

Intensity of real competitive soccer matches and differences among player positions

Intensidade de jogos de futebol de uma competição real e entre jogadores de diferentes posições táticas

Daniel Barbosa Coelho¹
Lucas Ávila Mortimer¹
Luciano Antonacci Condessa¹
Rodrigo Figueiredo Morandi¹
Bernardo Moreira Oliveira¹
João Carlos Bouzas Marins²
Danusa Dias Soares¹
Emerson Silami Garcia¹

Abstract – Most investigations on soccer match intensity have evaluated friendly, simulated or a small number of games on a recreational basis or including a small number of players. There are no studies investigating real competitive situations including a considerable number of athletes and games or differences among player positions using heart rate as an intensity parameter. The aim of this study was to determine Brazilian soccer game intensity (GI) during official competitive matches and to compare GI among different player positions. Heart rate (HR) was measured in 26 under-17 (U-17) and 18 under-20 (U-20) soccer players (age 16.38 ± 0.5 and 18.24 ± 0.66 years, respectively) during 14 and 15 official games, respectively. Individual maximal heart rate (HR_{max}) and anaerobic threshold (AT) HR were evaluated in field tests. GI defined as $\%HR_{max}$ was monitored considering five intensity zones ranging from 1 = $< 70\% HR_{max}$ to 5 = $95-100\% HR_{max}$. Mean GI and AT intensity were 84.4 ± 5.1 and $86.3 \pm 4.0\% HR_{max}$ for the U-17 category and 84.1 ± 4.1 and $87.0 \pm 5.1\% HR_{max}$ for the U-20 category, respectively. Wingbacks (WB) spent more time in zone 5 than forwards (FW) ($p < 0.05$). Midfielders (MF) spent more time in zone 3 than all other players and in zone 4 than defenders and FW ($p < 0.05$). Mean GI and AT intensity were similar. WB performed more maximum effort than FW. MF did not participate as much in maximum effort as did WB and FW.

Key words: Anaerobic threshold; Heart rate; Soccer.

Resumo – A maioria das investigações sobre a intensidade de jogos de futebol foi realizada em jogos amistosos, simulados ou com um pequeno número de jogos avaliados em caráter recreacional ou com uma pequena amostra. Não se observou nenhuma avaliação de frequência cardíaca (FC) em jogos oficiais com um número considerável de jogadores e de diferentes posições. O objetivo do presente estudo foi determinar a intensidade de jogos (IJ) do futebol brasileiro durante uma competição oficial e compará-la entre jogadores de diferentes posições táticas. A FC foi medida em 26 jogadores entre 16 e 17 anos (Sub-17) e 18 jogadores entre 18 e 20 anos (sub-20) (idades $16,38 \pm 0,5$ e $18,24 \pm 0,66$ anos, respectivamente). A frequência máxima individual (FC_{max}) e a FC de limiar anaeróbico (LAN) foram avaliadas em testes de campo. A IJ como $\%FC_{max}$ foi monitorada como cinco zonas de intensidade sendo desde a zona 1 = $< 70\% FC_{max}$; a 5 = $95-100\% FC_{max}$. A IJ média e a intensidade de LAN foram $84,4 \pm 5,1$; $86,3 \pm 4,0\% HR_{max}$ and $84,1 \pm 4,1$; $87,0 \pm 5,1\% HR_{max}$ para o sub-17 e sub-20, respectivamente. Os laterais permaneceram mais tempo na zona 5 em comparação aos jogadores atacantes ($p < 0,05$). Os jogadores de meio campo permaneceram mais tempo na zona 3 em comparação aos outros jogadores e na zona 4 em comparação aos zagueiros e atacantes ($p < 0,05$). A IJ média e a intensidade de LAN são similares. Os laterais apresentam mais esforços máximos do que os atacantes e os jogadores de meio campo não participam de tantos esforços máximos como os zagueiros, laterais e atacantes.

Palavras-chave: Frequência cardíaca; Futebol; Limiar anaeróbico.

