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Individual vs General Time-Motion Analysis and Physiological Response in 4 vs 4 and 5 vs 5 Small-Sided Soccer Games

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Abstract

The purposes of this study were to present a new time-motion analysis approach in soccer small-sided games by incorporating the physical potential of individual players and to evaluate the physiological response applied to 4 vs. 4 and 5 vs. 5 small-sided games. Thirteen professional soccer players participated in small-sided game training sessions. The physical demands (GPS) and physiological responses (Heart Rate – HR) of the 4 vs. 4 and 5 vs. 5 small-sided games were compared. In contrast to previous studies, speed zones were divided individually for each player according to his maximal running speed (Smax) and running velocity at the lactate threshold (V/LT). The analyses confirmed that the mean V/LT of the player was 3.8 ± 0.16 m·s^{-1} and the Smax speed was 8.26 ± 0.65 m·s^{-1}. The total distance covered during the 4 vs. 4 games was significantly longer than that covered during the 5 vs. 5 games. The application of obligatory limits for speed zones could result in an inappropriate assessment of the players' commitment during training. Utilizing an individual assessment of player motion during small-sided games can improve the optimization of training load application.

Key words: 4 vs. 4 and 5 vs. 5 small-sided games, individualization, interval training.

1. Introduction

During soccer matches, players perform varying acyclic activities at differing intensities. Therefore, soccer training should involve exercises that develop every component of physical fitness. In recent years, small-sided games have become the most popular training drill for simultaneously improving fitness and technical skills (Hill-Haas et al. 2011). Previous research has shown that small-sided game training may be an effective substitute for traditional interval running training for developing maximal oxygen consumption (Radziminski et al. 2013; Hill-Haas et al. 2009b; Chamari et al. 2005; Koklu, 2012). However, the efficiency of this training form is dependent on many factors. Previous studies (Hill-Haas, 2011; Iaia et al. 2009) have demonstrated that game intensity should be approximately 90-95% of the maximal heart rate (%HRmax). According to Rampinini et al., (2007c) factors such as pitch size, the number of players, the rules of the game, and coach encouragement may influence the intensity of small-sided games. Moreover, Kelly and Drust (2009) observed that pitch size during small-sided games alters a number of important technical skills required for match play. The large number of variables influencing game intensity contributes to the fact that only accurate game monitoring can guarantee the effective improvement of player physical fitness.

New technologies available in sport sciences now allow for the monitoring of physiological (heart rate) and physical (distance covered in different speed zones) responses in real time. The small global positioning system (GPS) devices worn in recent years by soccer players provide information about distance covered, running speed, and number of accelerations and jumps. The analysis of these efforts allows for a precise assessment of the training load of each player.

To ensure that this evaluation is valid, individual criteria of the time-motion analysis should be applied. There are only few studies including time-motion analyses considering individual values of physiological response and running speed. Harley et al. (2010) proposed to normalize speed zones according to "flying" 10 m sprint times measured between 10 m and 20 m for different age-groups. Another proposition of individualization of the speed thresholds was suggested by Buchheit et al. (2010). Sprint activities in this study were defined as at least 1-s run at intensity higher than 61% of individual peak running velocity. However, most studies that analyze the movement of soccer players on the field differentiate distances into running speed categories as follows: standing/walking, jogging, low-intensity running (LIR), high-intensity running (HIR), and sprinting. However, there is some inconsistency in determining the speed limits for each speed zone. Dellal et al. (2011) characterized a sprint as a running speed greater than 4.72 $m \cdot s^{-1}$ (17 $km \cdot h^{-1}$), whereas Casamichana et al. (2013) defined it as greater than 5.83 $m \cdot s^{-1}$ (21 $km \cdot h^{-1}$). Other authors accepted a speed of 6.67 $m \cdot s^{-1}$ (24 $km \cdot h^{-1}$) (Dellal et al. 2010) or even 8.33 $m \cdot s^{-1}$ (30 $km \cdot h^{-1}$) (Mohr et al. 2003). Reported maximal running speed values for soccer players are 31-32 $km \cdot h^{-1}$ (Haugen et al. 2013; Rampinini et al. 2007a; Rampinini et al. 2007b). Therefore, the range of speed zones considered as sprint in cited studies was between 53 – 94% of maximal running speed for soccer players. Such discrepancies lead to difficulties in accurate comparisons of kinematic results. Therefore, determining the precise limits for these speed zones seems highly justified. Common knowledge would suggest that player speed depends on individual energy potential. Therefore, creating a division of speed zones that refers to this potential should be an important task for scientists and coaches working on training optimization in soccer.

