Evaluation of fatigue in semi-professional football players: association between overtraining and physical fitness

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Summary

Study aim: overtraining (OT) has a detrimental effect on sport performance, but it is not clear to what extent it influences physical fitness. The aim of this study was to examine the relationship between OT and physical fitness in football players.

Material and methods: a sample of semi-professional male football players (n = 124) performed a series of anthropometric and physical fitness measurements, and completed the 54-item OT questionnaire of the French Society of Sports Medicine.

Results: the OT score was significantly correlated with sit-and-reach test (SAR; rho = −0.20, p < 0.05), theoretical maximal velocity (v₀; rho = −0.23, p < 0.05), theoretical maximal force (F₀) of the force-velocity test (F-v test; rho = 0.25, p < 0.01) and mean power (P_mean) in W · kg⁻¹ of the Wingate anaerobic test (WAnT; rho = −0.20, p < 0.05). The comparison between OT quartiles revealed that the first quartile scored higher than the third quartile in SAR and in v₀ (p < 0.05). The fourth quartile scored higher in F₀ than the first, second and third quartiles (p < 0.05). The magnitude of these differences among groups was medium.

Conclusions: the negative correlations between OT and physical fitness and the highest scores in fitness for the first OT quartile indicate a negative effect of OT on physical fitness (anaerobic capacity, maximal velocity and flexibility) of football players. In addition, because there is very limited prior relevant research on football players’ OT, our data can be used as reference for future research.

Keywords: Football – Questionnaire – Ergometry – Physiological characteristics

Introduction

From a physiological point of view, according to Bigard [1], human body reacts to the stimulus of exercise in two ways; either it develops mechanisms of adaption or activates defensive mechanisms in the context of a state of stress. Fatigue is characterized by a reduction of the “latent capacity” (sought-after, non-specific alarm signal of Selye’s General Adaptation Syndrome) of cells, tissues and organs [2]. In addition, OT is an imbalance between training and recovery [3], which affects the substrate utilization during exercise. It has been reported that it exerts its effect as follows: during low-intensity exercise, increase in lactate accumulation, decrease of ventilatory and lactate threshold, decrease in the utilization of lipids and increase in the utilization of carbohydrates, and depletion of glycogen; during high-intensity exercise, reduction in lactate production and decrease in the utilization of carbohydrates [4].

Most of previous research on OT in football has focused on methodological aspects (e.g., [5]). Various methods have been examined with regard to their ability to monitor OT (e.g., free testosterone to cortisol ratio [5, 6], lactate and perceived exertion [7], creatine kinase activity [8] and nocturnal “basal” urinary excretion of free catecholamines [9]). Monitoring of lactate as a diagnostic tool of OT presents the disadvantage that both optimal training and overtraining cause a right shift of the lactate curve [7]. These laboratory techniques are invasive, expensive and need specialized personnel and equipment. On the contrary, a questionnaire (e.g., the 54-item OT questionnaire of the French Society of Sports Medicine [10]) is non-invasive, inexpensive and easy to administer.

Although the abovementioned studies have enhanced our understanding of OT, several aspects have not been fully examined yet and need further research. For instance, there are very limited data regarding norms of OT in football players. Such data might help coaches and fitness trainers design more effective training programs. In
addition, it is not clear to what extent OT is related with physical fitness. Therefore, the aim of this study was to investigate OT in a large sample of football players and examine the relationship between OT and physical fitness. We focused on the preparatory period of the season, because there is an increased risk for the occurrence of OT during this period, when players try to get in shape quickly [6].

Methods

Participants and procedures
In this investigation, a non-experimental, descriptive-correlation design was used to examine the association between OT and physical fitness. Testing procedures were performed during the preparatory period of the 2011–2012 season. The study protocol was performed in accordance with the ethical standards laid down in the Declaration of Helsinki in 1975 and approved by the local Institutional Review Board. Written informed consent was received from all players after verbal explanation of the experimental design and potential risks of the study. Exclusion criteria included history of any chronic medical conditions and use of any medication. Semi-professional male football players (n = 124, experience 10.8 ± 5.0 yr, training units 4.3 ± 1.4 wk⁻¹, each unit lasting 1.5 ± 0.4 h and total training volume 7.0 ± 3.2 h · wk⁻¹) performed a series of anthropometric and physical fitness measurements—sit-and-reach test (SAR), physical working capacity at a heart rate of 170 (PWC₁₇₀), force-velocity test (F-v test) and Wingate anaerobic test (WAnT) and completed the 54-item OT questionnaire of the French Society of Sports Medicine [10]. They visited our laboratory once; first, they completed the questionnaire and anthropometric and body composition data were obtained, followed by a guided 15-min warm-up (stretching exercises, steady-paced cycling, and short submaximal sprints). Then the tests were performed in the following order: SAR, PWC₁₇₀, F-v test and WAnT.