1. Federal University of Minas Gerais. School of Physical Education Physiotherapy and Occupational Therapy, Center for Sports Excellence. Belo Horizonte, MG. Brazil

2. Federal University of Viçosa, Viçosa, MG. Brazil.

Received:
5 April 2011
Accepted:
22 May 2011



INTRODUCTION

In contrast to other activities in which the intensity remains constant or varies little, the intensity of official soccer games is difficult to quantify since the soccer rules prohibit the use of masks and wrist monitors. Some attempts have been made using different parameters, such as mean distance covered^{1,2}, mean velocity³, maximum oxygen uptake ($\text{VO}_{2\text{max}}$) estimated by the measurement of rectal temperature⁴, mean blood lactate concentrations³, and mean energy expenditure⁵. However, due to the difficulties in assessing some of these variables, heart rate (HR) is recommended as a practical variable to monitor a player's effort intensity during a soccer game since a linear relationship exists between HR and $\text{VO}_{2\text{max}}$ ^{6,7}. Since HR is influenced by factors such as age, fitness, gender, environmental conditions and hydration status, Karvonen and Vuorimaa⁸ recommend that HR should be determined as the percentage of maximum heart rate (HR_{max}) when used as a parameter of exercise intensity, representing an adequate parameter for intensity control in professional and non-professional soccer players^{9,10}.

Although relevant studies investigating soccer match intensity are available, most of them have evaluated friendly games¹¹, simulated games¹² and college games¹³, analyzed a small number of players¹³ and recreational players^{14,15}, or used questionable methods such as laboratory simulations¹. To our knowledge, there are no studies investigating a large number of players during various official games. Moreover, most studies have not evaluated differences among player positions using HR as an intensity parameter in real competitive situations.

Many details can be gained by the fractional analysis of soccer game data and by the evaluation players according to different positions. The importance of the present study lies in the fact that a large number of players were monitored during various official competitive games. Monitoring specific players, a small number of players or only few games does not provide representative data since the physiological demands of players during a game may vary according to opponent, environmental conditions or the tactical preferences of the coach. Therefore, the analysis of more than one game during an official competition should provide representative physiological data that can be used by coaches to better understand the demands of a soccer game.

The determination of maximum effort intensity and anaerobic threshold (AT) intensity permits

to evaluate the intensity of physical activities as the percentage of this maximum. A precise determination of maximum effort permits accurate game intensity monitoring. Therefore, the objective of the present study was to investigate the intensity of real competitive soccer matches, and to determine whether significant differences exist among different player positions using HR as a parameter of effort intensity.

METHODOLOGICAL PROCEDURES

Subjects

The study was approved by the Research Ethics Committee of the Federal University of Minas Gerais (ETIC-476/2004). All procedures, possible risks and benefits of the study were explained to the volunteers before they signed the informed consent form to participate in the experiment.

HR was monitored and analyzed in 26 players of the under-17 (U-17) category (five defenders, six wingbacks, eight midfielders, and seven forwards) in 14 official games (10,035 min), and in 18 players of the under-20 (U-20) category (four defenders, four wingbacks, six midfielders, and four forwards) in 15 official games (10,035 min). The inclusion criteria for this study were that all soccer players should belong to a Brazilian First Division soccer team, participate in regular training sessions (two training sessions per day, about 90 min each, 6 days per week), and compete in official events organized by the Brazilian Soccer Federation (CBF), in this case the state championship. All subjects had an average of 5.5 ± 1.0 years of experience with systematized soccer training. Each player participated in 2 to 8 games over the study. The competitive season comprised the period from April to November. The number of athletes available in each category, except for the goalkeeper, was used for the calculation of sample size.