The purposes of this study were to present an individual time-motion analysis approach in soccer small-sided games by incorporating the physical potential of individual players and to evaluate the physiological response applied to 4 vs. 4 and 5 vs. 5 small-sided games. Additionally, the individual time-motion analysis was compared with two general analysis proposed by Di Salvo et al. (2007) and Rampinini et al. (2007b).

2. Methods

2.1. Participants

During first experimental training session sixteen adult, professional soccer players took part in 4 vs 4 small sided games in total. In the second week (5 vs 5 small-sided games) twenty players were involved during the training session. However, only thirteen (mean ± SD: age, 27.1 ± 5.2 y; stature, 182.5 ± 5.2 cm; body mass, 77.2 ± 6.2 kg) players, who complete all eight games, were finally analyzed in the study. All the subjects passed their pre-season medical examinations and had their actual sportsmen medical cards. Their typical weekly training included 5-7 training sessions and 1 league game. The study was approved by the Ethical Committee of the Regional Medical Chamber.

2.2. Study design

Small-sided games were performed on Tuesdays in the second and third week of a competitive season. All the games were played on the same natural pitch at the same time of the day and in similar atmospheric conditions (i.e., wind < 1 $m \cdot s^{-1}$, temperature of 18-21 °C, 40-48% humidity, and atmospheric pressure of 1009-1014 Hpa). Before the games, the players performed a 10-minute warm up followed by dynamic exercises with balls.

During first experimental training session players participated in four small-sided games 4 vs. 4. In the second week, four bouts of 5 vs. 5 small-sided games were applied to the players. Data from thirteen players who completed all the games were analyzed. All games were played with goalkeepers. As in previous publications (Impellizzeri et al,. 2006; McMillan, Helgerud, Macdonald & Hoff, 2005), small-sided games were performed in an interval format (4 x 4 min, 2 min of active recovery). The pitch sizes were designed intentionally to keep the pitch area per player similar. The physical demands (GPS) and physiological responses (Heart Rate – HR) of the 4 vs. 4 and 5 vs. 5 small-sided games were compared.

2.2.1. Small-sided games

The subjects participated in small-sided game training sessions at least 72 hours after the match and after a day of recovery. During each session four small-sided games (SSG1, SSG2, SSG3, and SSG4) were completed by the players. In the first week, 4 vs. 4 games including goalkeepers were played on a 40 x 30 m pitch (120 m^2/player). The next week, 5 vs. 5 games with goalkeepers were played on a 43 x 33 m pitch (area per player -118.3 m^2). All the games were performed on natural grass. No modifications or limits regarding rules (e.g., the number of contacts with a ball) were imposed. During each game, the coaches actively motivated the players to increase their effectiveness (Rampinini et al., 2007c). When the ball went out of the playing area, assisting coaches near the pitch supported the players with another ball to minimize game breaks. The heart rate responses during the small-sided games were recorded in 5-s intervals using telemetry devices (Polar Team Sport System; Polar Electro OY, Kempele, Finland).

2.2.2. Lactate Threshold Determination

Individual lactate threshold of the player was determined as previously described (Radziminski et al. 2010) on a synthetic field at the beginning of a competitive season, 1 week before the first small-sided game training session. The test protocol included 3.5–

5 min running stages separated by a 1-min rest, during which a capillary blood sample was taken from the fingertip. The initial speed was set at 2.8 $m \cdot s^{-1}$ and increased by 0.4 $m \cdot s^{-1}$ after each stage until exhaustion. The Dmax method (Cheng et al., 1992) was used to determine the lactate threshold (V/LT) running velocity, and HR/LT. Blood samples were analyzed for lactate concentration by an EPOLL 20 spectrophotometer (Serw-med s.c. brand, Poland). Moreover, the maximal heart rate (HRmax) was determined during the test. If a higher HR value was observed during the small-sided games, the higher value was used as the HRmax.

2.2.3. Time-Motion Characteristics

The distance covered within small-sided games was measured using previously validated (Castellano et al. 2011; Varley et al. 2012) portable GPS devices (minimaxX version 4.0, Catapult Innovations, Melbourne, Australia) with a frequency of 10 Hz and analyzed using specialized software (Catapult Sprint 5.0, Catapult Innovations, 2010). During the games, the players wore vests with GPS devices placed on the upper back. As recommended in on the instructions, the GPS devices were activated 15 min before starting the training session.

Speed zones were divided individually for each player according to his maximal running speed (Smax) and running velocity at the lactate threshold. Smax was determined using the same GPS device during a 40-m sprint. Previous research has shown that this distance is adequate to achieve maximal speed in adult athletes (Buchheit, Simpson, Peltola, & Mendez-Villanueva, 2012). After the warm-up, the participants performed this sprint twice with 5 min of active recovery between sprints. The highest recorded speed value was considered the Smax.

