Aerobic fitness and field test performance in elite Spanish soccer referees of different ages

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Summary The major aim of this study was to examine the physical fitness of elite Spanish soccer referees in relation to their age. A secondary aim was to assess the population criterion validity of the 12 min running test (12 MRT) against aerobic-fitness laboratory tests. Participants were 45 soccer referees (age 35.5 ± 4.4 years, height 178.3 ± 5.0 cm, body mass 75.1 ± 6.6 kg, body fat 11.3 ± 2.15\%, VO\textsubscript{2max} 54.9 ± 3.9 ml kg\textsuperscript{-1} min\textsuperscript{-1}) who were enrolled in the Referees Technical Committee of the Royal Spanish Soccer Federation. They were divided into three age groups: young (Y, 27—32 years, \(n = 15\)), average (A, 33—38 years, \(n = 17\)) and old (O, 39—45 years, \(n = 13\)). No age-related effects were observed for VO\textsubscript{2max}, 12 MRT or 200 m sprint performance in either the pooled or grouped data. However, age-related performance decrements were observed for 50 m sprint performance and the ventilatory threshold (VT) running speed. Twelve MRT performance was moderately related to VO\textsubscript{2max} (\(r = 0.46, P = 0.002\)), VT (km h\textsuperscript{-1}) (\(r = 0.49, P < 0.001\)), and peak treadmill velocity (PTV) (\(r = 0.60, P < 0.001\)). The results showed that older elite-level referees may be able to limit the expected age-related performance decrements in both aerobic and anaerobic performance usually reported for sedentary people. Additionally, these results show that older referees are able to reach physical fitness levels that have been suggested to be appropriate for coping with match demands.

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Introduction

Recent studies have shown that soccer refereeing is a physically challenging exercise mainly stressing aerobic metabolism.\textsuperscript{1} During a competitive match, elite-level soccer referees can cover a mean distance of 11.5 km (range 9—14 km),\textsuperscript{2—6} attaining 85—95\% of their estimated and individual maximal heart rate.\textsuperscript{2,4—7} It has also been reported that elite-level soccer referees work at 68\% of their VO\textsubscript{2max} when officiating friendly matches. These physiological stresses imposed on the elite soccer referee are similar to that endured by mid-field soccer players.\textsuperscript{3,8} However, despite the similarities...
in general physiological demands, there are several aspects of referees’ performance that distinguish their match requirements from that of the players. For instance, officials are not directly involved with the ball and cannot be substituted during the match.

Professional soccer referees are usually older than professional soccer players. For example, the mean age of referees officiating at the Euro 2000 Championship was reported to be 40.2 ± 3.9 years compared to the mean age of the players competing in the Spanish championship: 24.5 ± 2.5 years [http://www.fifaworldcup.yahoo.com/; accessed 25th July 2002]. Further analysis of the ages of the world’s best referees who officiated the quarter-finals at the 2002 World Cup shows that the mean age was 41 ± 4 years (n = 8, [http://www.fifaworldcup.yahoo.com/; accessed 25th July 2002]). Paradoxically, these data show that elite soccer referees officiate at the highest level at an average age when most soccer players have retired from competition (i.e., >40 years). The difference in the mean age of players and referees may exist because of the time that it takes to gain the competitive match experience. Such experience is considered a fundamental prerequisite to officiate at the elite level by the refereeing governing bodies (Federation Internationale de Football Association, FIFA, and Union Europenne de Football Association, UEFA).

These data suggest that referees are selected to officiate at the highest level when they reach ages where physiological functioning is not optimal. For example, maximal oxygen uptake (VO$_{2\text{max}}$) has been reported to decrease by ∼10% per decade after the age of 25 years in healthy sedentary men. Moreover, age-related decrements have been reported in respiratory capacity and sub-maximal exercise performance. Training status seems to have a significant effect on the age-related decrements in aerobic fitness, by reducing the rate of decline in VO$_{2\text{max}}$ by ∼5% per decade. Recently, Mattern et al. reported a 3.3% decrease in sub-maximal aerobic performance per decade in well-trained subjects (cycling and triathlon). Since aerobic fitness has been shown to be related to physical performance, we suggest that this age-related decline in aerobic fitness may affect soccer referee match physical performance.