The HR of the players was recorded at 5-second intervals during the games (Team System, Polar Electro Oy, Kempele, Finland), transferred to a computer, and analyzed with a specific software (Polar Precision Performance SW 3.0, Polar Electro Oy). This system permits HR recording during an activity without the use of a wrist monitor, which is prohibited by soccer rules. Only data from athletes playing both halves of the game were considered for analysis. Data were collected from 6 to 10 players per game. The average environmental conditions during the games were as follows: dry temperature 23.9 ± 2.7 °C (range: 20.30 – 28.55 °C), humid temperature 18.9 ± 2.5 °C (range: 16.63 – 26.83

°C), and globe temperature 31.93 ± 2.36 °C (range: 26.45 – 36.80 °C) considering WBGT 25.03 ± 1.33 °C (range: 21.54 – 29.12 °C) and relative humidity $63.3 \pm 15.9\%$ (range: 45.30 – 82.20%). All matches occurred in the morning between 9 and 11 am. The diet of the players was controlled and monitored by a professional of the soccer team. Before and during the interval of each game the players were encouraged by the researchers to stay hydrated.

Determination of maximum heart rate

HR_{max} was determined as the highest HR seen in one of the three following situations: 1) running a distance of 1000 m at the maximum speed possible¹⁶; 2) running a distance of 2400 m at the maximum speed possible for indirect measurement of VO_{2max} ¹⁷; 3) highest HR achieved during all games. HR monitored during the games is reported as the percentage of HR_{max} ($\%HR_{max}$).

Intensity zones

The intensity of the games is reported as the percentage of game time spent in five different intensity zones as previously described by Helgerud et al.¹⁸: zone 1, < 70% HR_{max} ; zone 2, 70-85% HR_{max} ; zone 3, 85-90% HR_{max} ; zone 4, 90-95% HR_{max} ; zone 5, 95-100% HR_{max} .

HR at the onset of blood lactate accumulation (OBLA) intensity

HR corresponding to the OBLA intensity¹⁹ was obtained in a field test. The test consisted of 2 to 5 runs of 1000 m at a mean initial speed of 10 km/h²⁰. Sixty to 90 seconds after each run, a digital blood sample was collected (25 μ L) for the measurement of blood lactate concentration using the Accusport^o blood lactate analyzer. The test was interrupted if the blood lactate concentration reached or exceeded 4 mM. Otherwise, the volunteer performed another run at a speed that was 1 km/h faster. HR was monitored along the runs and the average was considered for HR determination. The HR corresponding to OBLA was determined by linear interpolation using the Microsoft Excel^o software. The test was performed in the morning (8-10 am) at the following average temperatures: dry temperature 22.1 ± 1.7 °C, humid temperature 19.0 ± 1.5 °C, and globe temperature 29.83 ± 1.26 °C considering WBGT 22.33 ± 1.83 °C and relative humidity $71.36 \pm 8.9\%$.

Maximum oxygen uptake

The VO_{2max} of the athletes was estimated in a field

test which consisted of running a distance of 2400 m in the fastest possible time¹⁷. The determination of VO_{2max} is a routine procedure in the club and this test is regularly used by trainers, with the players thus being familiar with the test.

Each physical test was applied at the beginning of the pre-season training period and was repeated at the end of it. The values shown in Table 1 refer to the second test. Each test was performed at least twice on each occasion. The reliability of these tests in the two situations was high, with the intraclass coefficient (ICC) ranging from 0.92 to 0.99.

Statistical analysis

One-way analysis of variance (ANOVA) followed by the Tukey *post-hoc* test was applied to compare the following situations: a) comparison of intensity between the different phases analyzed in the study (warm-up vs. interval and first vs. second half); b) comparison between intensity zones; c) comparison of effort intensity between different player positions; d) intensity values corresponding to OBLA; e) time spent above OBLA. A power of the test, which refers to its ability to detect differences between groups, of 80% was established and the level of significance was set at $p < 0.05$. The Student t-test for independent samples was applied to compare intensity between categories. The ICC was used to determine the between-subject reliability of the physical tests. All results are reported as the mean \pm standard deviation.

RESULTS

The characteristics of the subjects are shown in Table 1.

Table 1. Characteristics of the subjects. Values are presented as mean \pm sd.