We defined a sprint as a running velocity at 80% of Smax or higher, and HIR as a running velocity between V/LT and 80% Smax. These criteria ensure that the speed zones were assigned individually according to the potential of each player. Finally, the following speed zones were assumed: I - standing/walking (0 - 1 $m \cdot s^{-1}$), II - walking/jogging (1 - 2 $m \cdot s^{-1}$), III - LIR (2 $m \cdot s^{-1}$ ÷ V/LT), IV - HIR (V/LT - 80% Smax), and V - sprinting (>80% Smax)

Moreover, the results of our study were calculated according to speed zones included in studies of Di Salvo et al. (2007) (328 citations) and Rampinini et al. (2007b) (239 citations). Di Salvo et al. used in their study a multiple-camera match analyses system – Amisco Pro® (version 1.0.2, Nice, France). Rampinini et al. proposed in their study the speed zones division based on semi-automatic video match analysis image recognition system – ProZone® (Leeds, England, Tab.1).

Table 1. The division of speed zones used by other authors.

Di Salvo et al. (2007) Amisco Pro®	I Standing, walking, jogging	II Low speed runing	III Moderate-speed runing	IV High-speed runing	V Sprinting
	0-11 km·h^{-1} 0-3.06 m·s^{-1}	11.1-14 km·h^{-1} 3.06-3.89 m·s^{-1}	14.1-19 km·h^{-1} 3.89-5.28 m·s^{-1}	19.1-23 km·h^{-1} 5.28-6.39 m·s^{-1}	>23 km·h^{-1} >6.39 m·s^{-1}
Rampininin et al. (2007b) ProZone®	I Standing, walking	II Jogging	III Running	IV High-speed running	V Sprinting
	0-7.2 km·h^{-1} 0-2 m·s^{-1}	7.2-14.4 km·h^{-1} 2-4 m·s^{-1}	14.4-19.8 km·h^{-1} 4-5.5 m·s^{-1}	19.8-25.2 km·h^{-1} 5.5-7 m·s^{-1}	>25.2 km·h^{-1} >7 m·s^{-1}

2.3. Statistical analyses

All the results are presented as the mean ± SD. All the data sets were assessed using the Shapiro-Wilk test for normal distributions. A *t*-test for independent variables was used to evaluate the differences between 4 vs. 4 and 5 vs. 5 small-sided games. The Wilcoxon signed ranks test was conducted when the normality of the data distribution was disturbed. Levene's test was used to evaluate the homogeneity of the variances. Repeated-measures ANOVA was applied to assess the differences between the bouts. Moreover, ANOVA for independent variables was used to compare the results of different time-motion analyses. All statistical analyses were performed using the Statsoft, Inc. STATISTICA version 9.0 software (Statsoft, Tulsa, OK). The level of significance was set at $p < 0.05$.

3. Results

The analyses confirmed that the mean V/LT of the player was 3.8 ± 0.16 m·s^{-1} and the Smax speed was 8.26 ± 0.65 m·s^{-1}. Based on these results, the individual speed zones were determined according to the previously stated criteria. The intensity of physical effort, expressed as %HRmax, was 89–91% for both games. Similarly, during games played at an intensity greater than LT, the analysis showed that the total distance covered during the 4 vs. 4 game was significantly longer than that covered during the 5 vs. 5 game (p<0.05 for SSG1, SSG3, and SSG4). The longest distance was covered during the first 4 vs. 4 games (583.3 ± 42.44 m). However, the longest jogging distance was covered during the 5 vs. 5 games (p<0.05 for SSG2), but the longest distances of both LIR (p<0.05 for SSG1, SSG3, and SSG4) and HIR were covered during the 4 vs. 4 game; the latter differences did not reach significance. Sprints covered the shortest distance during both the 4 vs. 4 and 5 vs. 5 games (0.5 – 4.2 m). The significant differences between the results of different approaches to the time-motion analysis were noted. The distances covered by the players in speed zones I, II, III, and IV calculated individually differed considerably from the values obtained using zones suggested by Di Salvo et al. (2007) and Rampinini et al. (2007b).

Table 2. A comparison of distance covered in each speed zone in 4 vs 4 and 5 vs 5 small-sided games (*significantly different from 5 vs. 5; p<0.02).

