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PHYSIOLOGICAL RESPONSES ASSOCIATED WITH CARDIOPULMONARY EXERCISE TESTING IN ELITE SOCCER REFEREES, DISTANCE RUNNERS AND HEALTH CONTROLS

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ABSTRACT

The aerobic physical fitness levels of football referees is of great interest, because its can impact on the quality of the referees' performance during matches. This study evaluated the physiological response from aerobic physical fitness variables [maximal oxygen uptake (VO_2max), anaerobic threshold (AT) and respiratory compensation point (RCP)] obtained from the cardiopulmonary exercise test (CPET) in football referees and compare it to those of healthy controls and distance runners. A cross-sectional study was performed with 57 male adults that composed the following groups: control group (CG); recreational runners (RuG); and football referees (ReG). Anthropometric, resting and exertion electrocardiograms and CPET evaluations were determined. Brazilian elite football referees have a higher speed and VO_2max associated with AT, RCP and maximal exercise (CG=39.8±4.7 versus RuG=52.4±7.1; and ReG=45.8±5.5 ml/kg/min), than CG, but lower than the recreational runners. Physiological responses associated with the CPET of Brazilian elite football referees are higher than those of healthy controls, but lower than those of recreational runners. From our results and other findings in the literature, we can assume, that the football referees evaluated are able to withstand the physiological demands imposed by the match.

Key words: Football referee. Cardiopulmonary exercise test. Anaerobic threshold. Physical fitness. Exercise.

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RESUMO

Respostas fisiológicas associadas ao teste de exercício cardiopulmonar em árbitros de futebol de elite, corredores de longa distância e controles de saúde

Os níveis de aptidão física aeróbica dos árbitros de futebol são de grande interesse, pois podem afetar a qualidade do desempenho dos árbitros durante as partidas. Este estudo avaliou a resposta fisiológica das variáveis de aptidão física aeróbica [consumo máximo de oxigênio (VO_2máx), limiar anaeróbico (LA) e ponto de compensação respiratória (PCR) obtidas do teste de exercício cardiopulmonar (TECP) em árbitros de futebol e comparadas com as de indivíduos saudáveis e corredores de distância. Estudo transversal com 57 adultos do sexo masculino que compuseram os seguintes grupos: grupo controle (GC); corredores recreativos (RuG); e árbitros de futebol (ReG). Foram determinados eletrocardiogramas antropométricos, de repouso e esforço e avaliações do TECP. Os árbitros de futebol de elite brasileiros têm maior velocidade e VO_2máx associados a LA, PCR e exercício máximo (GC = 39,8 ± 4,7 versus RuG = 52,4 ± 7,1; e ReG = 45,8 ± 5,5 ml/kg/min), em relação ao GC, mas inferior aos corredores recreativos. As respostas fisiológicas associadas ao TECP dos árbitros de futebol de elite no Brasil são superiores às dos controles saudáveis, mas menores que as dos corredores recreativos. Pelos nossos resultados e outros achados da literatura, podemos supor que os árbitros de futebol avaliados são capazes de suportar as demandas fisiológicas impostas pela partida.

Palavras-chave: Árbitro de futebol. Teste de esforço cardiopulmonar. Limiar anaeróbico. Aptidão física. Exercício.

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INTRODUCTION

Football referees have an important responsibility to implement the rules of the game and are a significant part of the spectacle.

Thus, the knowledge of physical and physiological performance, especially those related to aerobic physical fitness and the demands of football referees has a great relevance because their technical and tactical procedures (which can be influenced by the level of physical fitness) are fundamental to the regular flow of the match (Mazaheri et al., 2016; Schenk, Bizzini, Gatterer, 2018).

When refereeing football matches, elite referees are subject to high physiological demands. During a match, the football referee needs to cover large distances which requires a high aerobic demand as well as the ability to perform repeated sprints (Weston et al., 2012).

For example, in the Spanish National Division during a match, football referees covered approximately 10 km (2.7 km at high speeds, >18 km/h) (Castillo et al., 2016a, 2016b, 2017) and performed 21.3-30.5 sprints at a speed above 25.2 km/h (Weston et al., 2012).

