

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>BW (kg)</th>
<th>BMI (kg·m\textsuperscript{-2})</th>
<th>BSA (m\textsuperscript{2})</th>
<th>HR (b·min\textsuperscript{-1})</th>
<th>SAP (mmHg)</th>
<th>DAP (mmHg)</th>
</tr>
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<tbody>
<tr>
<td>1.77 ± 0.07</td>
<td>77.1±12.6</td>
<td>24.6 ± 2.7</td>
<td>1.94±0.19</td>
<td>58.6 ± 7.3</td>
<td>115.0 ± 10.9</td>
<td>73.9 ± 9.2</td>
</tr>
</tbody>
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BW: Body Weight; BMI: Body Mass Index; BS: Body Surface Area; HR: Heart Rate; SAP: Systolic Arterial Pressure; DAP: Diastolic Arterial Pressure

Table 2 shows the echocardiographic data and the hypertrophy indexes of the sample. The maximum heart rate achieved by the referees during the incremental treadmill test was 190.0 ± 7.9 beats·min\textsuperscript{-1}, whereas the maximum respiratory rate averaged 53.0 ± 5.8 resp·min\textsuperscript{-1}. The maximum oxygen uptake during the test was 48.7 ± 4.3 ml·kg·min\textsuperscript{-1}. Heart rate at the second ventilator threshold was 175.1 ± 7.1 b·min\textsuperscript{-1} (92.7% of HR\textsubscript{max}).
Table 2: Echocardiographic parameters of the referees

<table>
<thead>
<tr>
<th>SDLV (mm)</th>
<th>DDLV (mm)</th>
<th>LVPW (mm)</th>
<th>IST (mm)</th>
<th>LVM (g)</th>
<th>LVMi (g·m⁻²)</th>
<th>ASI</th>
<th>LVCHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.8 ± 5.1</td>
<td>51.2 ± 5.2</td>
<td>9.8 ± 1.1</td>
<td>10.1 ± 1.0</td>
<td>236.8± 50.8</td>
<td>122.3± 23.6</td>
<td>1.04±0.12</td>
<td>0.19±0.03</td>
</tr>
</tbody>
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SDLV: Systolic Diameter Left Ventricle; DDLV: Diastolic Diameter Left Ventricle; LVPW: Left Ventricle Posterior Wall; IST: Interventricular Septum Thickness; LVM: Left Ventricular Mass; LVMi: Left Ventricular Mass Index; ASI: Asymmetric Septum Index; LVCHI: Left Ventricular Concentric Hypertrophy Index

Field tests
Mean time to complete each 40 m sprint was 5.53 ± 0.21 s, whereas the fastest sprint averaged 4.99 ± 0.20 s. The referees completed the 2000 m running test in 7 min 43 ± 32 s. The best score in this test was 7 min. Time to complete this test was not significantly related (r=0.30; p>0.05; n=22) to the VO₂max of the referees.

Discussion
This study has examined the physiological profile of Spanish national-level soccer referees. The anthropometric, cardiovascular, haematological, pulmonary function and echocardiographic basal parameters of these subjects lie within what has been reported for other populations of referees studied in the literature (12, 18). Specifically, the left ventricular mass index revealed small cardiac adaptations to endurance activity. The referees showed moderate aerobic and anaerobic performances on the laboratory and field tests, suggesting that the physical capacity of the national-level Spanish referees needs to be improved in order to fulfil the demands of the game imposed by the players.

Detailed match-analysis studies have revealed that the physical demands experienced by referees during competition have increased during the last few years (4,6,8,19). For instance, in order to be able to cope with the demands of the game, referees have to optimise their physical fitness. Performance in selected fitness tests has been extensively addressed in the literature. However, to these authors’ knowledge, only Rontoyannis et al., (20) and Galanti et al., (12) have carried out evaluations of the medical and morphological aspects of soccer referees.