Speed zone	4 vs 4 [m]	5 vs 5 [m]
I	163.2 ± 36.79	180.7 ± 43.83
II	572.77 ± 58.25*	612.5 ± 34.01
III	1175.9 ± 243.79*	948.4 ± 145.62
IV	416.0 ± 105.36	363.0 ± 92.90
V	5.9 ± 8.61	8.61 ± 20.45
Total	2307.7 ± 191.66*	2118.5 ± 151.48

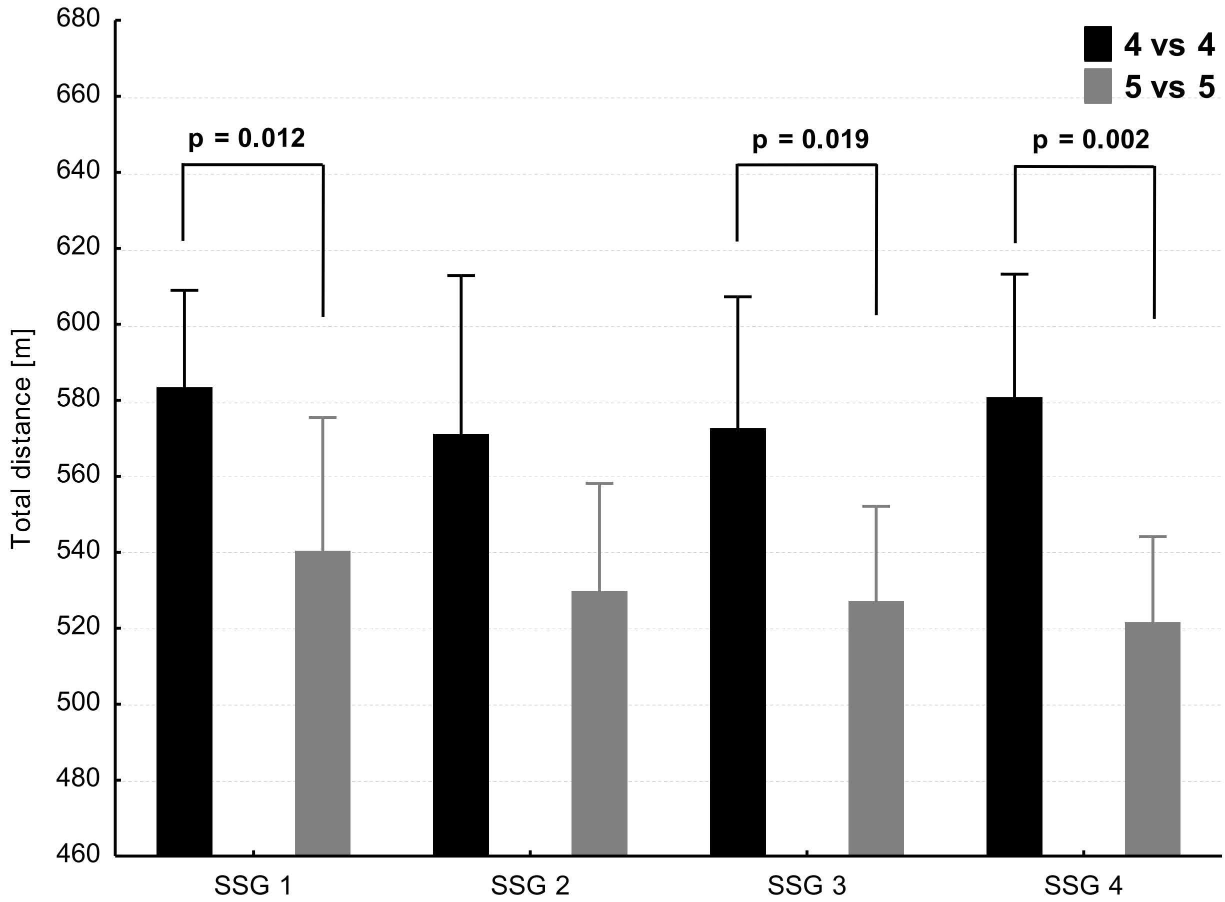

Figure 1**.** Total distance covered in the 4 vs. 4 and 5 vs. 5 small-sided games.

