

Blood lactate and oxygen consumption in soccer players: comparison between different positions on the field

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OBJECTIVE: We hypothesize that in players with better aerobic fitness, lactate production was not inhibited after high-intensity exercise, regardless of the footballer's position on the field.

METHOD: Sixty professional male soccer players performed cardiopulmonary exercise tests on an ergometric treadmill; respiratory gas exchanges were monitored throughout and blood lactate levels at peak effort was measured, using a portable device. The heart rate response was determined by computerized EKG. Training sessions took place over an average of ten hours per week, and the players had 6.8 years of experience in competitive soccer; they were tested a third of way into the season. The positions tested were (centerback, fullback, midfielder and striker).

RESULTS: The following results (mean \pm std. dev.) were obtained: (1) peak oxygen consumption of 58.8 ± 4.5 ml.kg⁻¹.min⁻¹; (2), blood peak lactate of 12.3 ± 1.6 mmol.L⁻¹; (3) maximum heart rate of 193 ± 3.3 beats. min⁻¹; (4); oxygen consumption at the second ventilatory threshold of 49.6 ± 5.0 mL. kg⁻¹.min⁻¹; (5); running speed at the second ventilatory threshold of 13.3 ± 0.8 km.h⁻¹; (6) percentage of oxygen consumption in the second ventilatory threshold of $84 \pm 6\%$. There was no correlation between maximum aerobic level vs. peak lactate concentration ($r = -0,031$; $p = 0.812$), nor between submaximal aerobic level vs. peak lactate concentration ($r = -0.146$; $p = 0.335$) in the positions tested.

CONCLUSION: Better or worse aerobic profiles according to game positions in soccer players do not influence peak lactate levels following high-intensity exercise, and confirms the study hypothesis.

KEYWORDS: training, aerobic and anaerobic exercise, ventilatory threshold, heart rate, cardiopulmonary exercise test.

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INTRODUCTION

Soccer is a multi-activity sport played at a relatively high mean work intensity interspersed with short periods of very-high- intensity sprint and jump performance, soccer should therefore be regarded as a sport with both aerobic and anaerobic demands. The match duration in combination with the load on the aerobic metabolic pathway indicates that the main energy contribution comes from aerobic processes. It

is estimated that aerobic metabolism accounts for 90% of the energy required during a soccer match, and is therefore a pre-requisite for this sport. Typical for soccer is also the continuous variation in work intensity related to action on the soccer field, involving standing, walking, jogging, running, high-speed running, and sprinting.¹⁻⁴

It is widely accepted that during a high-intensity stimulus, resynthesis of ATP occurs primarily via the anaerobic pathways.⁵ However, when this type of exercise is performed intermittently, as occurs in soccer, it has been suggested there is an increase in the contribution of the aerobic metabolism for the resynthesis of ATP.⁶ Thus,

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the participation of anaerobic glycolysis and consequently, the production of lactate during the intermittent effort throughout the game, are present.⁷ It may be noted that a more pronounced level of systemic oxidative stress has been reported after aerobic as compared to anaerobic training sessions in young soccer players.⁸

Soccer today is more compacted and more intense, and the tactical determinations require a more dynamic and sustainable physiological profile when it comes to the physical capacities required by the sport for the metabolic compensations of required during the game.⁹

However, in relation to the higher levels of aerobic fitness required in some positions, it has been noted that these athletes were less efficient in increasing their lactate levels at peak effort, because aerobic metabolism reduces lactate production¹⁰ due to an increase in the quantity of monocarboxylate transporters (MCT) of isoform 1,¹¹ which carry out the process of lactate influx¹² and also because of an increase the mitochondrial density and volume.¹³ This, in turn, leads to an increase in the rate of reduction of blood lactate at peak effort.¹⁴

In view of this, it is assumed that athletes of intermittent sports who have greater aerobic fitness have a higher capacity to maintain this performance in intense effort, even in the presence of high levels of blood lactate.¹⁵ The hypothesis of the present study is to determine whether maximum and sub-maximal aerobic capacity of professional soccer plays in different positions on the field affect the production of lactate after intense exercise.