Category	Age (years)	VO_{2max} (mL.kg ⁻¹ .min ⁻¹)	Height (cm)	Body weight (kg)
U-17 (n = 26)	16.4 \pm 0.5	56.1 \pm 2.0	175.1 \pm 6.8	68.1 \pm 4.2
U-20 (n = 18)	18.2 \pm 0.7	59.2 \pm 2.9	178.3 \pm 8.5	70.3 \pm 4.9

U-17 = under-17; U-20 = under-17. Values are reported as the mean \pm standard deviation. Maximum oxygen uptake (VO_{2max}) was assessed using the protocol of Margaria et al.¹⁷.

HR_{max} and mean intensity of the soccer game were 201 ± 9 bpm and $84.4 \pm 5.1\%$ HR_{max} for U-17 players, respectively, and 199 ± 7 bpm and $84.1 \pm 4.1\%$ HR_{max} for U-20 players, with no significant

difference between these two categories ($p>0.05$). Figure 1 shows the different intensity phases of the soccer game (warm-up, first half, half-time, second half).

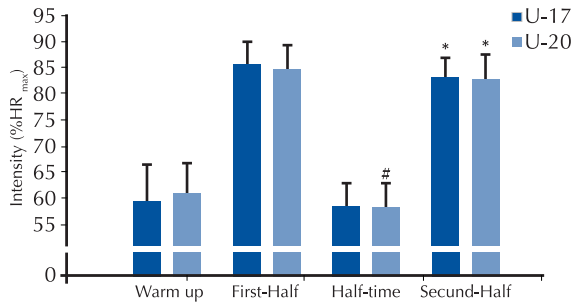


Figure 1. Intensity of the different phases of a soccer game expressed as the percentage of maximal heart rate (%HR_{max}). *Different from the first half; †different from warm-up ($p<0.01$).

Intensity evaluated as the percentage of game time spent in different intensity zones

Since no differences were found between the U-17 and U-20 categories ($p>0.05$), the percentage of game time spent in different intensity zones was analyzed using all data.

Analysis of the different intensity zones showed that most soccer matches are performed in zone 2 ($p<0.05$). The percentage of time spent in zones 3 and 4 was higher than that spent in zones 1 and 5 ($p<0.05$) (Fig. 2).

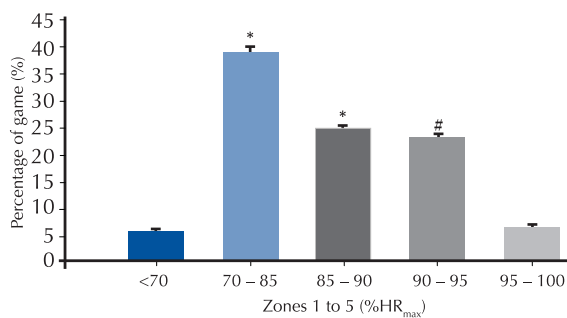


Figure 2. Intensity of soccer games reported as the percentage of game time spent in different intensity zones. *Different from zones 1 = <70% HR_{max}, 3 = 85-90% HR_{max}, 4 = 90-95% HR_{max} and 5 = 95-100% HR_{max}. #Different from zones 1 = <70% HR_{max}, 2 = 70-85% HR_{max} and 5 = 95-100% HR_{max}.

Forwards and wingbacks spent more time in zone 1 than midfielders ($p<0.05$). Forwards also spent more time in zone 2 than midfielders and wingbacks ($p<0.05$). Midfielders presented the highest percentage of time in zone 3 ($p<0.05$) and spent more time in zone 4 than defenders and forwards ($p<0.05$). Interestingly, wingbacks spent more time in zone 5 than forwards ($p<0.05$) (Fig. 3).