Given the importance of the physical and consequent technical and tactical performance of football referees, regardless of the competition level, scientific research has been conducted about the exercise physiology and physiological demand applied to football referees (Schenk, Bizzini, Gatterer, 2018).

D'Ottavio and Castagna (2001) evaluated the cardiovascular stress of male Italian compared with high level football field referees and showed that the heart rate (HR) attained 89.1% of the estimated maximal over the duration of a full game with no difference between the halves.

Krustrup and Bangsbo (2001) examined the physiological demands of top-class male Danish football referees by measuring their HR and blood lactate concentration during competitive matches and observed that the mean HR was 162±2 beats/min (85±1% of maximal HR) and the mean blood lactate concentration was 4.9±0.3 mmol/L.

Krustrup et al., (2002) determined the physiological demands of top class Danish assistant football referees, by measuring their HR and blood lactate concentration during competitive matches, they showed that the mean HR was 137 beats/min (73% of maximal HR and 65% of maximal oxygen uptake VO_2max) and the blood lactate concentration was 4.7 and 4.8 mmol/L after the first and second half, respectively. They concluded that, top-class assistant football referees have a moderate aerobic energy production during games with episodes of high aerobic and anaerobic energy turnover.

In this context, Mazaheri et al., (2016) pointed out that the elite-level referee is exposed to the similar physical demands placed on a midfield football player, whose predominant action is to run long distances during the game. These authors conducted a study to assess the cardiorespiratory fitness of all football referees officiating at the Iranian Premier League and showed that the mean VO_2max was 59.9 ± 7.1 mL/kg/min.

Despite of this knowledge little is known about the aerobic physical fitness of football referees when compared with athletes that performed aerobic activities (for example, runners) and health controls.

Therefore, the aim of the current study was to evaluate and to compare the physiological profile (associated with the cardiopulmonary exercise test - CPET) of referees in the elite Brazilian League with those of healthy controls and recreational runners, characterized by a high level of aerobic fitness.

We hypothesized that football referees have a similar aerobic physical fitness to recreational runners due to the demands imposed by the game.

MATERIALS AND METHODS

Sample

A cross-sectional study was performed comprising of 57 male adults. The sample was composed and distributed into the following groups: healthy controls (n=25), recreational runners (n=18) and football referees (n=14) of the Brazilian Football League, which are affiliated to the Brazilian Football Confederation (CBF).

All participants were healthy and were not smokers or had any cardiac, muscular, or joint disorders. In general, the basal characteristics of the participants that composed the different groups were:

Control (CG) - health participants who had not practiced physical exercise for at least six months on a regular and systematic basis,

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they were recruited through the distribution of leaflets.

Runner (RuG) - participants with at least two years of experience in predominantly aerobic long-distance running, with a weekly frequency of at least four sessions and a minimum of 40 kilometers per week, they were recruited through the distribution of leaflets between sports and exercise facilities and runner events 10 miles from Garoto (Brazilian Runner Competition).

Football referee (ReG) – composed of referees (6 main and 8 assistants) of the Brazilian Football League, affiliated to the Brazilian Football Confederation (CBF). In this group, all the individuals were not exclusively refereeing because they had other professional activities.

After a clear explanation of the experimental procedures, including the risks and benefits of participation, written consent was obtained.

This project was approved by the Human Research Ethics Committee of the Federal University of Espírito Santo (CAAE number 584002816.7.0000.5542; opinion: 1.775.507), following all the principles outlined in the Declaration of Helsinki. Table 1 below shows the general characteristics of the participants.

Table 1 - General characteristics of the control (CG), runner (RuG) and referee (ReG) groups.