Equipment and protocols
In the OT questionnaire, the participants were asked to answer “yes” or “no” to 54 questions. The score in this test consisted of the sum of “yes” answers; the higher the score was, the higher overtraining was, and vice versa. The questionnaire was initially developed by the French Society of Sport Medicine [10] to contribute to the diagnosis of overtraining. Flore and colleagues [11] examined its reliability in a sample of 30 high-level athletes over 3-day and 7-day periods and found it acceptable (r = 0.82, p < 0.001). A modified 30-item version of this questionnaire has been constructed to be suitable for use in the child sport population [12]. In a study on football players [13], it was speculated that OT was attributed more to an excess of training rather than to inadequate nutrition.

An electronic weight scale (HD-351 Tanita, Illinois, USA) was employed for body mass measurement (to the nearest 0.1 kg), a portable stadiometer (SECA, Leicester, UK) for stature (1 mm) and a caliper (Harpenden, West Sussex, UK) for skinfolds (0.5 mm). Body mass index (BMI) was calculated as the quotient of body mass to the square of height, and body fat (BF) was estimated from the sum of 10 skinfolds (cheek, neck, chest I, triceps, subscapular, abdominal, chest II, suprailiac, thigh and calf; BF = −41.32 + 12.59 × log x, where x is the sum of 10 skinfolds) [14]. Chronological age for each participant was calculated using a table of decimals of year [15].

The SAR protocol [16] was employed for the assessment of low-back and hamstring flexibility. Participants performed it twice with a 1-min break between the two trials, and the best score was retained for subsequent analysis. Participants were asked to sit barefoot with the legs straight ahead in front of the SAR box and to move their fingertips forwards as far as possible with slow movements over the box. The box provided a 15 cm advantage to the participant, i.e., when fingertips were over the soles, the score was 15 cm. Measurements were recorded to the nearest 0.25 cm.

The PWC₁₇₀ was performed according to Eurofit guidelines in a cycle ergometer (828 Ergomedic, Varberg, Monark, Sweden) [17]. Seat height was adjusted to each participant’s satisfaction, and toe clips with straps were used to prevent the feet from slipping off the pedals. Participants were instructed before the tests that they should pedal with a steady cadence of 80 revolutions per minute, which was given by both visual (ergometer’s screen showing pedalling cadence) and audio means (metronome set at 80 beats per minute). Briefly, this test consisted by three stages, each lasting 3 min, against incremental braking force in order to elicit a heart rate between 120 and 170 beats per minute. Based on the linear relationship between heart rate and power output, PWC₁₇₀ was calculated as the power corresponding to a heart rate of 170 beats/min and expressed as W and W · kg⁻¹.

The F-v test was employed to assess short-term power output (Pₘ₅ expressed as W and W · kg⁻¹), theoretical maximal velocity (vₒ in revolutions per minute, rpm) and force (Fₒ expressed as N). This test employed various applied braking forces that elicit different pedalling velocities in order to derive Pₘ₅ [18]. The participants performed four sprints, each one lasting 7 sec, against incremental braking force (19.6, 29.4, 39.2 and 49.0 N) on a cycle ergometer (Ergomedics 874, Monark, Varberg, Sweden), interspersed by 5-min recovery periods. The WAnT was performed on the same ergometer as the F-v did. Briefly, participants were asked to pedal as quickly [6].
fast as possible for 30 s against a braking force that was determined by the product of body mass in kg multiplied by 0.075 [18]. Peak power (P_{\text{peak}}), mean power (P_{\text{mean}}) in W and W·kg^{-1}, and fatigue index (FI) were the main outcomes of this test.

**Statistical and data analysis**

Statistical analyses were performed using IBM SPSS v.21.0 (SPSS, Chicago, USA). Data were expressed as mean and standard deviation. The association between OT and physical fitness was examined using Spearman’s rank correlation coefficient (rho). The magnitude of the correlation coefficient was considered trivial for rho < 0.1, small (0.1 ≤ rho < 0.3), moderate (0.3 ≤ rho <0.5), large (0.5 ≤ rho < 0.7), very large (0.7 ≤ rho <0.9), nearly perfect (0.9 ≤ rho < 1) or perfect (rho = 1) [19]. One-way analysis of variance (ANOVA) was employed to test differences in physical fitness between quartile groups of OT. To interpret effect sizes (ES) for statistical differences in the ANOVA, we used eta squared classified as small (0.01 < η^2 ≤ 0.06), medium (0.06 < η^2 ≤ 0.14) and large (η^2 > 0.14) [19]. The level of significance was set at α = 0.05.