At higher competition levels of soccer, the speed of the match play is higher, which may increase the physiological/running demands of refereeing. As a consequence of the increased physical demands at the higher levels of soccer competition, there is a clear need for an appropriate fitness level of the match referees. Accordingly, the governing bodies of elite-level referees now implement regular fitness testing and supervised training sessions in an attempt to control and regulate the physiological fitness of referees. For example, both FIFA and UEFA now systematically assess the fitness level of their affiliated referees with a battery of field tests consisting of 50 and 200 m sprints and 12 min running (12 MRT) for distance. Since FIFA and UEFA have adopted these tests, many other national referees’ associations have also used this test battery as evaluation tool for fitness and physical performance. However, although the 50, 200 m and 12 MRT have been widely used by national referees’ associations around the world, only few studies have evaluated the relevance of these tests to match performance. Additionally, to our knowledge, no scientific studies have examined the criterion validity of these tests for referees.

Therefore, the first aim of this study was to investigate possible age-related difference in physiological and field tests performance in elite soccer referees of different officiating experience. Furthermore, since the 12 MRT is the most popular field test for aerobic fitness in soccer refereeing, the second aim of this study was to determine the criterion validity of 12 MRT in a group of highly competitive officials.

The research hypothesis was that physical and physiological performance would be decreased with age in elite soccer referees.

**Material**

**Subjects**

The research examined the performance and physiological responses of 45 elite referees enrolled in the Referees Technical Committee of the Royal Spanish Soccer Federation. All subjects (n = 45, see Table 1) were experienced (>10 years professional level) elite-level referees from the Spanish Soccer Referees Association (CTA). Ten of the referees who participated in this study had previously officiated international matches. All referees were in good health and had taken part in the supervised physical training program that we had implemented.

**Methods**

**Experimental design**

Prior to exercise testing each referee was required to undertake a medical examination, which
included blood screening, electro-cardiogram at rest, basal lung function tests and blood pressure measurements. In addition, all referees provided a written informed consent after they were given a detailed explanation as to the nature of the research. All tests were conducted during the pre-season of the 2001–2002 Spanish championship (in August, after 4 weeks of training). The referees were all familiar with the testing procedures undertaken in this study. Specifically, all referees undertook the field test and laboratory test protocols in the 6 months prior to the study.

The referees used in this study were eligible to officiate in the professional Spanish championships (Liga \(^1\) Division and Liga \(^2\) Division, first and second soccer division, respectively) and were members of the CTA. In Spain, only 45 referees are selected to officiate in the professional Spanish championships each year. These referees are selected on the basis of their refereeing ability and physical fitness. Furthermore, referees who are older than 45 are not eligible to be selected to officiate in these championships. Due to the rigorous selection process and to the high level of play taking place in the Liga \(^1\) and \(^2\) championships, the referees in this study were considered to be representative of elite-level soccer referees.

In order to test the likelihood of age-related variations in fitness performance, the referees were grouped into three age-group categories: young (Y, 27–32 years \(n = 15\)), average (A, 33–38 years, \(n = 17\)) and old (O, 39–45 years, \(n = 13\)).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group</th>
<th>(n = 45)</th>
<th>(n = 15)</th>
<th>(n = 17)</th>
<th>(n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td></td>
<td>35.5 ± 4.4</td>
<td>30.4 ± 1.5(^{20})</td>
<td>35.8 ± 1.2(^{10})</td>
<td>40.4 ± 2.5(^{14})</td>
</tr>
<tr>
<td>Height (cm)</td>
<td></td>
<td>178.3 ± 5.0</td>
<td>178.7 ± 5.4</td>
<td>179.4 ± 4.8</td>
<td>176.4 ± 4.5</td>
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<tr>
<td>Body Mass (kg)</td>
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<td>75.1 ± 6.6</td>
<td>73.4 ± 6.1</td>
<td>77.3 ± 6.9</td>
<td>74.3 ± 6.2</td>
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<tr>
<td>Skinfolds sum (mm)</td>
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<td>83.2 ± 20.5</td>
<td>80.8 ± 11.3</td>
<td>81 ± 14.1</td>
<td>88.9 ± 32.8</td>
</tr>
<tr>
<td>% Fat</td>
<td></td>
<td>11.3 ± 2.15</td>
<td>11.1 ± 0.56</td>
<td>11.1 ± 0.53</td>
<td>11.9 ± 0.60</td>
</tr>
</tbody>
</table>

\(^{20}\)Significantly different from Average group \(P < 0.05\); \(^{10}\)Significantly different from Young group \(P < 0.05\); \(^{14}\)significantly different from Old group \(P < 0.05\).