Variables	Groups			F (DFn, DFd)	p value
	CG (n=25)	RuG (n=18)	ReG (n=14)		
Age (years)	34.0 ± 6.4	36.5 ± 5.1	34.4 ± 3.4	F (2, 54) = 1.212	0.306
Body mass (kg)	73.4 ± 11.9	65.9 ± 6.9*	82.8 ± 9.0#†	F (2, 54) = 11.4	<0.0001
Height (m)	1.76 ± 0.06	1.72 ± 0.06	1.79 ± 0.07‡	F (2, 54) = 4.045	0.0231
BMI (kg/m^2)	23.5 ± 3.3	22.0 ± 1.9	25.7±2.1¶+	F (2, 54) = 7.487	0.0013

Legend: BMI: Body mass index. Data expressed as mean ± SD. Statistically significant difference (One-way ANOVA) between groups. *CG vs. RuG; #CG vs. ReG; †RuG vs. ReG; ‡RuG vs. ReG; ¶CG vs. ReG; +RuG vs. ReG.

Study design

The study had a single phase and the variables were collected in one day. Participants performed the following evaluations: anthropometric, resting and exertion electrocardiogram (ECG) and cardiopulmonary exercise test (CPET). CPET was used to assess the physiological response to exercise. Specifically, the following physiological variables were assessed by CPET: anaerobic threshold (AT), respiratory compensation point (RCP) and VO_2 max.

Electrocardiogram (ECG) and cardiopulmonary exercise test (CPET)

Aerobic physical fitness and overall health status were assessed by a CPET and resting and exertion ECG, respectively. Initially, participants remained at rest in supine position for five minutes. The 12-lead resting ECG (MICROMED, Brasilia, Brazil) was performed to detect any disturbance that contraindicated maximum effort.

Electrocardiographic recording during pre-exertion (standing on the treadmill) and exertion (simultaneously with CPET) was performed using three simultaneous leads (MC5, D2Me V2M). CPET was performed on a treadmill (Inbra Sport, Super ATL, Porto Alegre, Brazil) maintained at a slope of 1% to simulate level-ground running with air resistance (Jones and Doust, 1996).

A protocol with an initial velocity of 6 km/h was used and progressively increased (at 1 km/h every minute) until the volunteer was exhausted (Viana et al., 2018; Lira et al., 2013).

The measurement of the ventilatory variables (during submaximal and maximal efforts) were performed using a metabolic gas analyzer (CortexMetalyzer 3B, Leipizig, Germany), with breath-to-breath collection, and analyzed using the Metasoft® program.

The criteria for identifying the test at maximum were to reach at least three of the following criteria: a) voluntary exhaustion of the participant; b) heart rate of at least 90% of predicted for age (220-age); c) respiratory exchange rate equal to or greater than 1.05; and d) maximal oxygen uptake, observed by the concept of plateau or peak (Billat et al., 2004).

In addition, the anaerobic threshold (AT/ ventilatory threshold - VT_1) and respiratory compensation point (RCP/ VT_2) were assessed using established criteria (Wasserman et al., 2005).

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Briefly, the AT corresponds to the break point in the plot of VCO_2 as a function of VO_2. At that point, VE/VO_2 increases without an increase in VE/VCO_2. RCP was located between AT and VO_2max, when VE/VCO_2 starts to increase and VE/VO_2 continues to increase.

AT and RCP were determined independently by two experienced investigators. If agreement between the investigators was not achieved,

AT and RCP were determined by consensus. To determine the VO_2 and VE in AT and RCP, the average of the last 10 seconds of each corresponding level was used. In practical terms, VT represents points that can be used to classify the intensity of aerobic exercise (Wasserman et al., 2005).

Statistical analysis

The normality of the data was verified by the D'Agostino & Pearson test. As all analyzed variables followed the normal distribution (alpha=0.05), the one-way analysis of variance (ANOVA) was applied followed by the Tukey's post hoc test (CG vs. ReG vs. RuG).

Data were presented as mean ± standard deviation (SD). All statistical analyses were performed using the Graph Pad Prism version 7.0 software (Graph Pad software Inc., USA). The level of significance was set at 5%.

RESULTS

Table 2 - Physiological variables associated with the CPET of the control (CG), runner (RuG) and referee (ReG) groups.