**Results**

The median and the interquartile range of OT were 8 and 4–13, respectively. The football players were grouped in OT quartiles: the first quartile ranged from 0 to 4, the second quartile, from 5 to 8; the third quartile, from 9 to 12; and the forth quartile, from 13 to 31. The physical fitness of the participants can be seen in Table 1. The OT score was significantly correlated with SAR (rho = −0.20, p < 0.05), v_{\text{o}} (rho = −0.23, p < 0.05), F_{\text{o}} (rho = 0.25, p < 0.01) and P_{\text{mean}} in W·kg^{-1} (rho = −0.20, p < 0.05). These correlations had low magnitude. The comparison between groups with different OT scores revealed differences in SAR, v_{\text{o}}, F_{\text{o}}, P_{\text{max}} in W, P_{\text{max}} in W·kg^{-1}, P_{\text{mean}} in W and P_{\text{mean}} in W·kg^{-1}. The first quartile scored higher than the third quartile in SAR (4.9 cm (0.2; 9.6), mean difference (lower and upper limits of 95% confidence interval) and v_{\text{o}} (14 rpm (0; 27)). The fourth quartile scored higher in F_{\text{o}} than the first (35.3 N (7.8; 66.6)), second (33.3 N (4.9; 61.7)) and third quartile (38.2 N (8.8; 66.6)). The third quartile scored lower than the fourth quartile in P_{\text{max}}.

**Table 1.** Descriptive characteristics of soccer players (n = 124) by quartiles of overtraining score

<table>
<thead>
<tr>
<th></th>
<th>1st quartile</th>
<th>2nd quartile</th>
<th>3rd quartile</th>
<th>4th quartile</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>22.1 ± 4.9</td>
<td>22.0 ± 4.4</td>
<td>20.0 ± 5.5</td>
<td>22.0 ± 5.2</td>
<td>n.s.</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.5 ± 7.3</td>
<td>74.5 ± 9.7</td>
<td>71.2 ± 11.9</td>
<td>74.8 ± 9.0</td>
<td>n.s.</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.9 ± 5.6</td>
<td>177.9 ± 8.6</td>
<td>178.1 ± 6.3</td>
<td>179.2 ± 4.9</td>
<td>n.s.</td>
</tr>
<tr>
<td>BMI (kg·m^{-2})</td>
<td>22.8 ± 1.7</td>
<td>23.5 ± 2.4</td>
<td>22.4 ± 3.1</td>
<td>23.2 ± 2.0</td>
<td>n.s.</td>
</tr>
<tr>
<td>BF (%)</td>
<td>15.8 ± 3.2</td>
<td>15.6 ± 3.7</td>
<td>17.5 ± 4.7</td>
<td>16.7 ± 2.7</td>
<td>n.s.</td>
</tr>
<tr>
<td>PWC_{170} (W)</td>
<td>207 ± 46</td>
<td>211 ± 37</td>
<td>191 ± 33</td>
<td>219 ± 55</td>
<td>n.s.</td>
</tr>
<tr>
<td>PWC_{170} (W·kg^{-1})</td>
<td>2.89 ± 0.58</td>
<td>2.90 ± 0.45</td>
<td>2.69 ± 0.36</td>
<td>2.90 ± 0.62</td>
<td>n.s.</td>
</tr>
<tr>
<td>SAR (cm)</td>
<td>26.0 ± 6.9(3)</td>
<td>24.3 ± 6.1</td>
<td>21.1 ± 7.8(1)</td>
<td>21.8 ± 6.5</td>
<td>F_{3,119} = 3.53, p &lt; 0.05, η^2 = 0.08</td>
</tr>
<tr>
<td>P_{\text{peak}} (W)</td>
<td>825 ± 106</td>
<td>831 ± 134</td>
<td>771 ± 157</td>
<td>851 ± 109</td>
<td>n.s.</td>
</tr>
<tr>
<td>P_{\text{peak}} (W·kg^{-1})</td>
<td>11.51 ± 0.89(3)</td>
<td>11.16 ± 1.24</td>
<td>10.78 ± 0.86(1)</td>
<td>11.26 ± 1.13</td>
<td>F_{3,117} = 2.61, p &lt; 0.1, η^2 = 0.06</td>
</tr>
<tr>
<td>P_{\text{mean}} (W)</td>
<td>634 ± 73</td>
<td>634 ± 88</td>
<td>576 ± 99(4)</td>
<td>641 ± 81(3)</td>
<td>F_{3,116} = 3.36, p &lt; 0.05, η^2 = 0.08</td>
</tr>
<tr>
<td>P_{\text{mean}} (W·kg^{-1})</td>
<td>8.87 ± 0.62(3)</td>
<td>8.59 ± 0.96</td>
<td>8.15 ± 0.65(1)</td>
<td>8.48 ± 1.07</td>
<td>F_{3,116} = 3.76, p &lt; 0.05, η^2 = 0.09</td>
</tr>
<tr>
<td>Fatigue index (%)</td>
<td>44.7 ± 6.0</td>
<td>42.8 ± 8.2</td>
<td>44.9 ± 7.6</td>
<td>45.0 ± 7.9</td>
<td>n.s.</td>
</tr>
<tr>
<td>V_{\text{o}} (rpm)</td>
<td>227 ± 13(3)</td>
<td>226 ± 22</td>
<td>213 ± 18(1)</td>
<td>214 ± 25</td>
<td>F_{3,114} = 4.26, p &lt; 0.01, η^2 = 0.10</td>
</tr>
<tr>
<td>F_{\text{o}} (N)</td>
<td>177.4 ± 36.3(4)</td>
<td>179.3 ± 40.2(4)</td>
<td>174.4 ± 39.2(4)</td>
<td>212.7 ± 43.1(1,2,3)</td>
<td>F_{3,114} = 5.81, p ≤ 0.001, η^2 = 0.13</td>
</tr>
<tr>
<td>P_{\text{max}} (W)</td>
<td>1021 ± 178</td>
<td>1025 ± 205</td>
<td>945 ± 210(4)</td>
<td>1152 ± 220(3)</td>
<td>F_{3,114} = 4.94, p &lt; 0.01, η^2 = 0.12</td>
</tr>
<tr>
<td>P_{\text{max}} (W·kg^{-1})</td>
<td>14.26 ± 2.13</td>
<td>13.83 ± 2.61</td>
<td>13.30 ± 2.17(4)</td>
<td>15.47 ± 2.63(3)</td>
<td>F_{3,114} = 4.12, p &lt; 0.01, η^2 = 0.10</td>
</tr>
</tbody>
</table>

