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Variations of external load variables between medium- and large-sided soccer games in professional players

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ABSTRACT
This study compared the relative physical demands of official matches and sided games (medium and large) in professional soccer players by means of a global positioning system. Twenty-three professional male soccer players (24.63 ± 2.84 years old; 180.94 ± 6.49 cm; 77.19 ± 6.46 kg; 52.99 ± 5.01 VO\textsubscript{2max}) participated in the study. Total distance, running distance, sprinting distance, number of sprints, and acceleration sum were quantified per minute to compare the different games. Running distance in full match was greater than in 5vs5+GK ($d = 2.303$, moderate effect), 6vs6+GK ($d = 1.719$, moderate effect) and 9vs9+GK ($d = 1.084$, minimum effect) sided games. Greater values for sprinting distance were found in the full match compared to 5vs5+GK ($d = 3.673$, strong effect), 6vs6+GK ($d = 2.606$, moderate effect) and 9vs9 +GK ($d = 1.903$, moderate effect) sided games. However, the load was greater in the 5vs5+GK game compared to the 6vs6+GK ($d = 1.323$, moderate effect) and 9vs9+GK ($d = 1.030$, minimum effect) games and the full match ($d = 1.478$, moderate effect). This study revealed that medium-sided games are not appropriate for simulating the sprinting conditions of official full matches. However, medium-sided games are more intense than full matches in that accelerations are made more often in medium-sided games.

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Introduction
Research on match analyses in adult male football players has been the subject of growing interest over the past five years (Sarmento et al., 2017). Nevertheless, a big challenge for researchers is aligning new findings with the needs of coaching staff, through a more interactive relationship between all practitioners, to produce relevant information that can improve players’ performance through constant adaptations of training design (Sarmento et al., 2017).
Training methods in football have evolved over the years (Selmi, Gonçalves, Ouergui, Sampaio, & Bouassida, 2018), from privileged exercises without a ball which develop physical capacities to new methods and exercises which simultaneously improve physical capacities along with technical and tactical skills in accordance with the modern demands of the game (Mello et al., 2017; Selmi, Marzouki, Ouergui, BenKhalifa, & Bouassida, 2018). In this sense, small-sided games (SSGs), also referred to as skill-based conditioning games (Gabbett, 2006), game-based training (Gabbett, Jenkins, & Abernethy, 2009) or small-sided and conditioned games (Davids, Araújo, Correia, & Vilar, 2013) are modified games played on small fields with modified rules and which involve a fewer players than traditional soccer games (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011; Silva, Garganta, Santos, & Teoldo, 2014). SSGs integrate all the specific needs of soccer and represent a useful solution to improve the efficiency of the training process (Beato, Jamil, & Devereux, 2018).

The evolution of technological devices (e.g. GPSs, heart rate monitors, etc.) help coaches and scientists study specific characteristics of different SSGs, and the progression of SSG research in soccer has increased exponentially in the past few years (Ade, Harley, & Brandley, 2014; Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014; Hill-Haas et al., 2011). The scientific evidence suggests that physiological responses (e.g. perceived exertion, heart rate, and blood lactate concentration) and tactical and technical skill requirements can be modified during SSGs by altering certain factors, such as the number of players, the size of the pitch, the rules of the game, and coach encouragement (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012; Castelão, Garganta, Santos, & Teoldo, 2014; Rampinini et al., 2007; Silva et al., 2014).

Nonetheless, some limitations remain in the published studies. Specifically, there is a lack of consistency in the design of SSGs, the age and level of ability of the players, the level of coach encouragement, and the rules (e.g. number and type of goals, number of touches in the ball, etc.) used by researchers. Such inconsistencies make it difficult to compare studies. Additionally, some potential weaknesses may be apparent in more recently published research, such as the small sample sizes used in some studies (Beenham et al., 2017; Halouani et al., 2014; Silva, Vilar, Davids, Araújo, & Garganta, 2016; Stevens, De Ruiter, Beek, & Savelsbergh, 2016). Additionally, the main body of research in this area is conducted with young players (Clemente, Wong, Martins, & Mendes, 2014; Halouani, Chtourou, Dellal, Chaouachi, & Chamari, 2014; Halouani, Chtourou, Gabbett, et al., 2014), while studies conducted with senior players (McLean et al., 2016; Ric et al., 2016; Stevens et al., 2016), and especially with professional players, are rare.