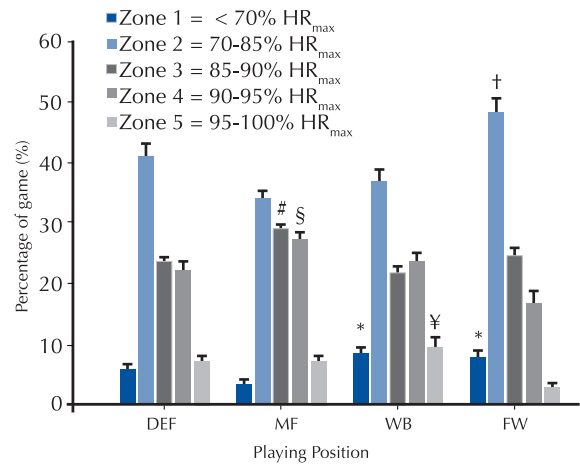


Figure 3. Intensity of soccer games reported as the percentage of game time spent in different intensity zones according to player position. DEF, defenders; MF, midfielders; WB, wingbacks; FW, forwards. Differences: * higher than MF; † higher than MF and WB; # higher than DEF, WB, and FW; \$ higher than DEF and FW; ¥ higher than FW ($p<0.05$).

First and second halves

The percentage of game time spent in zones 1 and 2 was higher in the second half (7.6 ± 0.7 and $43.9 \pm 1.1\%$, respectively) when compared to the first half of the game (4.50 ± 0.62 and $34.52 \pm 2.36\%$, respectively) ($p<0.05$). On the other hand, the percentage of time spent in zones 4 and 5 was higher in the first half (26.91 ± 0.93 and $9.10 \pm 0.93\%$, respectively) than in the second half (19.38 ± 0.85 and $3.83 \pm 0.72\%$, respectively) ($p<0.05$). No difference between the first ($24.96 \pm 0.59\%$) and second half ($25.15 \pm 0.65\%$; $p>0.05$) was observed for zone 3 (Fig. 4).

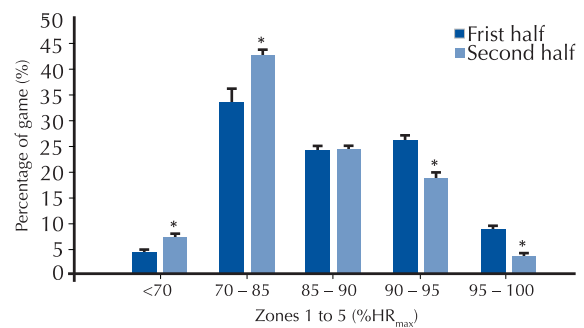


Figure 4. Comparison of the percentage of game time spent in different intensity zones between the first and second halves. *Different from the same zone in the first half ($p<0.05$). Zone 1 = <70% HR_{max}, zone 2 = 70-85% HR_{max}, zone 3 = 85-90% HR_{max}, zone 4 = 90-95% HR_{max}, and zone 5 = 95-100% HR_{max}.

Time above OBLA intensity

The AT of the athletes reported as the intensity corresponding to OBLA was 86.3 ± 4.0 and $87.0 \pm 5.1\%$ HR_{max} for the U-17 and U-20 categories, respectively ($p>0.05$). The mean value for the two categories was $86.6 \pm 4.6\%$ HR_{max}. The percentage

of game time spent above the OBLA intensity was $52.1 \pm 20.3\%$ and $51.3 \pm 19.8\%$ for U-17 and U-20 players, respectively ($p > 0.05$). No differences were observed between the two categories.

DISCUSSION

In the present study, mean soccer game intensity ($\approx 84\% \text{HR}_{\text{max}}$) was similar to OBLA intensity ($\approx 87\% \text{HR}_{\text{max}}$). This intensity can only be maintained because of the intermittent pattern of soccer games, which is characterized by periods of recovery between high intensity efforts³. Wisloff et al.²¹ argued that prolonged activity above the lactate threshold in soccer is not possible because of the long duration of the game. Therefore, no differences were found between U-17 and U-20 categories. Indeed, this is in agreement with the present study in which soccer players remained only 51% of the game above the HR corresponding to the 4-mM threshold.