The Ethics Committee of the University of Zaragoza (Spain) and the CTA approved the research design.

**Laboratory testing**

Aerobic fitness tests were performed at the same time of the day (09:00–14:00h) under similar environmental conditions (temperature \(\sim 20^\circ\text{C}\); relative humidity 45–55%; barometric pressure \(\sim 720\text{mmHg}\)). All subjects refrained from performing physical activity during the 24h period before each test. Each subject performed an incremental exercise test to exhaustion on a motorised treadmill (Jaeger Laufergotest, Germany) for determination of ventilatory threshold (VT), \(^{24}\) maximal ventilation (\(\text{VE}_{\text{max}}\)) and maximal oxygen uptake (\(\text{VO}_{2\text{max}}\)). Attainment of \(\text{VO}_{2\text{max}}\) was considered when at least two of the following criteria were satisfied:

1. plateau in \(\text{VO}_2\) despite an increase in exercise intensity;
2. HR greater than 90% of the age-predicted maximal value (220-age);
3. a respiratory exchange ratio (RER) greater than 1.15.

Following a 5 min warm-up, the incremental treadmill protocol commenced at a workload of \(8\text{km}\cdot\text{h}^{-1}\) and a 1% grade. The treadmill speed
was increased by 1 km h\(^{-1}\) every minute until volitional exhaustion. The heart rate was monitored electrocardiographically and displayed simultaneously on the screen of the oscilloscope (Hellige, Servimed, Germany). Gas exchange measurements were made breath-by-breath during the test and for 3 min during the recovery (Medical Graphics-Cardiopulmonary Exercise System CPX, USA). The speed at exhaustion was assumed as peak treadmill velocity (PTV) according to Noakes.\(^{25}\)

**Anthropometrical measurements**

Standard anthropometrical variables (stature, body mass, biceps-epicondylar humerus and femur width, arm flexed and extended and calf girths, and triceps, subscapular, supraspinal, abdominal, front thigh and medial calf skinfolds) were obtained on all subjects by a trained anthropometrist, following methods suggested by the International Society for the Advancement of Kinanthropometry.\(^{26}\) Anthropometric instruments used in this study included a stadiometer, scale, small sliding calliper (Rabonne Chesterman, Silverflex, UK), anthropometric tape (GPM Siber-Hegner Maschinen, Switzerland) and skinfold calliper (Holtain LTD, Crymych, UK). Percentage of body fat was estimated according to Carter’s equation.\(^{27}\) Sum of six skinfolds was also used as index of adiposity.

**Field tests**

Field tests were performed on a tartan athletic track 5 days after the cardiorespiratory test. Each testing session was performed with well-rested (moderate exercise during the 24–48 h preceding testing, i.e., 20–30 min running at 70% of individual maximal heart rate) subjects and all test bouts were completed at the period of the day when most Spanish matches are played (16:00–18:00 h). Furthermore, the environmental conditions during testing sessions were similar to those experienced by referees during matches.

The field tests were conducted in the following order: 50, 200 m and 12 MRT. Ten minutes of active rest (walking-jogging) was provided between the 50 m and the 200 m test and 15 min of rest was allowed between the 200 m sprint and the start of the 12 MRT. The 50 and 200 m times were assessed with the aid of photo-cells (Racetime 2 Kit SF, Bolzan, Italy), whereas 12 MRT times were clocked with an electronic stopwatch (Casio HS 30 W, Tokyo, Japan). The 12 MRT consisted in covering as much as distance as possible running for 12 min on a tartan athletic-track. Only 10 referees at a time were tested and time passage feedback was provided to referees throughout the test at regular intervals (i.e., every 2 min). Distance covered was assessed making subjects remain on the athletic-track spot reached at end of the 12 min run and counting laps performed plus possible extra space (rounded to the nearest metre using a measurement wheel). Experienced and qualified fitness trainers implemented all tests on behalf of the CTA.