Variables	Groups			F (DFn, DFd)	p value
	CG (n=25)	RuG (n=18)	ReG (n=14)		
Resting HR (beats/min)	64.8 ± 9.0	50.8 ± 5.4*	63.0±12.5#	F (2, 54) =13.29	<0.0001
AT					
Velocity (km/h)	7.5 ± 1.1	11.1 ± 2.5*	10.3 ± 1.3#	F (2, 54) = 24.8	<0.0001
HR (beats/min)	138 ± 20	139 ± 15	145 ± 16	F (2, 54) = 0.6139	0.5450
% HRmax	73.5 ± 9.0	76.9 ± 7.1	75.9 ± 7.7	F (2, 54) = 1.012	0.3702
VO_2 (L/min)	1.7 ± 0.4	2.4 ± 0.4†	2.6 ± 0.4‡	F (2, 54) = 19.42	<0.0001
VO_2 (mL/kg/min)	23.8 ± 5.6	38.4 ± 8.6¶	32.1 ± 4.6⸸δ	F (2, 54) = 26.2	<0.0001
%VO_2max	59.6 ± 11.2	69.3 ± 11.7¹	71.6 ± 6.9⁜	F (2, 54) = 7.403	0.0014
RCP					
Velocity (km/h)	10.6 ± 1.9	15.8 ± 2.5*	14.1 ± 1.9#	F (2, 54) = 33.38	<0.0001
HR (bpm)	174 ± 15	164 ± 13	172 ± 12	F (2, 54) = 3.023	0.0570
% HRmax	92.4 ± 5.4	91.7 ± 6.5	90.5 ± 8.2	F (2, 54) = 0.3762	0.688
VO_2 (L/min)	2.5 ± 0.5	3.1 ± 0.4†	3.3 ± 0.3‡	F (2, 54) = 17.09	<0.0001
VO_2 (mL/kg/min)	34.4 ± 5.2	47.9 ± 7.8¶	40.9 ± 4.8⸸δ	F (2, 54) = 25.38	<0.0001
%VO_2 max	86.1 ± 8.5	90.9 ± 6.2	89.8 ± 8.2	F (2, 54) = 2.172	0.1238
Maximal					
Velocity (km/h)	12.9 ± 1.8	17.9 ± 2.8*	16.5 ± 1.1#	F (2, 54) = 33.08	<0.0001
HR (beats/min)	188 ± 12	179 ± 11†	191 ± 13‡	F (2, 54) = 4.862	0.0114
VO_2 (L/min)	2.9 ± 0.5	3.4 ± 0.3¶	3.7 ± 0.4⸸	F (2, 54) = 14.71	<0.0001
VO_2 (mL/kg/min)	39.8 ± 4.7	52.4 ± 7.1δ	45.8 ± 5.5¹⁜	F (2, 54) = 24.53	<0.0001

Legend: HR: heart rate; AT: anaerobic threshold; RCP: respiratory compensation point. Data expressed as mean ± SD. Statistically significant difference between groups. Resting - *CG vs. RuG; #RuG vs. ReG; AT - *CG vs. RuG; #CG vs. ReG; †CG vs. RuG; ‡CG vs. ReG; ¶CG vs. RuG; ⸸CG vs. ReG; δRuG vs. ReG; ¹CG vs. RuG; and ⁜CG vs. ReG. RCP - *CG vs. RuG; #CG vs. ReG; †CG vs. RuG; ‡CG vs. ReG; ¶CG vs. RuG; ⸸CG vs. ReG; and δRuG vs. ReG. Maximal - *CG vs. RuG; #CG vs. ReG; †CG vs. RuG; ‡RuG vs. ReG; ¶CG vs. RuG; ⸸CG vs. ReG; δCG vs. RuG; ¹CG vs. ReG; and ⁜RuG vs. ReG.

Table 2 shows the CPET results. We observed statistically significant differences between the groups CG, RuG and ReG. Regarding the resting HR (beats/min), RuG presented a value 21.6% lower than the CG (p<0.0001) and ReG a value 19.6% higher than the RuG (p=0.0013).