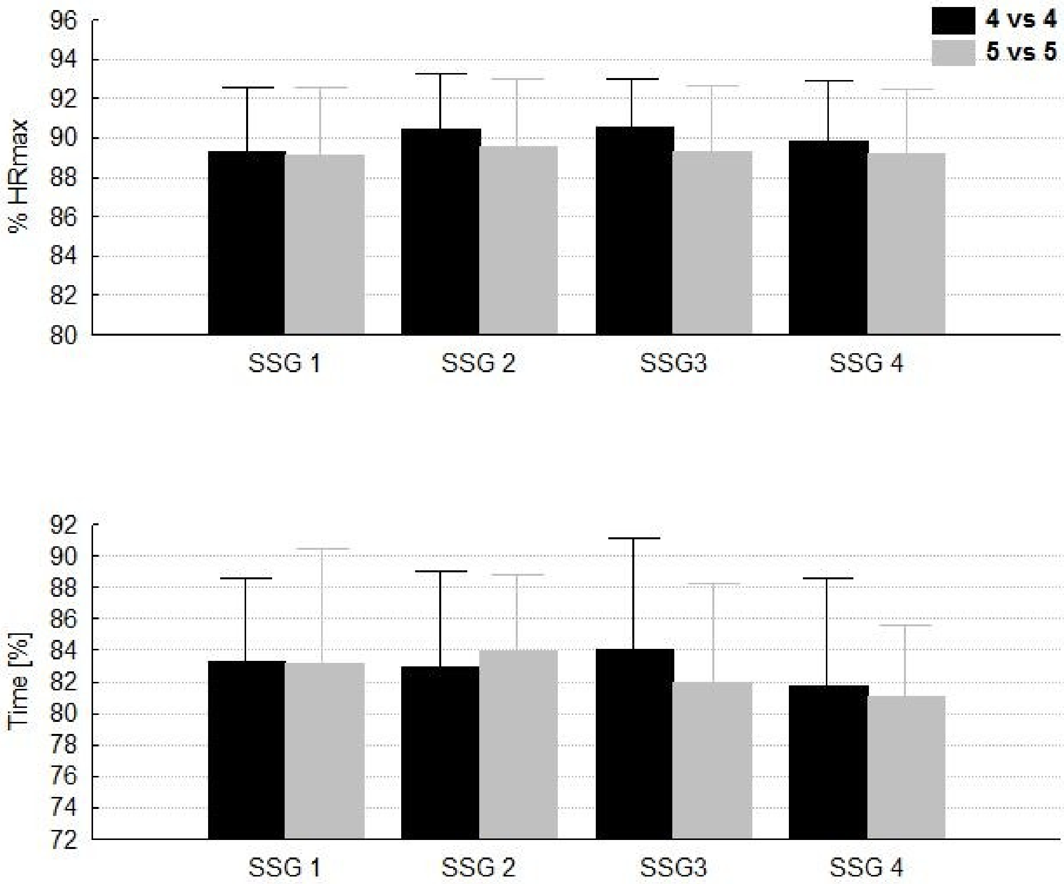

Figure 2. Mean values of HR response (%HRmax) and percentage of time played at >HR/LT in each of the small-sided games.

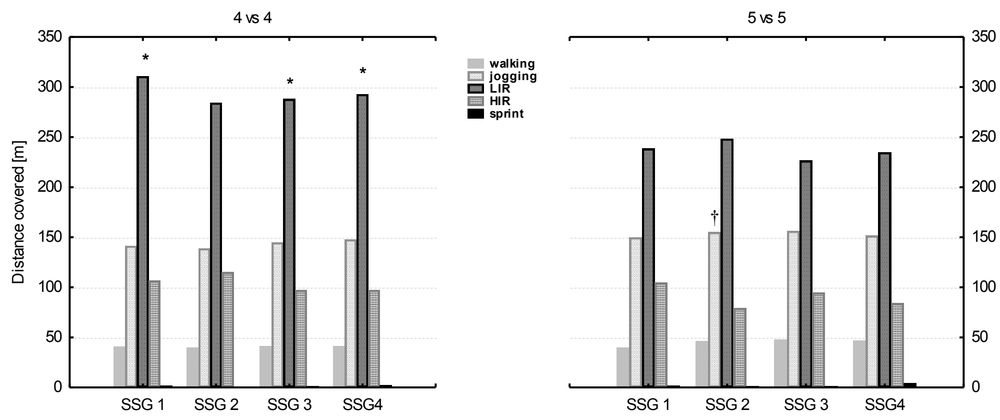

Figure 3. Total distance covered in each speed zone during the 4 vs. 4 and 5 vs. 5 small-sided games. *significantly longer distance compared with 5 vs. 5 ($p<0.05$), †significantly longer distance compared with 4 vs. 4 ($p<0.05$).