**Statistical analyses**

Data are presented as mean and standard deviation. The Kolmogorov—Smirnov test was applied to ensure a normal distribution of parametric data. One-way analysis of variance (ANOVA) with a Tukey HSD post hoc comparison was used to determine significant differences between the young, average and old groups of referees. The relationships between variables of interest were detected using Pearson’s correlation coefficient (\(r\)) and estimations were performed using bivariate regression equations. Significance was set for the calculations at 5% (\(P \leq 0.05\)). All calculations were performed using Statistica software package (Version 6.01 StatSoft, Tulsa, USA).

**Results**

The anthropometrical and physiological characteristics of the participants to this study are shown in Tables 1 and 2, respectively. The mean age of each of the groups was significantly different (\(P < 0.001\)). No significant group differences were observed for height, body mass, skinfolds sum and percentage of body fat (% Fat) (\(P > 0.05\)). Referees in the O group were significantly slower in the 50 m sprint compared to Y group (6.90 ± 0.31 and 6.62 ± 0.18 s, respectively, \(P < 0.001\)). No significant age effects were evident for 200 and 12 MRT performances (\(P > 0.05\)). Heart rate at VT (VT% HR\(_{max}\)) and relative PTV at VT (VT% PTV) of the Y group was significantly different from that of the O group (\(P < 0.01\)). Speed at VT was significantly higher in the A group compared to the O group (15.5 ± 9 and 14.5 ± 1.4 s, respectively, \(P < 0.001\)). Both relative and absolute \(\text{VO}_2\)\(_{max}\) was not significantly different across the age groups (\(P > 0.05\)).

Twelve MRT performance was moderately related to \(\text{VO}_2\)\(_{max}\) (\(r = 0.46, P = 0.002\), see Fig. 1), VT (km h\(^{-1}\)) (\(r = 0.49, P < 0.001\)) and PTV (\(r = 0.60, P < 0.001\), see Fig. 2). The 200 m sprint performance was significantly correlated to %PTV at VT (\(r = -0.51, P < 0.001\)). The 50 m performance was significantly related to 200 m performance (\(r = 0.79, P = 0.001\)).
Table 2  Physiological and fitness tests results of the entire group (n = 45) and Y, A and O groups

<table>
<thead>
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<tbody>
<tr>
<td>( \text{VO}_2 ) (L min(^{-1}))</td>
<td></td>
<td>4.1 ± 0.4</td>
<td>4.1 ± 0.4</td>
<td>4.2 ± 0.3</td>
<td>4.0 ± 0.4</td>
</tr>
<tr>
<td>( \text{VO}_2 ) (ml kg(^{-1}) min(^{-1}))</td>
<td></td>
<td>54.9 ± 3.9</td>
<td>55.3 ± 4.5</td>
<td>55.3 ± 3.3</td>
<td>53.8 ± 3.8</td>
</tr>
<tr>
<td>( \text{VE} ) (I min(^{-1}))</td>
<td></td>
<td>137 ± 15</td>
<td>139 ± 15</td>
<td>137 ± 17</td>
<td>134 ± 15</td>
</tr>
<tr>
<td>VT (km h(^{-1}))</td>
<td></td>
<td>15.1 ± 1.1</td>
<td>15.2 ± 1.0</td>
<td>15.5 ± 0.9(^o)</td>
<td>14.5 ± 1.4</td>
</tr>
<tr>
<td>PTV (km h(^{-1}))</td>
<td></td>
<td>17.9 ± 0.9</td>
<td>17.8 ± 1.0</td>
<td>18.2 ± 0.8</td>
<td>17.8 ± 1.0</td>
</tr>
<tr>
<td>( \text{HR} ) max (beat min(^{-1}))</td>
<td></td>
<td>182 ± 9</td>
<td>185 ± 7</td>
<td>181 ± 10</td>
<td>180 ± 9</td>
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<tr>
<td>VT (ml kg(^{-1}) min(^{-1}))</td>
<td></td>
<td>46.3 ± 3.9</td>
<td>47.3 ± 3.4</td>
<td>46.6 ± 3.1</td>
<td>44.7 ± 4.9</td>
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<tr>
<td>VT %( \text{VO}_2 ) max</td>
<td></td>
<td>84.4 ± 5.4</td>
<td>85.7 ± 5.8</td>
<td>84.3 ± 3.7</td>
<td>83.0 ± 6.7</td>
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<tr>
<td>VT% ( \text{HR} ) max</td>
<td></td>
<td>92.5 ± 3.0</td>
<td>94.1 ± 2.0(^o)</td>
<td>92.3 ± 2.5</td>
<td>91.0 ± 3.6</td>
</tr>
<tr>
<td>VT% PTV</td>
<td></td>
<td>84.29 ± 4.29</td>
<td>85.7 ± 3.7(^o)</td>
<td>85.2 ± 2.9(^o)</td>
<td>81.6 ± 5.4</td>
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<tr>
<td>50 m (s)</td>
<td></td>
<td>6.76 ± 0.25</td>
<td>6.62 ± 0.18(^o)</td>
<td>6.78 ± 0.20</td>
<td>6.90 ± 0.31</td>
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<tr>
<td>200 m (s)</td>
<td></td>
<td>28.95 ± 1.28</td>
<td>28.43 ± 1.02</td>
<td>29.02 ± 1.02</td>
<td>29.47 ± 1.60</td>
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<tr>
<td>12 MRT (m)</td>
<td></td>
<td>2984 ± 125</td>
<td>2986 ± 122</td>
<td>2978 ± 97</td>
<td>2988 ± 165</td>
</tr>
</tbody>
</table>