■ MATERIALS AND METHODS

Study Design and population

The study design was cross-sectional. Sixty male professional soccer players took part in the study (centerbacks = 14, fullbacks = 14, midfielders = 19, and strikers = 13]. The players played for various first division Brazilian teams. Table 1 shows the anthropometric and metabolic characteristics all the players at rest. All were of a high competitive level, spent an average of 10 ± 1.5 hours a week in training, had six years of experience as professional footballers, and played an average of one or two games per week. All the players were in good health (defined as being free of diabetes, heart disease, musculoskeletal dysfunction, and cancer). The tests were performed in a physiology laboratory, during the morning, starting at 8 a.m., or during the afternoons, at 1 p.m. During the tests, the temperature in the laboratory varied between 18°C and 22°C and relative humidity between 50% and 70%. The athletes ate a light meal one hour before the tests, and were dressed in appropriate sports clothes and shoes for the test.

Table 1 - Baseline characteristics of the soccer players according to playing position and in general

Playing Positions	Age (years)	Body mass (kg)	Body Height (cm)	BMI (kg/m ²)	Blood Lactate (mmol.L ⁻¹)
CB (n = 14)	20.7 ± 2.4	79.8 ± 8.1	186 ± 4.6	23.1 ± 0.3	1.4 ± 0.3
FB (n=14)	21.6 ± 3.3	67.5 ± 4.8	176 ± 3.3	21.8 ± 0.2	1.5 ± 0.3
MF (n = 19)	20.3 ± 2.2	67.7 ± 5.1	175 ± 4.4	22.1 ± 0.3	1.5 ± 0.3
SK (n = 13)	20.8 ± 3.2	74.3 ± 4.6	178 ± 7.2	23.5 ± 0.4	1.3 ± 0.2
All players (n = 60)	20.8 ± 2.7	71.9 ± 7.6	178 ± 6.5	22.6 ± 0.8	1.4 ± 0.1

Legend: CB, centerbacks; FB, Fullback; MF, Midfielder; SK, Striker.

Ethical considerations

Prior to their participation in the study, all participants were given a verbal explanation of the aim of the research, and the procedures to be carried out; an informed consent form was signed by all the athletes. The study was carried out in strict accordance with the ethical guidelines of the Declaration of Helsinki, and was approved by the Ethics Committee (CAPPESQ case #1251/2007) of the Hospital das Clínicas of the School of Medicine of Universidade de São Paulo, São Paulo, Brazil.

Determining the maximum oxygen consumption (peak VO₂)

Oxygen consumption was measured by means of a respiration gas exchange system using a computerized metabolic analyzer (CPX/D, MedGraphics, St. Paul, MN, USA). The oxygen and carbon dioxide analyzers were calibrated before and immediately after each test, by means of a known gaseous mixture (O₂ = 11.9% and 20.9%), (CO₂ = 5.09%) and balanced with nitrogen. The pneumotachograph was calibrated with a 3-liter syringe (Hans Rudolph®, USA). The ventilatory variables were analyzed every 30sec after the end of the test. The peak VO₂ was defined as the maximum VO₂ measured at the end of the exercise, when the athlete was no longer able to maintain the speed imposed by the ergometric treadmill with a fixed tilt maintained of 3% (ATL Inbramed®, Porto Alegre, Brazil), through a continuous progressive protocol, until exhaustion. In this protocol, the players rested for two minutes and warmed up for four minutes, at speeds of 4, 5, 6 and 7 km·h⁻¹ (one minute at each speed). They then started the test, running at 8km·h⁻¹ and increasing the speed by 1 km·h⁻¹ every two minutes until voluntary fatigue.¹⁶ During the test, verbal encouragement was given, to increase the players' levels of motivation.¹⁷ The subjective perception of effort by the Borg scale for the exercise was also obtained, through an oral questionnaire applied during the exercise.¹⁸

Determining the second ventilatory threshold (VT_2)

This was determined through ventilatory gaseous exchange at the point where the ventilatory equivalent of carbon dioxide (VE/VCO_2) reached its lowest value before starting to increase, and when the end-tidal carbon dioxide pressure ($PETCO_2$) reached its maximum value before decreasing.¹⁹

Determining the maximum peak lactate

One minute after interrupting the test, a drop of blood was taken from the fingertip, and a portable lactate meter (Accusport Lactate Meter, Boehringer Mannheim®, Germany) which requires between 10 and 25 μ L of blood was used to measure the lactate level in the blood. Blood collections to determine peak lactate are generally carried out at one-minute intervals.²⁰ The equipment was calibrated regularly, at the beginning of each day and after every 10 samples with standards of known concentration (1.7-3.1 to 4.5-7.0 $\text{mmol}\cdot\text{L}^{-1}$).²¹

Determining the maximum heart rate (HRmax)

The HRmax was obtained at peak effort through computerized 12-lead ECG (Marquette® Exercise Testing System, Max Personal, USA) using the Tanaka equation [$208 - (0.7 * \text{age})$].²² Blood pressure was measured using a mercury-column sphygmomanometer (Tycos, USA) prior to the start of the test, during progressive exercise, every two minutes, and in the recovery phase until the sixth minute.