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In relation to AT, it was observed that the AT velocity (km/h) of the RuG and ReG were significantly higher, 32.4% ($p<0.0001$) and 27.1% ($p<0.0001$), respectively, than the CG; the AT relative VO_2 (mL/kg/min) of the RuG and ReG were significantly higher, 38.0% ($p<0.0001$) and 25.8% ($p=0.0011$), respectively, than the CG; and the $\%VO_2max$ of the RuG and ReG were significantly higher, 13.9% ($p=0.0120$) and 16.7% ($p=0.0036$), respectively, than the CG.

Considering the RCP, the results showed that the RCP velocity (km/h) of the RuG and ReG was significantly higher, 32.9% ($p<0.0001$) and 24.8% ($p<0.0001$), respectively, than the CG; and the RCP relative VO_2 (mL/kg/min) of the RuG and ReG was significantly higher, 28.1% ($p<0.0001$) and 15.8% ($p=0.0066$), respectively, than the CG; Finally, regarding the CPET maximal variables, we observed that: the maximal velocity (km/h) of the RuG and ReG were significantly higher, 27.9% ($p<0.0001$) and 21.8% ($p<0.0001$), respectively, than the CG; the maximal HR of the RuG was significantly lower, 5.0%, ($p=0.0322$) and 6.1% ($p=0.0189$), respectively, than the CG and ReG; and the maximal relative VO_2 (mL/kg/min) of the RuG and ReG was significantly higher, 24.0% ($p<0.0001$) and 13.1% ($p=0.0096$), respectively, than the CG.

DISCUSSION

The aim of the present study was to evaluate and compare the aerobic physiological responses obtained from CPET among the control group, recreational runners and football elite referees. Our main findings were that the elite football referees have a higher speed and VO_2 associated with AT, RCP and maximal exercise than the control group, but lower than the recreational runners. In addition, the VO_2max of the control, runner and football referee groups were 39.8±4.7, 52.4±7.1 and 45.8±5.5 mL/kg/min, respectively, being significantly different among the groups.

The football referees have a similar exercise physiological demand to that observed in midfield players (Castagna, Abt, D'Ottavio, 2007).

therefore, it is reasonable to assume this is similar with distance runners. That is, despite the intermittent nature of football (and referee activity), particularly, in the midfield position athletes cover great distances using predominantly aerobic running.

For example, a football referee covers approximately 11 km during a match with ~900 m of high-speed running (Weston et al., 2012). This was one of the reasons for the choice of the distance recreational runners as one of the control groups.

Damasceno et al., (2015) evaluated, through CPET, male recreational runners, they obtained a mean VO_2max of 53.8±5.4 mL/kg/min. The mean values of VO_2max found by Damasceno et al., (2015) are in line with those of the present study.

Castagna, Abt, D'Ottavio (2007) pointed out that elite football referees have VO_2max values between of 44-50 mL/kg/min, which is lower than those observed among football players but may be higher than that observed in healthy controls, as observed in the current study.

The results presented by the current study are meaningful, because a better knowledge of the physiological profile of football referees could help in the improvement of quality and dynamics of the game since wrong judgments may have irreversible and negative implications (2007), added to this fact, unlike players, referees cannot be substituted in the matches and this characteristic is a tremendous disadvantage.

It was demonstrated that an overload of the physical task appears to be an important factor in the decrease in physical performance due to mental fatigue (Van Cutsem et al., 2017).

In addition, mental fatigue reflects a change in the psychobiological state and can be triggered by prolonged periods of high cognitive demand. It has been demonstrated that mental fatigue negatively impairs cognitive performance and endurance performance (Van Cutsem et al., 2017; Martin et al., 2018).

The negative impact of mental fatigue on endurance performance is primarily mediated by the greater perception of effort experienced by mentally fatigued participants (Martin et al., 2018).

In this way, it is possible to assume that to make adequate arbitration decisions during football matches, in a context of high physical, cognitive and emotional demands, referees must have superior physical fitness and physiological capacity.