\(^o\)Significantly different from Older group; \( P < 0.05 \).

Discussion

The results of this study showed that there were age-related differences in selected components of physical fitness in this group of elite-level soccer referees. Specifically, both short maximal anaerobic sprinting (50 m sprint) and sub-maximal (VT) aerobic measures were significantly better in younger referees compared to their older counterparts. However, both \( \text{VO}_2 \) max and 12 MRT, the variables that have previously been shown to strongly relate to match running performance,\(^17,19\) showed no significant difference among the age groups. These findings suggest that older referees possess aerobic performances similar to those showed by their younger colleagues.

In this study, we found no age-related effects on \( \text{VO}_2 \) max. The present results are in contrast to previous research that has reported age-related decrements in \( \text{VO}_2 \) max of 5—15% per decade after the age of 25 years.\(^12\) The age-related decrement in \( \text{VO}_2 \) max has been mainly attributed to decreased cardiac output\(^12,28\) and decreased heart contractility.\(^16,29\) However, we did not observe any changes in \( \text{HR} \) max between the age groups in this study. Similarly, there were no differences in any of the anthropometrical measures between the young, average or older referees in this study. It is possible that the maintenance of appropriate body composition may have also contributed to the maintenance of aerobic fitness in the older referees.\(^14\) The small but significant correlation between body fat percentage and relative \( \text{VO}_2 \) max \((r = -0.34, P < 0.02)\) supports this suggestion. It is possible that the history of regular high-intensity training among this group of older elite-level referees may have prevented or
diminished the anticipated decline in VO$_{2\text{max}}$ that is common in a non-elite population.$^{30}$ A lower sub-maximal exercise performance was observed in the older referees compared to their younger counterparts. Specifically, the O group showed a significantly lower running velocity (km h$^{-1}$) and %PTV at VT compared to the Y group. These results are in contrast to previous research$^{13}$ that reported neither age-related declines in VO$_2$ nor increments in % of VO$_{2\text{max}}$ during sub-maximal aerobic exercise. The decline in sub-maximal exercise performance observed in older referees is in line with that which has been reported in non-professional cyclists.$^{11}$ Although the mechanisms underlying these age-related changes are not understood, it is possible that an age-related reduction in muscle power was the cause for the reduction in sub-maximal running performance. In fact, several previous studies have shown a strong relationship between neuromuscular efficiency and sub-maximal running performance in active individuals.$^{31–33}$ In support, we observed a moderate correlation between 50 m performance and VT (km h$^{-1}$) ($r = -0.41$, $P = 0.05$) and VT (ml kg$^{-1}$ min$^{-1}$) ($r = -0.55$, $P < 0.001$). Taken collectively, these results might suggest that the reduction in neuromuscular power with ageing is related to the reduced sub-maximal aerobic performance in older referees. However, caution must be taken when interpreting these suggestions as the correlation analysis does not demonstrate a cause-effect relationship.