Statistical Analysis

Data (expressed as mean \pm standard deviation - SD) for each of the evaluated anthropometric and physiological variables were grouped for each game position. The normality of distribution of the data was verified by the Kolmogorov-Smirnov test. Levene's test was used to examine the equality of variances between the groups. If the data showed normal distribution between the groups, they were compared using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test. When the data fell outside the normal range, the Kruskal-Wallis non-parametric test was used, followed by the Mann-Whitney test. To verify the relationship between VO_2VT_2 , peak VO_2 and peak lactate in all the players, and also by position, Pearson's correlation was used. The level of significance was established as $p < 0.05$ for all the statistical analyzes. When differences between specific positions were detected, the Tukey post hoc test was used to determine which game positions were expressing these differences. All the statistical analyzes were performed using SPSS 11.5 for Windows (SPSS Inc., Chicago) A probability value < 0.05 was adopted as the limit of significance.

■ RESULTS

There were no statistically significant differences according to playing positions in relation to age, body mass, height, body mass index, and blood lactate level at rest (Table 1).

There were no statistically significant differences between game positions for the peak lactate and the maximum heart rate obtained in the test (Table 2). There was a significant difference in peak VO_2 between the positions. It was significantly lower ($p < 0.05$) for the positions of center-back and striker in relation to the fullbacks and midfielders (Table 2). The peak VO_2 between fullbacks and midfielders showed no differences (Table 2). There were also no significant differences in blood peak lactate between the positions. However, the oxygen consumption in the second ventilatory threshold (VO_2VT_2) and running speed ($\text{km}\cdot\text{h}^{-1}$) in VT_2 (Vel- VT_2) between the positions showed significant differences (Table 2). In the positions of centerbacks and striker, the VO_2VT_2 and the Vel- VT_2 values were significantly lower ($p < 0.05$) compared to the fullbacks and midfielders (Table 2). The relative percentage of VO_2VT_2 showed no differences between the positions (Table 2).

No significant correlations ($p > 0.05$) were observed between VO_2VT_2 , peak VO_2 , peak VO_2 , and the upward increase in blood peak lactate, indicating that higher aerobic capacity is not related to lactate concentration after high-intensity exercise (Table 3).

■ DISCUSSION

The present study addressed aerobic and anaerobic performance factors simultaneously in relation to team play position among elite soccer players. In players with better aerobic fitness through higher VO_2 in the second ventilatory threshold (VT_2) and greater aerobic power through peak VO_2 , the production of lactate was not inhibited after high-intensity exercise, regardless of the footballer's position. If it were the case, then anaerobic energy would be affected in the players with greater aerobic fitness, but this is not an advantage for this high-intensity intermittent sport, which depends on this pathway for the production of energy during the game. In the present study, we did not observe any relationship between the aerobic indicators (VO_2VT_2 and peak VO_2) and the production of blood lactate at peak effort in all the game positions (Table 3). This response means that the improvement of both metabolisms - aerobic and anaerobic - in soccer players is important, as it creates an advantage for maintaining the intense pace of the movements, regardless of the position played.

Table 2 - Peak oxygen consumption (VO_{2peak}), peak blood lactate, maximal heart rate (HRmax), oxygen consumption at second ventilatory threshold (VO_{2VT_2}), velocity at second ventilatory threshold (Vel- VT_2), and percentage of VO_{2max} at second ventilatory threshold ($VO_{2VT_2}(\%)$), among the soccer players according to playing positions and in general.