Referees are, on average, 10 to 15 years older than elite soccer players, which implies a negative relationship between the referee’s age and physical performance (11,21,22). However, the national-level referees that participated in this study were one of the youngest ever reported in the literature (5,7,8,11,23). Top-class referees require years of experience to reach this status and can officiate at international-level until they are 45-years-old (24). For instance, the referees examined in the actual study had not yet reached their refereeing maturity. The basic anthropometric characteristics (height and body mass) of the referees were similar to that reported for elite Spanish referees (25) with a body mass index very close to the values found in the top-class referees participating in the Euro 2000 Championship finals (11). Although anthropometric characteristics are not a limiting factor, there is a trend in top-class soccer to find taller referees (6,8,26) as it could be expected that stature provides an additional physical authority to apply the laws of the game. The cardiovascular examination revealed that the basal heart rate of the referees was lower than that reported for Italian professional referees and players (12). In addition, the systolic and diastolic arterial pressure values were very similar to that reported for referees (12) and soccer players (27), lying within the population regarded as normotensive. Blood tests revealed hematocrit and haemoglobin concentrations lower than
expected for aerobically trained individuals. These parameters have not been previously reported for soccer referees and can represent a limiting factor of the oxygen transport system. For this reason, it appears important to periodically assess the haematological parameters in the course of the season to detect and prevent possible weakness in the referees’ fitness.

The pulmonary function of soccer referees had not, to the knowledge of these authors, been previously examined. In the present study, the referees showed a 12-22% higher Tiffenau’s index than that expected for “normal” individuals. This data could be due to the systematic refereeing activity and suggests that the pulmonary system did not represent a limiting factor.

The incidence of endurance and strength training in cardiac morphological adaptations is a matter of controversy in the literature (28). Aerobic endurance training leads to an increased left ventricular cavity dimension and left ventricular mass, due to the effect of consecutive prolonged workloads. On the other hand, strength training is supposed to increase left ventricular wall thickness. In this study the referees were subjected to an echocardiographic examination to assess these parameters. The referees’ left ventricular mass was very similar to that found in Italian professional referees (12). When this parameter was expressed in relation to body surface area, the values were higher than that from the Italian referees (12). However, both these data were slightly lower than that reported elsewhere for soccer players (12,27) and other sportspeople (29). Complementarily, the left ventricular concentric hypertrophy index presented a lower value than that reported for anaerobic sports athletes. Altogether, these data suggest that referees experience small cardiac aerobic endurance adaptations as a consequence of their habitual training and competitive activity.

While carrying out a complete basal medical examination, the referees performed laboratory and field tests to evaluate their fitness profile. Relative VO2\text{max} values determined in the incremental treadmill test averaged 48.7ml·kg·min\(^{-1}\). This value is similar to those reported in other studies for Brazilian (30), Italian (31) and Danish (5) referees respectively, although it was lower than that examined in English referees (32). Moreover, it has been expected that soccer players would reach a value close to 60ml·kg·min\(^{-1}\) (33), which suggests that referees must carry out specific high-intensity aerobic training in order to increase this parameter. Additionally, referees showed discrete scores on the 2000 m test. Performance in this test was low correlated to VO2\text{max} values determined in the incremental treadmill test. This low correlation supports previous observations (7) which have led to the recent suppression of continuous endurance tests from the FIFA’s battery of field tests due to their scarce validity to predict physical match performance. For instance, FIFA has developed a new high-intensity running test in which international level referees alternate running 150 m in 30 s with active recovery periods in which they walk 50 m in 35 s until 4000 m has been covered. This test has recently been used to evaluate the physical capacity of top-class referees (8,9). Complementarily, since the year 2005, FIFA has introduced a repeated sprint test in the periodical evaluation of the fitness capacity of the referees. Mean time during the 6 x 40 m test averaged 5.53 s. This value is lower than that reported for top-class international (8) and English (9) referees. The fact that the national-level referees examined in the actual study were younger would probably be beneficial for repeated sprint ability activities.

CONCLUSION
This study has examined the physiological profile of national-level Spanish soccer referees. The demands placed on these officials during competitive games require a complete medical evaluation to assess their physical status. In this sense, cardiovascular, haematological, pulmonary function and echocardiographical basal parameters integrated with laboratory and
field tests can help in developing an exhaustive physiological profile of the referee. Additionally, longitudinal tracking of these parameters, intra- and inter-seasons, can be very useful to optimise the physical performance of the referees during their entire professional career.

References