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PHYSIOLOGICAL CHARACTERISTICS OF GREEK SOCCER REFEREES OF PROFESSIONAL AND AMATEUR CATEGORIES

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Abstract:
Aim: The aim of this study was to examine the physiological characteristics of Greek soccer referees in professional and amateur categories. **Material and methods:** Twenty Greek soccer referees (10 amateur, 10 professional level) underwent laboratory evaluation to determine anthropometrical characteristics, cardiorespiratory endurance parameters, anaerobic alactic power, maximal power for the knee extensors and flexors, leg explosive power and optical stimulus reaction time. **Results:** Mean values of body weight (78,22 ± 6.87 v 90,5 ± 15,66), relative lower limb power (10,3 ± 0,85 v 9,47 ± 1), peak oxygen intake (54,96 ± 4,88 v 45,79 ± 4,58), speed of peak oxygen intake (16,54 ± 0,88 v 14,06 ± 1,55), speed of anaerobic threshold (12,4 ± 0,81 v 10,6 ± 1,13), maximum power of right leg knee extensors (356,2 ± 62,7 v 421,3 ± 84,4) and left leg knee flexors were different (276,8 ± 39,48 v 308,1 ± 37,51) ($p < 0.05$) between professional and amateur referees. No significant differences ($p > 0.05$) were observed for mean age (31,4 ± 3,66 26,7 ± 6,11), height (179,8 ± 4,96 v 181,00 ± 4,50), % fat (17,51 ± 2,36 v 20,39 ± 5,4), flexibility (18,6 ± 5,82 v 13,4 ± 9,96), anaerobic alactic power (804,8 ± 93,4 v 846 ± 97,8), maximal leg frequency (181,3 ± 20,65 v 180,7 ± 11,59), leg explosive force (31,4 ± 4,33 v 30,48 ± 2,68), reaction time (0,24 ± 0,03 v 0,24 ± 0,03), maximum heart rate (184,4 ± 11,44 v 188,2 ± 10,11) maximal blood lactate concentration (9,62 ± 2,71 v 9,47 ± 2,65) maximum left leg knee extending power (369,3 ± 74,34 v 422,7 ± 97,24) as well as right leg flexors (274,9 ± 26,13 v 298,1 ± 51) and the relative power of left and right lower limb extensors and flexors(4,55 ± 0,70 v 4,66 ± 0,63), (4,73 ± 0,84 v 4,67 ± 0,77), (3,52 ± 0,29 v 3,32 ± 0,48), (3,55 ± 0,49 v 3,47 ± 0,53) respectively. **Conclusions:** Professional-level referees compared to referees who manage games in amateur categories, mainly present increased cardiorespiratory endurance

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parameters. This difference can be attributed to the long-term systematic preparation and their frequent periodic fitness level examinations by the federation with fitness tests that are also a criterion of failure from this level of refereeing.

Keywords: soccer referees, physiological characteristics, cardiorespiratory parameters

1. Introduction

Soccer as a popular sport with millions of registered members, is one of the world's largest sports show industry (7). The attempt to acquire and possess the ball should fulfil the requirements of the rules of the game and the referee is responsible for their compliance (6). The increasing physical fitness demands of soccer matches have also increased the fitness level requirements of referees who need to adapt, in order to be able to perform successfully (1), (2). A typical example is that in 1993 the average distance covered by a referee in a football match was 9438 ± 707 m, while 8 years later distances of 11376 ± 1600 m were recorded (8).

The distance is a factor directly dependent on the level of the match (1). A research by Harley and colleagues (2002) indicated that local-level referees in England (n = 14) covered distances of 7496 ± 1122 m range between 5760 and 8979 m). D'Ottavio and Castagna (2001) reported longer distances (11469 ± 983 m) having analyzed 96 football matches in Italy's 1st division. However, the range (7818 to 14156 m) of the distances covered is significantly different.

The greater the ability of a referee to maintain a higher mean speed during the first and second part of the game, the more capable it is to follow the pace of the game (4). Published studies using laboratory-based of field-testing physical performance values to compare with corresponding soccer match data, and explore the contribution of selected cardiorespiratory and anaerobic power/capacity parameters to the referee's match performance. Castagna and D'Ottavio (2001) in a total of 16 matches reported a significant correlation between the relative value of VO_2max and the total distance travelled and the intensity of the effort. The higher value of VO_2max allows the referees to be more active and close to the points of action and this shows the importance of VO_2max.

The purpose of this study was to investigate the physiological characteristics of Greek football referees of the 1st - 2nd national and local categories.