4. Discussion

The main purpose of our study was to present an individual time-motion analysis of small-sided games by incorporating individual player potential. Moreover, different approaches of time-motion analyses were examined. The practical purpose was to evaluate the physiological response and compare the physical demands of 4 vs. 4 and 5 vs. 5 small-sided games. The results of this study indicate that the total distance covered during the 4 vs. 4 games was significantly longer than in the 5 vs. 5 games, despite maintaining a constant pitch area per player. The largest differences were noted in the LIR zone (2 $m \cdot s^{-1}$ – V/LT). Moreover, running velocity defined as sprint was rarely observed during small-sided games. To the best of our knowledge, this study is the first in which an individual division of players' speed zones was applied to small-sided games. We found significant differences between the results of different approaches to the time-motion analyses in the distance covered in different speed zones. In our opinion, establishing equal criteria according to players' individual potential would enable to compare the results of time-motion analyses. Evaluation of physiological response during small-sided games according to individual players' potential, provide a lot of valuable information. When players with the same level of V/LT (e.g. 4 $m \cdot s^{-1}$) cover significantly different distance in HIR zone, it might be the result of fatigue or different motivation level. Therefore, individual approach in time-motion analyses seems to be appropriate and give more information about physical effort of each player.

In previous studies, different speed zones were applied by the authors (Dellal et al., 2011; Casamichana et al., 2013; Dellall,et al., 2010; Impellizzeri et al., 2006; Casamichana and Castellano, 2010; Hill-Haas et al. 2009a). However, in most of these papers, the proposed speed zones did not consider the individual potential of the players. Such an approach both ensures the difficulty of replicating the research and makes comparisons of the results from different authors almost impossible. Dellal et al. (2011) tested elite soccer players and found that the distance covered by sprinting during a 4 vs. 4 small-sided game was between 76.5 and 140.7 m. They defined a sprint as a running speed greater than 17 $km \cdot h^{-1}$ (4.72 $m \cdot s^{-1}$). According to previously reported maximal running speed results (Haugen et al., 2013; Rampinini et al., 2007a; Rampinini et al., 2007b) this value is only 53 – 55% of soccer player' Smax and 57% of Smax presented in this study. In our research, the lowest speed value considered a sprint (80% Smax) for the player with the lowest speed potential was 5.5 $m \cdot s^{-1}$. This finding explains the differences in the distances covered in the sprint zone. In contrast, Mohr et al. (2003) defined a sprint as running with a velocity greater than 30 $km \cdot h^{-1}$ (8.3 $m \cdot s^{-1}$). In our opinion, this value is unattainable for many players, especially young ones. The short distance covered in sprinting in our small-sided games seems to be typical for this training drill. Buccheit et al. (2012) claimed that adult players reach their maximum speed between 30 and 40 m at Smax. During games played on a reduced pitch area, this level of effort is very rare. Long distance sprints rarely occur even during matches played on a full-size pitch; only 4% of sprints performed during the match are longer than 30 m (Valquer, Barros & Sant'anna, 1998).

Currently, there is a lack of papers concerning individualized speed zones. Abt and Lovell (2009) proposed that a running velocity above the ventilatory threshold (VT_{2speed}) should be considered HIR during a soccer match. They defined the VT_{2speed} as the point at which there was an abrupt increase in the ventilatory equivalent for oxygen ($VE \cdot VO_2^{-1}$) and carbon dioxide ($VE \cdot VCO_2^{-1}$), together with a decrease in the end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$). They compared the total distance traveled at a running speed greater than VT_{2speed} with the distance arbitrarily considered the HIR by a semi-automatic match analysis system (ProZone®, Leeds, UK). The authors revealed that the individual high-intensity speed threshold is 1.33 $m{\cdot}s^{-1}$ lower than the value proposed by ProZone®. Their VT_{2speed} value was 4.17 $m{\cdot}s^{-1}$ (15 $km{\cdot}h^{-1}$), which is higher than our results for V_{LT} by approximately 0.4 $m{\cdot}s^{-1}$. However, these authors used a laboratory treadmill test to determine the border speed, but in our research a natural grass surface was applied. Previous work (Di Michelle et al. 2009) has suggested that the same subjects achieve significantly higher running speed at 4 $mmol{\cdot}l^{-1}$ LA when performing on a mechanical treadmill than on a synthetic surface.

In the other study, authors Lovell & Abt (2013) used a similar speed zone categorization for soccer matches. Using arbitrary speed thresholds, they noticed that 2 middle halfbacks cover similar distances at high-speed-running and at very high-speed-running (differences of 5–7%). However, when individual speed zones were considered, the analysis showed that one of the players covered a 41% longer distance in high-speed-running than the other player. This finding shows that an individual approach to time-motion analysis provides more detailed information about the relative workload for each player.