Playing Positions	VO_{2peak} (mL.kg ⁻¹ .min ⁻¹)	Peak blood lactate (mmol.L ⁻¹)	HRmax (beats.min ⁻¹)	VO_{2VT_2} (mL.kg ⁻¹ .min ⁻¹)	Vel- VT_2 (km.h ⁻¹)	$VO_{2VT_2}(\%)$
CB (n = 14)	54.4 ± 2.5	12.4 ± 1.1	191 ± 2.8	45.4 ± 3.9	12.5 ± 0.6	84 ± 2
FB(n = 14)	61.3 ± 3.1*	11.9 ± 1.2	192 ± 3.4	50.3 ± 5.3*	13.7 ± 0.9*	83 ± 7
MF(n = 19)	61.2 ± 3,6*	12.5 ± 1.6	194 ± 3.5	52.4 ± 4.1*	13.8 ± 0.7*	85 ± 5
SK(n = 13)	56.9 ± 4.4	12.4 ± 1.5	194 ± 2.7	49.4 ± 3.8	13.0 ± 0.5	88 ± 4
All players (n = 60)	58.8 ± 4.5	12.3 ± 1.6	193 ± 3.3	49.6 ± 5.0	13.3 ± 0.8	84 ± 6

* p < 0.05. Legend: (VO_{2max} : FB > CB and SK) and MF > CB and SK), (VO_{2VT_2} : FB > CB and MF > CB). (Vel- VT_2 : FB > CB and SK) and MF > CB and SK). Abbreviations: CB, Centerback; FB, Fullback; MF, Midfielder; SK, Striker.

Table 3 - Pearson correlation between the second ventilatory threshold, maximal peak oxygen uptake and maximal peak blood lactate value among the soccer players according to playing positions and in general.

Playing positions	Submaximal intensity VO_{2VT_2} vs. Peak blood lactate	Maximal intensity VO_{2peak} vs. Peak blood lactate
CB (n = 14)	r = -0.274 p = 0.365	r = -0.185 p = 0.409
FB(n = 14)	r = 0.001 p = 0.995	r = -0.129 p = 0.532
MF (n = 19)	r = -0.171 p = 0.485	r = -0.133 p = 0.510
SK(n = 13)	r = -0.013 p = 0.964	r = 0.079 p = 0.746
All players (n = 60)	r = -0.146 p = 0.270	r = -0.031 p = 0.812

Legend: VO_{2VT_2} = oxygen consumption at second ventilatory threshold; VO_{2peak} = maximal oxygen uptake. CB, Centerback; FB, Fullback; MF, Midfielder; SK, Striker.

Despite the players' different positions on the field, the group was very homogeneous in relation to aerobic capacity, as reflected in the low standard deviation of the aerobic indicators Vel- VT_2 (0.4 km.h⁻¹), VO_{2VT_2} (1.4 mL.Kg⁻¹.min⁻¹) and % VO_{2VT_2} (4%).

The highest rate of VO_{2VT_2} between positions was 13.8 and 13.7 km.h⁻¹, which was found for midfielders and fullbackers, respectively. Our results are very close to those found by some studies on soccer players in these two positions.^{23,24} The greater running speed found at VT_2 in the players with higher aerobic performance appears to be a response that is related to the type of movement and the distance covered by these players (fullbacks and midfielders); these values are smaller in defenders and strikers; however, fullbacks and midfielders exhibit, much lower values than those observed in long-distance runners. This is probably due to the low emphasis given to specific aerobic training.²⁵

The anaerobic contribution to the global energy demand is emphasized when the frequency of rapid stimuli occurs due to accelerated anaerobic glycolysis.^{26,27} This response is evident through the blood lactate levels, which can exceed 12 mmol.L⁻¹ during a competitive soccer game.²⁸

Therefore the blood lactate concentrations observed in soccer may be the result of a cumulative effect of numerous stimuli performed at high intensity.²⁹

In the present study, the players who showed higher oxygen consumption capacity in the submaximal condition (VO_{2VT_2}) and in aerobic power at peak effort (peak VO_{2peak}) also presented higher lactate production capacity. This suggests that in today's soccer, maintaining endurance and speed requires high levels of this blood metabolite, to keep pace with the intense physical demands of the game.²⁹ These results confirm the fundamental connection and synergy between the aerobic and anaerobic metabolisms in all the game positions, since there was no difference between them in lactate response at peak effort. This response has important practical implications for footballer training, and demonstrates that physical coaches need to determine the effectiveness of the anaerobic lactic metabolism in all the positions evaluated.