2. Material and Methods

2.1 Participants

Twenty Greek male soccer referees volunteered to participate in this study (mean ±sd: age ± years, height ± cm, body mass ± kg) recruited to participate in this study. Participants were categorized according to the competitive level, 1st- 2nd National Division, professionals (n=10) and local categories amateurs (n=10). They were informed of the purpose, benefits and risks of the study and gave their written consent to serve as subjects. Study design was also accepted by the local ethical committee. A buttery of tests included a) anthropometrical characteristics: body mass, height, % fat-skinfold, b) strength and power of lower limbs: explosive strength of lower limb (vertical jump), leg knee flexors and extensors maximal power, maximal alactic leg power (Wingate test) and maximal leg frequency, c) cardiorespiratory parameters: peak oxygen consumption (peakVO_2), running speed at VO_2 max, (vVO_2max), running speed at ventilatory threshold (vVT), HRmax (bpm), post-test maximal blood lactate concentration (mmol/l), and d) flexibility.

2.2 Measurements

Referees were informed to visit the laboratory after at least 48 hours of abstinence from alcohol, caffeine, smoking and intense exercise. Verbal encouragement was given throughout testing trials.

2.2.1 Anthropometrical characteristics

Body mass (kg) was measured to the nearest 0.01 kg (Seca 770 UK), height (cm) was measured to the nearest 0.1cm using a stadiometer (Seca Leicester, U.K.). Skinfolds thicknesses were measured at the biceps, triceps, subscapular, and suprailiac sites, using Harpenden skinfold caliper (UK). The Durnin and Womersley (1974) equation used to estimate % body fat (11).

2.2.2 Flexibility

The hamstring flexibility was tested by using a standard sit-and-reach box (Cranlea, UK). The subjects were asked to remove their shoes and sit with their legs extended in front of them against the box. The subjects then placed one hand over the other and stretched forward along the top of the box until they could stretch no further, holding this position for 3 seconds. The best trial of the three allowed was recorded to the nearest 1.0cm (Nieman, 1990) for further analysis.

2.2.3 Lower body strength and power

The maximal power of knee leg extensors and flexors was measured with isotonic–ballistic tries. Chrono Jump power system (Spain) dynamometer was used. Power calculations are based on accurate recording of weight movement. The vertical movement of the weight is recorded by a linear sensor connected to the computer. The computer through a special program calculates the speed, acceleration, force, power and work corresponding to the movement of the weight. Participants performed three maximal knee flexions and extensions with submaximal load with 20 sec rest between attempts. The highest value of power was recorded for later statistical analysis. The highest power value was used for statistical analysis (12).

2.2.4 Vertical jump performance

Vertical jump tests were conducted on a switch mat (Bosco *et al*., 1983) connected to a digital timer (accuracy±0.001s, Ergojump, Psion XP, MA.GI.CA. Rome, Italy), which recorded the flight time (t_f) of each single jump (14). In order to avoid upper body work and to minimize horizontal and lateral displacements the hands were kept on the hips through the tests. The rise of the center of gravity above the ground (h in m) was measured (Bosco *et al*., 1998) from flight time (t_f in seconds) applying ballistic laws: $h=t_f^2 \cdot g \cdot 8^{-1}$ (m) where g is the acceleration of gravity ($9.81\ m \cdot s^{-2}$). The subjects were jumping from a semi-squatting position without countermovement (SJ). Three trials were performed, and the best result was considered for statistical analysis (15).

2.2.5 Maximal anaerobic alactic leg power

A modified Wingate anaerobic test (WAnT) was used to measure maximal anaerobic alactic power. The WAnT was performed on a cycle ergometer (Monark 894E, Sweden). The seat was adjusted to a predetermined height to allow for complete knee extension with the ankle flexed at 90°. Toe clips were used and the subject was required to remain seated for the duration of the test. The subjects warmed up for 5 minutes at a pedaling rate of 50-60 rpm against a resistance of 1 kgr. Two unloaded 5-second sprints were performed at the end of the third and fifth minutes of the warm-up period. The maximal pedaling rate (LF max) attained during the sprints was recorded. Following a 2-minute rest, the subjects performed the 6 second WAnT against a resistance of 0.075 kg/kg body mass^{-1}. The subjects were instructed to increase pedal frequency progressively until they reach 80-100 revolutions.min^{-1} and then as fast as possible for the duration of the test while the resistance was also applied. The subjects were verbally encouraged to maintain as high the pedaling rate as possible throughout the6-second test duration. Pedal revolutions were monitored at a resolution of 0.025 revolutions and recorded at 1-second intervals. Subjects' peak power (PP) was determined as the highest value over the first 5-second period of testing (16).