Data are mean ±SD. BMI = body mass index, BF = body fat, PWC_{170} = physical working capacity in 170 bpm, SAR = sit-and-reach test, P_{\text{peak}} = peak power, P_{\text{mean}} = mean power, P_{\text{max}} = maximal power, V_{\text{o}} = theoretical maximal velocity, F_{\text{o}} = theoretical maximal force. The exponents in brackets next to SD denote significant differences among overtraining quartiles according to Bonferroni post-hoc test.
The main findings of this study were that OT is inversely related with back and hamstring flexibility and with anaerobic capacity. Moreover, it was related with an altered force-velocity profile (i.e., positive correlation with force and negative correlation with velocity). These findings were in agreement with the comparison between groups differing for OT, where we observed the best physical fitness scores in the first OT quartile (i.e., the one with the lowest OT score).

These findings have practical implications for football performance, because previous research has indicated that the scores in the WAnT and in the F-v test might be predictive of one’s athletic performance. For instance, the indices of the F-v test have been shown to relate with indices of football performance [20–22]. The main indices of the WAnT (P\textsubscript{peak} and P\textsubscript{mean}) have also been suggested to correlate with sprint performance, especially when they are expressed in W · kg\textsuperscript{-1} [23]. In addition, both F-v test and WAnT discriminate between football players according to their age and level [24, 25].

The main drawback of this study was that its cross-sectional study design did not allow for monitoring the effect of the temporal changes of OT level on physical fitness. A longitudinal design might help to verify our findings by examining whether changes in OT account for the variance in changes in physical fitness. An unresolved issue remains: to examine the physical fitness of a football player after having modified his or her OT score (e.g., changing from 10 to 3, does fitness improve? and conversely, changing from 3 to 10, does fitness decrease?). Despite these limitations, this study is the first, to best of our knowledge, to examine the relationship between OT and physical fitness in a large sample of football players.

Conclusions

The negative correlations between OT and physical fitness and the highest scores in fitness for the first OT quartile indicate a negative effect of OT on the physical fitness (anaerobic capacity, maximal velocity and flexibility) of football players. In addition, because there is very limited prior relevant research on football players’ OT, our data can be used as reference for future research.

References

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