The soccer game intensities estimated from $\% \text{HR}_{\text{max}}$ in the present study did not differ markedly from those reported in other investigations^{11,22}. Mohr et al.¹¹ reported an intensity of $85\% \text{HR}_{\text{max}}$ during a friendly match of the 4th Danish Division. O'Connor²² evaluated HR during two women's and men's soccer games and also found an intensity of $85\% \text{HR}_{\text{max}}$. However, both studies evaluated friendly games and O'Connor²² did not mention how HR_{max} was determined.

The soccer game intensity observed in the present study was slightly lower than that obtained by Tumilty et al.¹², who evaluated 16 players of an Australian U-20 team and found a mean intensity of $87\% \text{HR}_{\text{max}}$. However, the game studied by those authors was a simulation and HR_{max} was determined in a laboratory situation. Reilly & Keane¹⁵ evaluated senior soccer players and found lower intensities than those observed in the present investigation. In that study, HR_{max} was obtained in a specific field test and the mean intensity was $80\% \text{HR}_{\text{max}}$ during an official game. Although specific maximum effort tests are suitable for the determination of HR_{max} ²³, a previous study from our laboratory showed that HR_{max} is lower in specific field tests than during games²⁴.

A reduction in game intensity occurs during the second half of a soccer game²⁵. Factors influencing fatigue may play a role in this reduction². One possible explanation would be the progressive utilization of glycogen during the game, which decreases performance in the second half³. In the present

study, a decrease of game intensity was observed in the second half (Fig. 1). A similar decline has been reported in other studies^{3,11,20}, even in those evaluating children¹⁴ or simulated games¹². This reduction of game intensity in the second half can be better observed when the percentage of game time spent in low-intensity zones (zones 1 and 2) and high-intensity zones (zones 4 and 5) are compared between the two halves (Fig. 4). This pattern of distribution has also been reported by Helgerud et al.¹⁸ and Orendurff et al.¹³. In the former study, the reduction of game intensity in the second half was attenuated by specific high-intensity aerobic training. In the study of Orendurff et al.¹³, forwards of a college soccer team presented a shorter duration of high-intensity efforts at the end of the second half than at the beginning of the same half.

Although soccer is a team sport, physical training should consider different player positions and different tactical tasks during a game. One of the main findings of the present study was that wingbacks spent more time in zone 5 than forwards ($p < 0.05$) (Fig. 3). This result demonstrates the importance of high-intensity training for these players. Tumilty²⁶, analyzing the evolution of soccer, describes the function of wingbacks to be highly offensive, with these players constantly participating in offensive actions on the sides of the field along with forwards. In addition, these players must also participate in the defensive system, which sometimes implies actions such as sprinting back to cover their opponent. Therefore, since high intensities and short-duration efforts are necessary to win a soccer game, not only forwards but also wingbacks play a key role in these actions in winning a game. Furthermore, this result should be included in physical training programs using appropriate workloads to increase the performance of wingbacks at this intensity level.

Another important finding was that midfielders spent a higher percentage of game time in zone 3 than all other players and more time in zone 4 than defenders and forwards ($p < 0.05$). Orendurff et al.¹³ investigated differences between soccer player positions during a game using step rate as an intensity parameter and obtained results similar to those observed in the present study, with midfielders presenting a similar game pattern characterized by few maximum intensity actions (step rate = 7) and short recovery bouts of moderately high intensity (step rate = approximately 4). This agrees with studies showing a higher aerobic capacity of midfielders^{21,26-28}, who cover a greater distance dur-

ing a game²⁹. These differences can be explained by the fact that these players connect the defensive and offensive systems and play in a larger area of the field^{2,3}. Therefore, the aerobic workload of midfielders should be higher than that of other players to improve their recovery and hence their performance during a match.

Forwards and defenders spent a higher percentage of game time in zone 2 (70-85% HR_{max}) than players from other positions. Since they spent a high percentage of time in this intensity zone, they remained less time in other intensity zones when compared to midfielders and wingbacks. The similarity in the intensity distribution of forwards and defenders might be explained by the specificity of their tasks during the game, with these players performing similar efforts in the same sector of the field using a similar movement pattern as reported by Tumilty²⁶. These players participate in crucial moments of the game that are characterized by high-intensity and short-duration efforts².