In this sense, a study that analyzes the training process of an adult professional team by monitoring the most common types of sided games (medium and large) and comparing their specific demands with the activity profile of official matches seems to have emerged as a necessity. Based on this, the purpose of this study was to compare the relative physical demands of official matches and sided-games (medium and large) in professional soccer players by means of a global positioning system (GPS). Comparisons between playing positions were also conducted.
Methods

Subjects
Twenty-three professional male soccer players (24.63 ± 2.84 years old; 180.94 ± 6.49 cm; 77.19 ± 6.46 kg; 52.99 ± 5.01 VO_{2max}) participated in the study. They were all members of the same team that competes in Portuguese Second League. Participants included four wide defenders (WDs), four central defenders (CDs), nine central midfielders (CMs), three wide forwards (WFs) and three strikers (STs). The data was collected from daily player external load monitoring in which player activities were routinely measured during training sessions and matches. Participants agreed to participate in the data-collection process and signed a free informed consent about the purpose of the study. The procedures followed the Declaration of Helsinki for the study of human beings.

Experimental approach
In this study, medium-sided (5vs5+GK and 6vs6+GK) and large-sided (9vs9+GK) games were compared with official full matches in terms of the activity profiles of the players. A nonexperimental descriptive comparative design was used to inspect possible differences between sided games and full matches over arbitrary categories normalized per exercise duration. Activity profiles were obtained using 10-Hz GPS technology which enabled us to monitor players’ movements in a valid and reliable manner (Aughey, 2011; Malone, Lovell, Varley, & Coutts, 2017). Comparisons were conducted by analyzing male professional soccer players for four weeks (August: Microcycles 9 to 12) during the 2017–2018 competitive season. The training sessions were conducted between 10:00 and 11:30 a.m. on natural turf with sunny weather conditions and similar temperatures (21.2 ± 2.3°C). The official matches were played in both home and away conditions, between 4:00 and 6:00 p.m. on natural turf with sunny conditions and similar temperatures (25.7 ± 1.7°C).

Data collection
A 10-Hz GPS (JOHAN Sports, Noordwijk, The Netherlands), consisting of a GPS sensor (10 Hz, including EGNOS correction), an accelerometer, a gyroscope, and a magnetometer (100 Hz, 3 axes, ± 16 g) was used to monitor the players. The value of 10 Hz seems to be valid and reliable enough to measure position and speed in a sports setting (Scott, Scott, & Kelly, 2016). The GPS sensor used in this study was tested with a 2.5 ± 0.41% (error ± deviation) reliability for in-line movements and change of direction (Nikolaidis, Clemente, van der Linden, Rosemann, & Knechtle, 2018). Each participant wore a body-tight vest to ensure valid (i.e. body-oriented) accelerometer data. A motion tracker was then placed in a pocket of the vest that was located at the dorsal region of the players. After each training session, motion data from the trackers were uploaded to the JOHAN Sports online analysis platform. Normalized data per minute was treated to derive total distance (TD, m/min), running distance (RD, m/min at 14–20 km.h^{-1}), sprinting distance (SD, m/min at >20 km.h^{-1}), number of sprints (NS: n.min^{-1}), and acceleration sum. Acceleration sum (AS) was calculated as the sum of the squared rates.
of change in acceleration in \( n \) consecutive moments of the sided games along the three movement axes, where \( ay \) represents acceleration along the forward-backward axis, \( ax \) represents acceleration along the sideways axis, and \( az \) represents acceleration along the vertical axis (see Equation 1) (Boyd, Ball, & Aughey, 2011).