2.2.6 Cardiorespiratory parameters

Subjects performed an incremental test for the determination of VO_2max, vVO_2max and the ventilatory threshold (VT). Subjects fasted for four hours prior to testing. Following a 5-min warm-up, treadmill (Technogym runrace 1200, Italy) velocity was increased by 1km.h-1 every two minutes until volitional fatigue. This protocol has been validated from other studies for the determination of VO_2max, VT and vVO_2max simultaneously (16), (17), (18). Gas collection was made during the last 30 s period of each 2min stage in order to allow the subject to attain steady state VO_2 (20). VO_2 was measured by the open-circuit Douglas Bag method. The subject breathed through a low resistance 2-way Hans-Rudolph 2700 B valve. The expired gases passed through a 90cm length of 340mm diameter flexible tubing into 150-liter capacity Douglas Bags. The concentration of CO_2 and O_2 in the expired air were measured by using the Electrolab, FerMac 368, UK Carbon Dioxide and Oxygen Analyzers. The gas analyzers were calibrated continuously against standardized gases (15,88% O_2, 3.95% CO_2 and 100% N_2). Expired volume was measured by means of a dry gas meter (Harvard) previously calibrated against standard airflow with a 3-liter syringe. Barometric pressure and gas temperature were recorded and respiratory gas exchange data for each workload (i.e. VO_2, VCO_2, VE and R) were determined on a locally developed computer program based on the computations described by McArdle, Katch and Katch when VE atps, $FECO_2$ and FEO_2 are known (21). The highest VO_2 value obtained during an incremental exercise test was recorded as the subject's VO_2max which also elicited a heart rate within ± 10bpm of age-predicted HRmax, a Respiratory Exchange Ratio (RER) greater than 1.05, and finally as core on the completion of the test equal or greater than 19 in the 20 grade Borg scale (22).

2.2.7 Velocity at VO_2max (vVO_2max)

The lower running speed that elicits a VO_2 equivalent with VO_2max during the VO_2max test was defined as vVO_2max (23).

2.2.8 Ventilatory threshold assessment

Criteria described by others were used for the VT detection (23), (24). The VT was primarily determined as the VO_2 or workload as which VE began to increase nonlinearly. To check the onset of hyperventilation other subsidiary criteria were used such as: 1) a systematic increase of VE/VO_2, 2) a nonlinear increase of VCO_2 and 3) a systematic decrease of $FECO_2$. The highest test-retest reproducibility (r=0.93) and the closest correlation (r=0.96) with LT have been reported by Sucec (1982) when ventilatory transients such as FEO_2, VE/VO_2 and $FECO_2$, VE/VCO_2 are used for the VT detection. The workload before a systematic increase of either VE/VO_2, or VE/VCO_2 with a concomitant decrease of $FECO_2$, when a two-minute incremental protocol has been employed can be easily defined. Yoshida *et al*. examined the use of the Douglas Bag technique for VT assessment and found it a valid non-invasive measure of the onset of metabolic acidosis (OMA) (26).

2.2.9 Blood lactate analysis

Fingertip blood samples were taken 5 minutes after the completion of VO_2max test. Blood lactate concentration was determined by electro enzymatic method (Nova Biomedica, USA) on 0.7-μl micro blood samples from the fingertip as a check for submaximal aerobic exercise.

2.2.10 Heart rate

Heart rates were continuously recorded throughout the tests by a Polar heart rate monitor (S 710, Finland).

2.3 Statistical analysis

Descriptive statistical analysis was used to calculate the mean values and standard deviations (sd) of the parameters. To compare the mean values of the physiological characteristics, T-test for independent samples was used. All statistical analyses were performed using the Statistical Package for Social Sciences (version 21.0; SPSS, Inc, Chicago, Illinois, USA). The level of significance was set at $p \leq 0.05$.