To the best of our knowledge, this is the first study showing the importance of the aerobic and anaerobic metabolisms with respect to field positions in the specific conditions imposed by the way soccer is played in Brazil. Good aerobic capacity plays a role in accelerating recovery between intermittent stimuli, while good anaerobic capacity is responsible for compensating for high intensity demands during the game.³⁰

The specific training for soccer players consists of sessions that focus on endurance, anaerobic exercises, agility, strength, coordination, and sprinting speed. This training format requires training for endurance and muscle speed in the athletes' movements. Therefore, it is not unexpected that lactate levels in the muscle fibers of these players would increase. Reports in the literature have shown that athletes who perform exercises with these characteristics have a higher capacity for lactate transport.³¹

In the present study, the response of the HRmax above 95% for age and the blood lactate above 12.3 mmol.L⁻¹ at peak effort indicated that the test on the treadmill was maximal.³² It is important to emphasize that the players

came from various clubs, and that there was no control over the independent variable (training). The results of this study should therefore be analyzed with caution, and it is suggested that additional, more controlled, longitudinal studies should be carried out, with a higher number of players from each position. This could rule out the possibility of bias presented by a cross-sectional study.

■ CONCLUSION

Better or poorer aerobic performance in the positions of this group of soccer players was not sufficient to decrease the peak lactate concentration after high-intensity exercise. Based on our results which show an absence of positional differences in both peak VO_2 and lactate, it is recommended that coaching staff implement regular training programs to monitor current players' physical development, given that aerobic and anaerobic fitness are claimed to be two of the most important physiological factors behind soccer performance. Therefore, the results were in line with the study hypothesis.

■ CONFLICT OF INTEREST

The authors state that they have no conflicts of interest regarding the publication of this article.

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■ AUTHOR PARTICIPATION

Santos-Silva PR: had the overall responsibility for the study and was responsible for the following items: Conception and design, statistical analysis, data collection and interpretation, writing of the manuscript and approved the final version of the manuscript. Pedrinelli A, Greve JMDA: were responsible for the following items: review, and written approval of the final version of the manuscript.

LACTATO SANGUÍNEO E CONSUMO DE OXIGÊNIO EM JOGADORES DE FUTEBOL: COMPARAÇÃO ENTRE POSIÇÕES NA EQUIPE

OBJETIVO: Nossa hipótese era que em jogadores com melhor condicionamento aeróbio, a produção de lactato não seria inibida após o exercício de alta intensidade, independentemente da posição do jogador no campo.

MÉTODOS: Sessenta jogadores de futebol profissional masculino foram submetidos a testes de exercício cardiopulmonar em um analisador metabólico troca gasosa respiratória em esteira ergométrica, com medição dos níveis de lactato no sangue no pico do esforço, usando um dispositivo portátil. A resposta da frequência cardíaca foi determinada por eletrocardiograma computadorizado. As sessões de treinamento duraram uma média de dez horas por semana, e os jogadores participantes tinham 6,8 anos de experiência no futebol competitivo. Os jogadores foram testados a um terço para o final da temporada. As posições testadas foram (defesa-central, defesa lateral, meio-campista e atacante).

RESULTADOS: Os resultados obtidos foram: consumo de oxigênio pico de $58,8 \pm 4,5 \text{ mL}\cdot\text{Kg}^{-1}\cdot\text{min}^{-1}$, pico de lactato no sangue $12,3 \pm 1,6 \text{ mmol}\cdot\text{L}^{-1}$; frequência cardíaca máxima de $193 \pm 3,3 \text{ batimentos}\cdot\text{min}^{-1}$; consumo de oxigênio no segundo limiar ventilatório de $49,6 \pm 5,0 \text{ mL}\cdot\text{Kg}^{-1}\cdot\text{min}^{-1}$; velocidade de corrida no segundo limiar ventilatório de $13,3 \pm 0,8 \text{ km}\cdot\text{h}^{-1}$ e porcentual do consumo de oxigênio no segundo limiar ventilatório de $84 \pm 6\%$. Não houve correlação entre o nível de aeróbio máximo ($r = -0,031$; $p = 0,812$) e o nível de aeróbio submáximo ($r = -0,146$; $p = 0,335$) nas posições testadas e na concentração pico de lactato.

CONCLUSÃO: Melhor ou pior perfil aeróbio nas posições de jogo em jogadores de futebol não influenciam os níveis de lactato de pico durante a realização de exercício de alta intensidade, e confirmam a hipótese do estudo.

PALAVRAS-CHAVE: Treinamento, Exercício aeróbio e anaeróbio, Segundo limiar ventilatório, frequência cardíaca, teste de esforço cardiopulmonar.

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