\[
AS = \sqrt{(ax_n - ax_{n-1})^2 + (ay_n - ay_{n-1})^2 + (az_n - az_{n-1})^2}
\]

(1)

**Medium- and large-sided games**

The most commonly-used SSGs played during the four-week period of the study were compared with full matches. These SSGs were (i) 5vs5+GK, dimensions: 40 × 31 m, average area per player (excluding GKs): 124 m\(^2\), repetitions: 2, duration: 6 min; resting time: 3 min; (ii) 6vs6+GK, dimensions: 45 × 32 m, average area per player (excluding GKs): 120 m\(^2\), repetitions: 3, duration: 7.5 min; resting time: 3 min; and (iii) 9vs9+GK, dimensions: 70 × 50 m, average area per player: 194 m\(^2\), repetitions: 2, duration: 11 min; resting time: 3 min. The format and size of the pitch were selected based on previous studies of medium- and large-sided games (Owen, Wong, Paul, & Dellal, 2014). All the participants took part in the sided games during training sessions.

A ball was immediately replaced every time it crossed the sideline or end line during sided games. There were four balls placed around the pitch to make this replacement process quick. Coaches gave verbal encouragement to players during the exercises. All sided games were implemented immediately after a warm-up that constituted moderate running, dynamic stretching, balance and agility exercises, and accelerations. This process helped to ensure similar conditions across all sided games. The sided games were played in the middle training days of the week (i.e. 3–4 days before an official match and 2–3 days after an official match).

**Official matches**

Match activities were assessed from data collected over four official 11-a-side games. Each microcycle finished with an official match. The system of play used by the observed team in all the full matches was 1-4-3-3, comprising 2 WDs, 2 CDs, 3 CMs, 2 WFs, and 1 ST. A player had to have played for a minimum of 45 minutes in a match for their data to be included in the data analysis for any given match. Each game lasted ~93 minutes with a 15-minute halftime break. The same warm-up protocol was conducted before each game, including moderate running, dynamic stretching, mobility and balance exercises, agility exercises, accelerations, and ball possession drills in a 5vs5 format. The playing area relative to each player was approximately 260 m\(^2\) across the four games, and the length-width ratio of the pitch was 1.45:1.

**Statistical procedures**

Data are presented as mean, standard deviation and 90% confidence intervals. One way ANOVA was executed to analyze the variance of distance covered, running distance, sprint distance, number of sprints and acceleration sum between sided games and full
matches. The partial eta squared ($\eta^2_p$) has tested the effect size of ANOVA (ES). The Ferguson’s classification for the ES was used (Ferguson, 2009): no effect (ES < 0.04); minimum effect (0.04 < ES < 0.25); moderate effect (0.25 < ES < 0.64); and strong effect (ES > 0.64). The pairwise comparisons were tested with Cohen’s $d$ to analyze the effect size. The following classification to measure the magnitude of ES was used (Ferguson, 2009): no effect ($d < 0.41$), minimum effect ($0.41 < d < 1.15$), moderate effect ($1.15 < d < 2.70$) and strong effect ($d > 2.70$). All statistical analysis was carried out using SPSS statistical analysis software (SPSS version 23.0, Chicago, USA). The level of statistical significance was set at $p \leq 0.05$.

**Results**

Descriptive statistics (mean and 90% confidence intervals) of distance covered, running distance, sprinting distance, acceleration sum and number sprints per minute can be found in Figure 1. One-way ANOVA tested the variance of dependent variables between sided games and full match. Results found minimum differences in total distance covered ($p = 0.001; \eta^2 = 0.173$, minimum effect), moderate differences in running distance ($p = 0.001; \eta^2 = 0.484$, moderate effect), acceleration sum ($p = 0.001; \eta^2 = 0.261$, moderate effect) and number of sprints ($p = 0.001; \eta^2 = 0.478$, moderate effect); and strong differences were found on sprinting distance ($p = 0.001; \eta^2 = 0.716$, strong effects).