3. Results

Table 1: Aggregated data of the measured parameters

Parameter	**Referees 1st - 2nd category**	**Amateur referees**	**p**
Age	31,4 ± 3,66	26,7 ± 6,11	0,06
Weight	78,22 ± 6,87	90,5 ± 15,66	0,016*
Height	179,8 ± 4,96	181,00 ± 4,50	0,31
% Fat	17,51 ± 2,36	20,39 ± 5,4	0,09
Flexibility	18,6 ± 5,82	13,4 ± 9,96	0,1
Maximum Power (watt)	804,8 ± 93,44	846 ± 97,8	0,18
Maximum power (watt.kg^{1})	10,3 ± 0,85	9,47 ± 1	0,012*
Maximum rotations	181,3 ± 20,65	180,7 ± 11,59	0,47
Height of squat jump (cm)	31,4 ± 4,33	30,48 ± 2,68	0,28
Reaction time (ms)	0,24 ± 0,03	0,24 ± 0,03	0,46
VO_2max	54,96 ± 4,88	45,79 ± 4,58	0*
vVO_2max	16,54 ± 0,88	14,06 ± 1,55	0,001*
Speed @ Ventilatory threshold	12,4 ± 0,81	10,6 ± 1,13	0,00003*
HR max	184,4 ± 11,44	188,2 ± 10,11	0,17
Maximum lactic acid concentration (mmol.L^{-1})	9,62 ± 2,71	9,47 ± 2,65	0,45
Right leg extenders (Nm)	356,2 ± 62,7	421,3 ± 84,4	0,028*
Right leg flexors (Nm)	274,9 ± 26,13	298,1 ± 51	0,081
Left leg extenders (Nm)	369,3 ± 74,34	422,7 ± 97,24	0,11
Left leg flexors (Nm)	276,8 ± 39,48	308,1 ± 37,51	0,043*
Relevant power right leg extenders (Nm.kg^{-1})	4,55 ± 0,70	4,66 ± 0,63	0,38
Relevant power left leg extenders (Nm.kg^{-1})	4,73 ± 0,84	4,67 ± 0,77	0,43
Relevant power right leg flexors (Nm.kg^{-1})	3,52 ± 0,29	3,32 ± 0,48	0,13
Relevant power left leg flexors (Nm.kg^{-1})	3,55 ± 0,49	3,47 ± 0,53	0,36

*$p<0.05$.

4. Discussion

The main objective of this study was to compare the physical and physiological characteristics of Greek soccer referees of professional and amateur categories. Body mass values of this study are not in line with the findings of the Talovic *et al*. study (2018) as well as those of Castillo *et al*. (2016) as they not revealed any differences in weight. It has to be mentioned also that amateur referees have shown large standard deviation in body mass compared with 1st and 2nd class referees. More frequent and intensive training as well as continuous testing with fitness tests over time may explain this difference. Age did not show statistically significant differences. The larger age span of the amateur referees is due to a mix of young age referees who recently started refereeing and older ones close to retirement. Body stature was not different between the experimental groups in this study. This is in line with the results of Talovic *et al*. (2018). The increased percentage of body fat of the amateur referees can be explained by the greater body mass, the diminished physical fitness requirements of the category they play and the lack of supervisory control by the competent authorities. Papanikolaou *et al*. (2020), in 1st class Greek referees, have published approximately the same values (15.3 ± 2.8%). In contrast, an increase of 20.67 ± 3.92% is reported in the investigation of Mazaheri and associates (2016). Castagna *et al*. (2019) also reported values for the %fat (20,4 ± 3,6%).

The mean relative value of maximum anaerobic power was higher mean value in the professional referees, as measured with the Wingate test, compared with the amateur referees. This is the first study to measure anaerobic power and report values between professionals and amateur referees. A very important and widely studied parameter for the evaluation of cardiorespiratory fitness of referees is VO_2max. The significant difference between 1st-2nd class referees and amateur referees in the present study are in line with the results of the study by Hrusa and Orel (2017) who reported also statistically significant differences between 3rd national class referees and amateurs. The investigation of Castillo and associates (2016) reports identical VO_2max values between armatures and professional referees. Finally, the study of Tessitore *et al*. (2007), in 10 amateur Italian referees reported mean value of 51.8 ± 3.2 $ml.kg^{-1}.min^{-1}$ with the measurements carried out using a closed-circuit metabolic system. The differences in the values of VO_2max may be due to several reasons including systematic training as well as greater race requirements. At the same time, they are obliged to participate in fitness tests many times in the entire year to check their readiness. In contrast, the authorities responsible for amateur referees exert less supervisory control over their physical preparation.

Another parameter found to differ significantly between the two groups is vVO_2max. In the study of Castagna and colleagues (2001), the value of vVO_2max was 16.27 ± 0.94 $km.h^{-1}$, almost identical with the present study 16.54 ± 0.88 $km.h^{-1}$.

The running speed corresponding with the ventilatory threshold was also higher in the first-second class referees. This was to be expected as the highest value of vVO_2max also corresponds to a higher value of νVT. The maximum distance that the referees can cover in a match without reaching exhaustion that would also affect the ability to judge directly depends of the vVO_2max and νVT. The mean speed at the anaerobic threshold in the study of Castagna *et al*. (2019) was 13.98 ± 1.03 $km.h^{-1}$, compared with the Greek referees 1st-2nd class 12.4 ± 0.81 $km.h^{-1}$. The mean value of maximum heart rate did not show statistically significant differences.

The mean value of the maximum blood lactate concentration between the two groups was not different. The 9,62 ± 2,71 $mmol{\cdot}l^{-1}$ value of the present study is comparable with the value of 10.02 ± 2.26 $mmol{\cdot}l^{-1}$ reported by Castagna *et al.* (2001).

Conflict of interest statement

The authors declare no conflicts of interest.

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