In our study, an individual time-motion analysis was applied for 4 vs. 4 and 5 vs. 5 small-sided games. Such games are one of the most commonly used forms of soccer-specific practice. No relevant differences in the physiological response during the games were stated for either format. However, despite the similarities in the intensity of physical effort and the time of performance above HR/LT for both forms, slightly higher values of HRmax were observed in all 4 bouts of the 4 vs. 4 game. Our research shows that the intensity of both game formats was approximately 90% HRmax. According to Hoff and Helgerud (2004), such intensity is required for improvements in aerobic fitness. Although the area per player was similar for both forms of the game, the total distance covered during the game was significantly longer for the 4 vs. 4 games. Dellal et al. (2011) studied soccer players that were subjected to similar drills before the final world championships match. The average distance covered by the players was between 597 and 835 m, depending on the rule modifications. The longer distance could be an effect of imposing a limited number of contacts with the ball and introducing 4 neutral players around the playing area who were permitted 1 contact with the ball. Moreover, the limited number of contacts with the ball requires the greater engagement of the players without the ball to enable passing by the player in possession. The size of the playing area, at 30 x 20 m (75 m^2/player without the goalkeeper), was also an important factor.

According to previous publications it can be assumed that presented in this study criteria of speed zones division are compatible with physiological determinants. Due to high-intensity of the game, appropriate pitch size and players number, small-sided games are often used to improve physical fitness of the players. Individual time-motion analysis showed that the players cover 24% of total distance in HIR during 4 vs 4 games and 17.2% during 5 vs 5 games. In contrast, using the speed zones division proposed by

Di Salvo et al. (2007) only 2.1% and 2.8% of total distance was covered in HIR. When applying zones published by Rampinini et al. (2007b) results for 4 vs 4 and 5 vs 5 games are 1.6% and 2.5% respectively. In our opinion, non-individual time-motion analysis does not express properly the distances covered by players during small-sided games. Time-motion analysis with the application of speed zones division proposed by Amisco Pro® and ProZone® shows that 83 – 86% of total distance was covered in two lowest speed zones (Figure 1 and 2). However, the mean HR values were between 89 and 91% of HRmax. There were no significant differences between analysis approaches only in distance covered in the highest zone (sprinting).

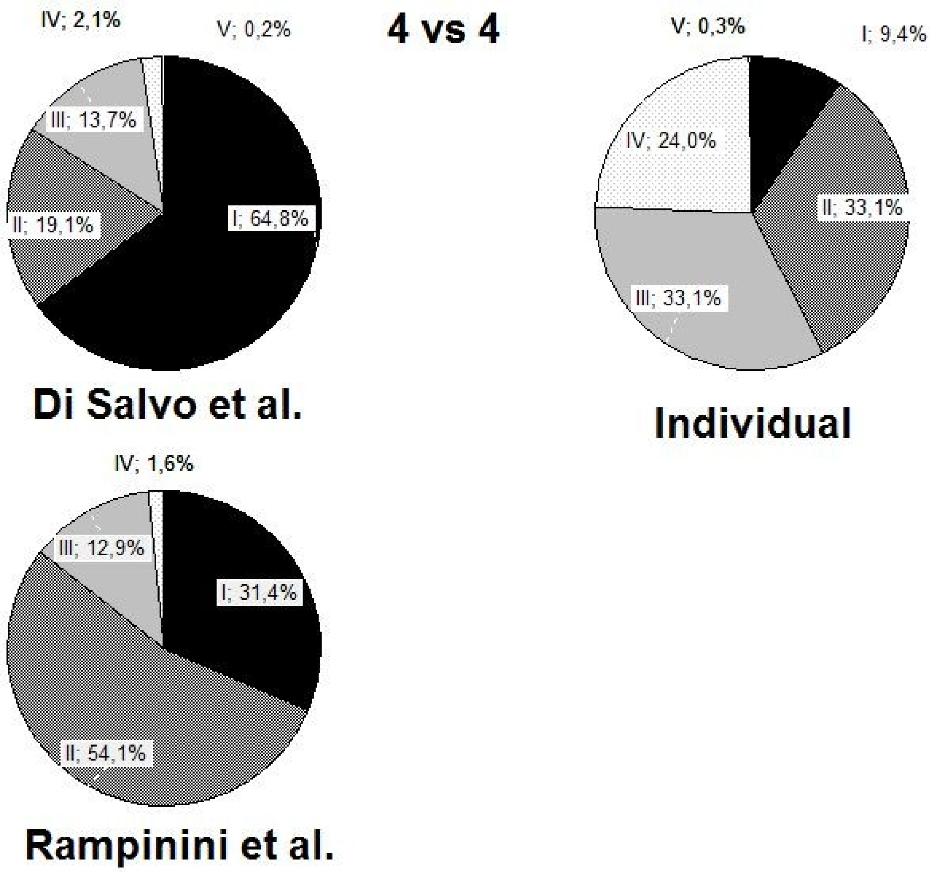

Figure 4. Distance covered by the players in each speed zone during 4 vs 4 small-sided games.