Pairwise comparisons revealed no effect and minimum effect of difference in total distance covered between games. Nevertheless, running distance in full match was greater than in 5vs5+GK ($d = 2.303$, moderate effect), 6vs6+GK ($d = 1.719$, moderate effect) and 9vs9+GK ($d = 1.084$, minimum effect). Greater values of sprinting distance were found in full match comparing to 5vs5+GK ($d = 3.673$, strong effect), 6vs6+GK ($d = 2.606$, moderate effect) and 9vs9+GK ($d = 1.903$, moderate effect). Moreover, 9vs9+GK had greater values of sprinting distance than 5vs5+GK ($d = 1.681$, moderate effect). Considering the number of sprints, full match had greater average than 5vs5+GK ($d = 3.091$, strong effect) and 6vs6+GK ($d = 1.395$, moderate effect); and 9vs9+GK had greater values than 5vs5+GK ($d = 1.294$, moderate effect). The load was greater in 5vs5+GK comparing to 6vs6+GK ($d = 1.323$, moderate effect), 9vs9+GK ($d = 1.030$, minimum effect) and full match ($d = 1.478$, moderate effect).

**Discussion**

The purpose of the present study was to compare the relative physical demands of sided games (medium and large) with those of official matches in professional soccer players. The main findings of our study are (i) medium-to-large (5vs5+GK, 6vs6+GK, and 9vs9+GK) sided games and official matches demand different physical efforts from players in terms of running, sprinting, loading, and positional roles; and (ii) large-sided games (9vs9+GK) simulate the official full match more accurately than other sided games in terms of sprinting and loading demands.

Differences in total distance covered between full matches and sided games are in agreement with previous reports (Casamichana, Castellano, & Castagna, 2012; Owen et al., 2014). However, the magnitude of these differences was minimal compared to the
values reported by Owen et al. (2014), who showed that there was a large superiority of large-sided games over medium-sized games in terms of the distance covered by players (120.4 vs. 108.3 m.min$^{-1}$). It could be that different skill levels of the players (elite vs. professional) or other possible influential factors (e.g. pitch dimensions, playing rules) might have been responsible for this discrepancy. Indeed, covering a greater distance during a match has been highlighted as a distinguishing factor between players with different skill levels (Mohr, Krustrup, & Bangsbo, 2003).

The results of present study show that, in terms of running performance (running at a speed $\sim$ 14–20 km·h$^{-1}$), the 9vs9+GK sided game format is most similar to an official match (minimal difference), as the medium-sized games (5vs5+GK and 6vs6+GK) require less running. The importance of running is well recognized by the findings of Casamichana et al. (2012) which show that higher-level competitions (i.e. international level vs. domestic and national league level) demand greater running (striding) performance in elite women soccer players. In this sense, our results are consistent with a recent study (Owen et al., 2014) which showed that greater running activity (effect size: 1.3) is required for large-sided games than for medium-sided games. Our results, however, are not in agreement with those of Casamichana et al. (2012), who did not report any significant differences between small-to-large-sided game formats in terms of the amount of running activity required. The size of the playing area used in the study of Casamichana et al. (2012) for sided games (210 m$^2$) was large and was kept constant, whereas the present study varied the size of the playing area (120–194 m$^2$); the experiment conducted by Owen et al. (2014) also used playing areas of various sizes (177–184 m$^2$). This difference might be responsible for this disagreement. Indeed, as the size of the playing area increases, players have less ball possession and need to run more in defensive (to close gaps and apply pressure) and offensive (to open spaces and build up) moments of the game (Owen, Wong, McKenna, & Dellal, 2011).

Our data showed moderately greater playing loads in the 5vs5+GK game compared to the other sided games (6vs6+GK and 9vs9+GK) and even compared to full matches. This result supports recent findings (Beenham et al., 2017; Casamichana et al., 2012; Montgomery, Pyne, & Minahan, 2010) that showed higher playing loads in small-sided games compared to full matches. Indeed, it seems that playing soccer with a smaller number of players may result in greater accelerometer-derived loads (Beenham et al., 2017; Casamichana et al., 2012).