In one of the few studies that compared the percentage of game time spent in different intensity zones, Reilly & Keane¹⁵ evaluated senior players during a competitive match. The players analyzed in the present study spent a higher percentage of game time in higher intensity zones than the subjects evaluated by these authors. This finding might be expected considering the lower aerobic fitness and older age of the players in the study of Reilly & Keane¹⁵ compared to the present subjects. Helgerud et al.¹⁸ evaluated Nordic junior soccer players during two soccer games and monitored their HR, which was classified into the same five intensity zones as used in the present study. The Nordic players spent more time in zone 3 than the Brazilian players analyzed here. On the other hand, the present subjects spent a higher percentage of time in zones 2 and 4, suggesting differences in the game pattern between the two teams. However, Helgerud et al.¹⁸ determined HR_{max} in a laboratory test and evaluated only two games performed on artificial grass and in a closed environment.

Since the present study only investigated the U-17 and U-20 categories, the results may not be extrapolated to a different category. Moreover, since the study was conducted in a real competitive situation dehydration could not be controlled. Finally, each player participated in a variable number of two to eight games over the study, mainly because of high-performance sport issues such as injuries or the tactical system adopted in the championship. Since soccer game intensity is influenced by the opponent

as well as by the tactical preference of the coach, the range of games analyzed per player should be taken into account when interpreting the present findings.

CONCLUSIONS

In summary, soccer match intensity is similar to OBLA intensity, with no differences between U-17 and U-20 categories. Wingbacks spent a higher percentage of game time in the highest intensity zone than forwards in a real competitive situation. These data should be included in specific training programs addressing the tactical positions of players. In the case of wingbacks, the objective is to increase performance at short-duration, high-intensity efforts since the outcome of a game is decided at these moments.

Midfielders are the players who most spent time in zone 3. In addition, they spent a higher percentage of game time in zone 4 than defenders and forwards, suggesting higher aerobic requirements of these players. This higher requirement of aerobic activities should be included in the physical training of midfielders to improve their recovery and, consequently, their performance. Intensity distribution was similar in defenders and forwards, a finding that might be explained by the specificity of their tasks in the game, with these players presenting similar efforts in the same sector of the field using a similar movement pattern.

Acknowledgements

We thank CAPES, CNPq, FAPEMIG, and the Brazilian Ministry of Sports for financial support.

REFERENCES

1. Bangsbo J, Lindquist F. Comparison of various exercise tests with endurance performance during soccer in professional players. *Int J Sports Med* 1992;13(2):125-32.
2. Rienzi E, Drust B, Reilly T, Carter JEL, Martin A. Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *J Sports Med Phys Fitness* 2000;40(2):162-9.
3. Bangsbo J. The physiology of soccer, with special reference to intense intermittent exercise. *Acta Physiol Scand* 1994;619(Suppl.):1-155.
4. Bangsbo J. Energy demands in competitive soccer. *J Sports Sci* 1994;12:S5-12.
5. Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. *Sports Med* 2005;35(6):501-36.
6. Hilioscopi HK, Pasanen ME, Fogelholm MG, Laukkanen RM, Manttari AT. Use of heart rate to predict energy expenditure from low to high activity levels. *Int J Sports Med* 2003;24(5):332-6.