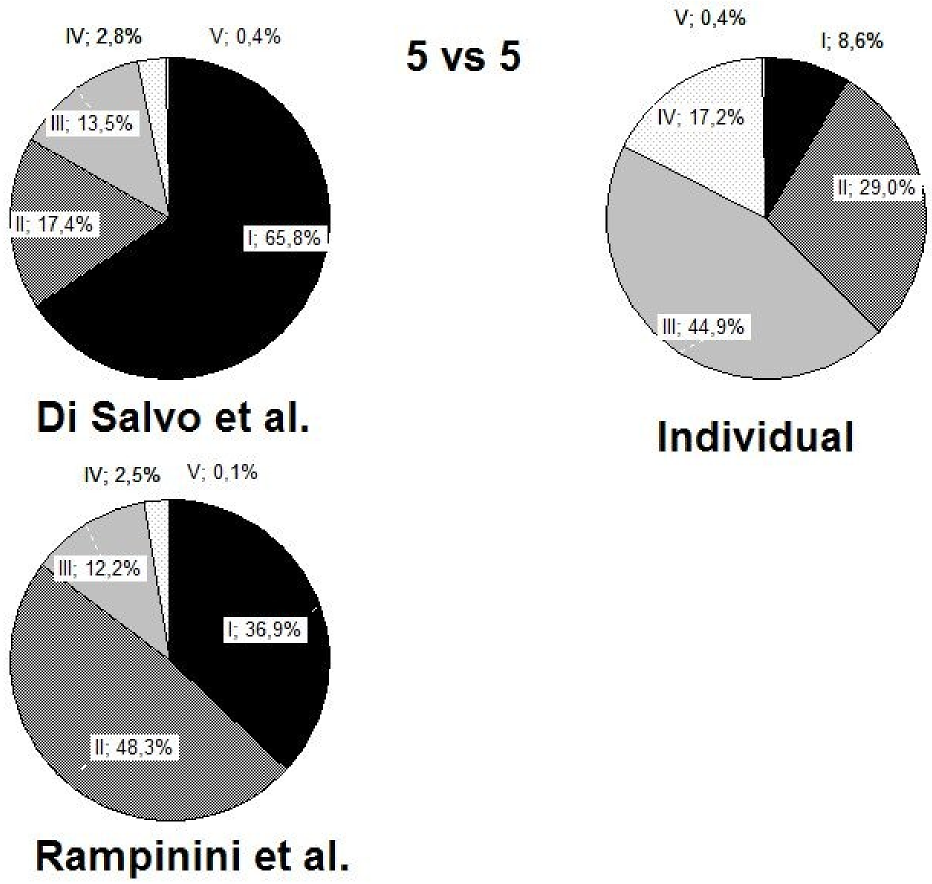

Figure 5. Distance covered by the players in each speed zone during 5 vs 5 small-sided games.

In our studies, the greatest differences in covered distances were observed in the LIR category. For this speed zone, the players covered a distance 14-30% longer during the 4 vs. 4 games. LIR comprises both jogging and accelerations over short distances in which higher speed has not yet been achieved. The inclusion of fewer participants in the 4 vs. 4 games requires greater engagement of the player and more frequent positioning to enable ball passes. Moreover, Castelao et al. (2014) claim that modifying the number of participants in soccer small-sided games changes tactical behavior of the payers. These outcomes are likely to underlie the significant differences observed in the covered distances within this speed zone. Considering the results of our study and other works, the assessment of the motion of soccer players during small-sided games could be considered to be difficult to compare if varying criteria are used. Application of individually matched speed zones with reference to Smax and V/LT enables comparison of the motion results of the players subjected to the same training tasks (small-sided games).

In our opinion, introduction of an individual assessment of player motion during small-sided games has a great applicable value. It can improve the optimization of training load application by providing an objective and individual assessment of physical abilities of the player. The fact that some authors assume static speed values precludes an accurate assessment of running abilities of a player. When the sprint speed limit is set too high, some players are unable to reach it and are underestimated in terms of running speed. Similar mistakes could be observed when the length of the covered distance within HIR is considered. The application of obligatory limits for speed zones could result in an inappropriate assessment of the players' commitment during training. Each player has an individual physical potential; therefore, the assessment should include his abilities. Such an approach could contribute to a more precise programming of the training load and avoid overtraining. Moreover, an important advantage of this assessment procedure is that it enables the comparison of the results of soccer players at different levels.

In conclusion, both the 4 vs. 4 and 5 vs. 5 games, performed on a pitch of approximately 120 m^2/player, are recommended for training at 90% HRmax. Games on a smaller pitch could not be considered a means of developing Smax speed as the players can rarely reach a high running speed on a constrained surface.

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