The possible effects of the reduced sprint and sub-maximal aerobic performance on match physical performance are difficult to quantify accurately. In fact, 50 m sprint performance has been previously reported to not be significantly related to match physical performance.$^{17}$ Conversely, higher speeds at selected lactate threshold have been reported to be related to greater match coverage in elite-level soccer referees.$^{18}$ As total-match distance has been related to optimal positioning in soccer refereeing,$^{1}$ higher speed at VT could be of some benefit for older referees.$^{17,19}$ Bangsbo et al. have recently reported that older top-class referees (age 40–46 years) do not have greater difficulty in keeping up with the game when compared to their younger counterparts (age 29–34 and 35–39 years).$^{34}$ Probably, 12 MRT and VO$_{2\text{max}}$ levels similar to those found in the younger counterparts may compensate for the reported under-performance in VT.

In this study, there was a moderate relationship between the 12 MRT, VO$_{2\text{max}}$ ($r = 0.42$, $P = 0.002$) and sub-maximal (VT) aerobic fitness ($r = 0.49$, $P < 0.001$). Indeed, the correlation between the 12 MRT and VO$_{2\text{max}}$ was lower than the values reported in previous research.$^{23,35}$ It is possible that the lower correlation between these variables in this study compared to previous research (VO$_{2\text{max}}$ standard deviations $±3.9$ and $5.91$ ml kg$^{-1}$ min$^{-1}$, respectively) is that there is a greater level of homogeneity of the aerobic fitness levels of the referees in this study.$^{23}$

In agreement with previous research,$^{25,36}$ this study also demonstrated that PTV has a stronger relationship with aerobic-performance than other component of aerobic-fitness measured in this study. In fact, previous studies have shown PTV to be associated with endurance performance over a large range of distances from 1500 m through to the marathon.$^{25,36}$ The likely explanation for the higher relationship between 12 MRT and PTV found in this study is that PTV may reflect the interaction between an individual’s VO$_{2\text{max}}$, exercise economy, anaerobic capacity and muscle power and thus better characterising aerobic performance.$^{25,31–33,36}$ This test may be a useful measure for assessing changes in performance and fitness changes in elite referees. Furthermore, since the 12 MRT is usually conducted in the outdoors, performance may be affected by environment changes and therefore may not be sufficiently reliable or sensitive to small changes in performance.

The VO$_{2\text{max}}$ levels ($54.9 ± 3.9$ ml kg$^{-1}$ min$^{-1}$) of the elite Spanish soccer referees in this study are considerably higher than those previously reported for competitive level referees of other countries.$^{1}$ For example, the mean VO$_{2\text{max}}$ values of 49.30 ± 8.0 and 50.9 ± 5.7 ml kg$^{-1}$ min$^{-1}$ have been reported in elite-level Italian referees$^{19}$ and English Premier League referees,$^{7}$ respectively. Similar values were reported for Danish top-class referees with the mean VO$_{2\text{max}}$ of 46.3 ml kg$^{-1}$ min$^{-1}$ (range: 40.9–56 ml kg$^{-1}$ min$^{-1}$).$^{5}$ However, the VO$_{2\text{max}}$ levels measured in this study are approximately 16% lower than those reported by Casajus$^{37}$ for the same period of the season in Spanish elite-level soccer players ($65.5 ± 8.0$ ml kg$^{-1}$ min$^{-1}$) competing in the same League. The reasons for the higher VO$_{2\text{max}}$ levels found for this group of officials are difficult to determine. It is possible that the higher VO$_{2\text{max}}$ levels observed in this study may be due to the supervised fitness training performed throughout
the competitive year, daily lifestyle and/or genetic factors. The results of this study showed that older elite-level referees may be able to limit the expected age-related performance decrements in both aerobic and anaerobic performance usually reported for sedentary people. Additionally, they show that older referees are able to maintain physical fitness levels that have been suggested to be appropriate for coping with match demands.

Practical implications

- Training should focus on training maximal aerobic power and aerobic endurance development of elite-level referees of all ages.
- Trainers of referees should focus on control of the body mass and composition of older referees.
- Training of referees should also include activities that focus on increasing explosive-strength and running speed.

References

Fitness performance in soccer referees