Although playing load has been reported to be strongly related to other internal load measures (e.g. Edwards’ training impulse and session rating of perceived exertion [sRPE]) and external load measures (e.g. total distance) in soccer players (Casamichana, Castellano, Calleja-Gonzalez, San Román, & Castagna, 2013), this measure is mostly calculated based on accelerometer data and is sensitive to minor high-intensity actions (e.g. accelerations, decelerations, jumping) in all planes (Beenham et al., 2017). When the number of players reduces in skill-based sided games, quick high-intensity actions (e.g. dribbles, shots, and tackles) are increased, and players have more involvement with the ball (Owen et al., 2014). Such increases in high-intensity actions might be the reason for the moderately greater playing loads in the 5vs5+GK format compared to those observed in other sided games (i.e. 6vs6+GK, 9vs9+GK, and 11vs11+GK) in the present study. Nevertheless, these results are not consistent with the reports of Montgomery et al. (2010) in which playing load was greater in a full match than in small-sided games. However, this discrepancy may be explained by the differences in terms of
the sport that was studied (basketball vs. soccer) and by the use of different methodological approaches.

Greater sprint performance (in terms of both the number of sprints and sprinting distance) was observed in the full match compared to medium-sided (5vs5+GK, 6vs6+GK) and large-sided (9vs9+GK) games in the present study (with moderate-to-strong effects) (Figure 1). The 9vs9+GK game also demanded greater sprint performance than the 5vs5+GK format. These results suggest that medium- and large-sided games cannot completely simulate a full match. However, as the number of players and pitch size increase, the conditions become more similar to those of a real match scenario in terms of sprint performance. These results are in agreement with the findings of previous studies that

![Figure 1. Mean ± 90% confidence intervals of distance covered, running distance, sprinting distance, number of sprints and acceleration sum intensity in the sided games and official matches.](image)
have reported a higher number of sprints (Casamichana et al., 2012; Gabbett & Mulvey, 2008) and greater sprint distance (Casamichana et al., 2012; Owen et al., 2014) in full matches than in small- or medium-sided games.

The importance of sprint performance has been highlighted, as players in international-level competitions have shown greater sprint performances than players in domestic- and national-level games (Gabbett & Mulvey, 2008). Because players are more involved with the ball and because space is limited in smaller rectangles (Owen et al., 2011), high-speed thresholds (~ > 20 km·h⁻¹) are not usually reached, and so lower sprint performance and greater acceleration/decelerations would be expected on smaller pitches. Given that performing repeated sprints or high-speed runs in a full match is of paramount importance (Dupont, Akakpo, & Berthoin, 2004; Gabbett & Mulvey, 2008), conducting friendly games (Casamichana et al., 2012) and adding high-speed runs to sided games (Harrison, Kinugasa, Gill, & Kilding, 2015; Vitale et al., 2018) during preparation phases are strongly recommended. Although previous studies (Hill-Haas et al., 2011; Owen et al., 2011) have suggested that playing smaller-sided games as opposed to larger-sided games more accurately replicates the intensity of a full match, these suggestions have been derived mostly from observed heart rate responses and not from actual physical demands. Furthermore, lactate levels have been reported to be higher in larger-sided games than in smaller-sided games (Dellal et al., 2012), confirming the higher specificity of playing in larger rectangles with a greater number of players to simulate an official match.

Conclusions

This study conducted in professional soccer players revealed that medium- to large-sided games and official matches put different demands on players in terms of running, sprinting, loading, and positional roles; large-sided games (9vs9+GK) simulate official full matches more accurately than the other sided-games that were studied (5vs5+GK and 6vs6+GK).

Disclosure statement

No potential conflict of interest was reported by the authors.

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