7. Howley ET, Basset DR, Welch HG. Criteria for maximal oxygen uptake: review and commentary. *Med Sci Sports Exerc* 1995;27(9):1292-301.
8. Karvonen J, Vuorimaa T. Heart rate and exercise intensity during sports activities. Practical application. *Sports Med* 1988;5(5):303-12.
9. Impellizzeri F, Rampinini E, Marcora S. Physiological assessment of aerobic training in soccer. *J Sports Sci* 2005;23(6):583-92.
10. Achten J, Jeukendrup AE. Heart rate monitoring: applications and limitations. *Sports Med* 2003;33(7):517-38.
11. Mohr M, Krstrup L, Nybo L, Nielsen JJ, Bangsbo J. Muscle temperature and sprint performance during soccer matches – beneficial effect of re-warm-up at half-time. *Scand J Med Sci Sports* 2004;14(3):156-62.
12. Tumilty D. The relationship between physiological characteristics of junior soccer players and performance in a game simulation. In: *Science and Football II*, London: E & FN Spon; 1993. p. 281-286.
13. Orendurff MS, Walker JD, Jovanovic M, Tulchin KL, Levy M, Hoffmann DK. Intensity and duration of intermittent exercise and recovery during a soccer match. *J Strength Cond Res* 2010;24(10):2683-92.
14. Capranica L, Tessitore A, Guidetti L, Figura F. Heart rate and match analysis in pre-pubescent soccer players. *J Sports Sci* 2001;19(6):379-84.
15. Reilly T, Keane S. Estimation of physiological strain on Gaelic football players during match-play. In: *Science and Football IV*, London: E & FN Spon, 2002. p. 157-159.
16. Pini MC. *Fisiologia do Esporte*, 2nd ed, Rio de Janeiro: Guanabara Koogan; 1993.
17. Margaria R, Aghemo P, Pinera LF. A simple relation between performance in running and maximal aerobic power. *J Appl Physiol* 1975;38(2):351-2.
18. Helgerud J, Engen LC, Wisloff U, Hoff J. Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc* 2001;33(11):1925-31.
19. Sjodin B, Jacobs I. Onset of blood lactate accumulation and marathon running performance. *Int J Sports Med* 1981;2(1):23-26.
20. Smith M, Glarke G, Hale T, McMorris T. Blood lactate levels in college soccer players during match-play. In: *Science and Football II*, London: E & FN Spon, 1983. p. 129-134.
21. Wisloff U, Helgerud J, Hoff J. Strength and endurance of elite soccer players. *Med Sci Sports Exerc* 1998;30(3):462-7.
22. O'Connor DT. Motion analysis of elite touch players. In: *Fourth World Congress of Science and Football*, Sydney. London: E & FN Spon; 2002. p. 126-136.
23. Boudet G, Garet M, Bedu M, Albuisson E, Chamoux A. Median maximal heart rate for calibration in different conditions: laboratory, field and competition. *Int J Sports Med* 2002;23(4):290-7.
24. Antonacci L, Mortimer LACF, Rodrigues V, Coelho DB, Soares DD, Silami-Garcia E. Competition, estimated, and test maximum heart rate. *J Sports Med Phys Fitness* 2007;47(4):418-21.
25. Mortimer LACF, Condessa L, Rodrigues V, Coelho DB, Soares DD, Silami-Garcia E. Comparison between the effort intensity of young soccer players in the first and second halves of the soccer game. *Rev Port Cien Desp* 2006;6(2):154-9.
26. Tumilty D. Physiological characteristics of elite soccer players. *Sports Med* 1993a;16(2):80-96.
27. Shephard RJ. The energy needs of the soccer player. *Clin J Sport Med* 1992;2(1):62-70.
28. Casajús AJ. Seasonal variation in fitness variables in professional soccer players. *J Sports Med Phys Fitness* 2001;41(4):463-9.
29. Caixinha PF, Sampaio J, Mil-Homens PV. Variação dos valores da distância percorrida e da velocidade de deslocamento em sessões de treino e em competições de futebolistas juniores. *Rev Port Cien Desp* 2004;4(1):7-16.

Endereço para correspondência

Daniel Barbosa Coelho
 Federal University of Minas Gerais
 School of Physical Education, Physiotherapy and
 Occupational Therapy
 Physiology Exercise Laboratory
 Av. Antônio Carlos, 6627, 31270-901 - Belo
 Horizonte, MG. Brazil
 E-mail: danielcoelhoc@bol.com.br