In contrast to elite players, most football referees are non-professional and engaged in different occupations (Schenk, Bizzini, Gatterer, 2018), which was observed in the present work.

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Therefore, given the relevant role of the football referees, for the dynamics and flow of the game, it is imperative that they have a high level of physical fitness (such as football players) and that their exercise physiological profile is known and established and that football referees have a high aerobic fitness.

Helsen and Bultynck (2004) suggested that to optimize the physical preparation, performance, perceptual-cognitive performance and match decisions, of top-class football referees, a good strategy would be to apply intensive and intermittent aerobic training sessions and video training.

Castillo et al., (2016) showed that the physical demands (collected during official matches - Spanish National 3rd Division) of football referees are sufficient to elicit increases in blood lactate and small decrements in sprint performance and thereby, provide some evidence for match-related fatigue.

Weston et al., (2011) assessed the physiological fitness and performance of an elite football referee from the referee's final season before attaining full-time, professional status (2002) until the season when he refereed the 2010 UEFA Champions League and FIFA World Cup finals.

The authors demonstrated that the VO_2max remained stable (52.3 vs. 50.8 mL/kg/min), whereas running speed at the lactate threshold (14.0 vs. 12.0 km/h) and running economy (37.3 vs. 43.4 mL/kg/min) both improved in 2010 compared with 2002.

This denotes the importance of exclusive dedication to football refereeing, when choosing the profession of football referee. Which, it is reasonable to suppose, is unfortunately impossible for most football referees around the world.

Silva et al., (2008) evaluated the intensity of the physical activities performed by official football referees accredited to the Brazilian Confederation of Football during a match and observed that football refereeing may be considered a highly intermittent exercise activity, with physiological demands similar to midfield football players. In addition, they pointed out that during officials' matches football referees perform physical aerobic activities of a low and moderate intensity.

Therefore, due to the high intermittent exercise performed by football referees during a match, an elevated VO_2max is necessary in order to allow for recovery during rest/low intensity exercise period (Lira et al., 2013).

Reilly and Gregson (2006) showed that field referees cover 10,000 meters on average during a game with a mean HR between 160-165 beats/min and an VO_2 close to 80% of the VO_2max and assistant referees approximately 7500 m with a mean HR of about 140 bpm and the corresponding VO_2 is 65% of the VO_2max.

Of the total distance covered about 4-18% is covered at high intensity. The blood lactate concentration has been reported to be in the range of 4-5 mmol/L. This scenario is very similar to that observed in football midfield players (Castagna, Abt, D'Ottavio, 2007).

In addition, Costa et al., (2013) assessed the external and internal loads of Brazilian football referees during official matches. For this, they monitored field referees during 35 matches.

No differences in the mean distance covered (5.219±205 vs. 5.230 ± 237 m) and maximal speed (19.3±1.0 vs. 19.4±1.4 km/h) were observed between the halves of the matches. However, the mean speed was higher in the first half of the matches (6.6±0.4 vs. 6.4±0.3 km/h) than in the second half.

The mean HR during the matches was ~89% of the HRmax. In ~95% of the matches, the referees demonstrated a HR ≥ 80% of the HRmax.

Nonetheless, the time spent at 90-100% of the HRmax was higher in the first half (59.9 vs. 52.3%). In our study, we observed that the velocity (km/h), HR (beats/min) and % HRmax, associated with AT, RCP and maximal point for the CPET were, respectively, [AT - (10.3±1.3), (144.6±16.2), and (75.9±7.7); RCP - (14.1±1.9), (172.0±11.8), and (90.5±8.2); Maximal - (16.5±1.1) and (190.7±13.0)].

According to the results observed by Costa et al., (2013) and the findings of the present study associated with CPET there is in some way a parallel in the exercise physiological responses associated with the football matches and that assessed by CPET.

CONCLUSION

Exercise physiological responses associated with the CPET of elite football referees of Brazil are higher than those of healthy controls, but lower than those of recreational runners.

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