THE INFLUENCE OF BALL-TOUCHES NUMBER ON PHYSICAL AND PHYSIOLOGICAL DEMANDS OF LARGE-SIDED GAMES

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Original scientific paper
UDC: 796.3:796.015.546:796.332:796.077-055.1

Abstract:

The main aim of the study was to evaluate the relation between the number of ball touches for individual possession and physical and physiological demands during the large-sided soccer games (LSGs) of 7 vs. 7 players plus two goalkeepers (who were not monitorized).. During the exercise, the number of assigned touches for individual possession (1-touch, 2-touch and free-touch) was altered. Fourteen amateur soccer players (age: 24.4±4.7 years; height: 180±5.6 cm; weight: 77.9±5.6 kg) were monitored during exercise with 10 Hz GPS devices and heart rate (HR) monitors. The following variables were recorded: HR responses, total distance covered, distance covered in different speed ranges (0–6.9, 7.0–12.9, 13.0–17.9, 18.0–20.9 and >21 $km \cdot h^{-1}$), player load and number of accelerations. The number of ball touches altered physical and physiological demands during exercise. Higher HR responses and greater distances covered were recorded during the free-touch assignment ($p<.05$). No significant differences were found in 1-touch and 2-touch protocols. These results may help coaches to modify different variables in LSGs concerning physical and physiological demands of soccer.

Key words: *exercise intensity, specific training, time-motion, GPS device, heart rate, number of ball touches*

Introduction

The utilization of small-sided games (SSGs) to develop a specific physical conditioning profile has been demonstrated as an effective method in training soccer players (Dellal, Varliette, Owen, Chirico, & Pialloux, 2012; Hill-Haas, Coutts, Rowsell, & Dawson, 2009; Impellizzeri, et al., 2006), regardless of age, gender, previous experience or competitive level (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Training which includes SSGs simultaneously improves both the technical and tactical elements, inducing similar responses in HR as compared to the short intermittent running training (Dellal, et al., 2008). The SSGs allow a specific competitive atmosphere under pressure and fatigue, optimizing the time spent during training (Little & Williams, 2007).

One of the parameters most commonly manipulated to alter the physical and physiological demands of soccer playing during SSGs is the number of ball touches allowed for individual possession. As few ball touches as possible in the game seems to be the key prerequisite for playing soccer at elite level (Dellal, Chamari, Wong, et al., 2011).

Traditionally, coaches manipulate the number of ball contacts with technical and tactical purposes. However, they ignore the physical and physiological demands. In previous studies, when SSGs of 3 vs. 3 players with small soccer goals in amateur players (Aroso, Rebelo, & Gomes-Pereira, 2004), or SSGs of 2 vs. 2 and 3 vs. 3 players with small soccer goals in young players (Sampaio, et al., 2007) were compared, the authors observed a significant increase of blood lactate concentrations and higher rating of perceived exertion (RPE), respectively, when the number of touches allowed was limited. Recently, Dellal, Chamari, Owen, et al. (2011) have studied SSGs (2 vs. 2, 3 vs. 3 and 4 vs. 4) in professional players with the instruction to maintain collective possession of the ball and with four exterior floaters, but altered the number of touches (1-touch, 2-touch and free-touch). The authors

found higher blood lactate concentrations, RPE, the total distance covered, the total distance covered at high speed and at very high speed with less touches (1-touch vs. 2-touches and free-touch), while HR was kept constant except for 4 vs. 4 SSGs. In this case, the HR was higher in the 1-touch situation (Dellal, Chamari, Owen, et al. 2011), with a higher number of technical mistakes (Dellal, Lago-Penas, Wong, & Chamari, 2011), and greater distance covered with fewer technical mistakes performed by elite players in comparison to amateur players (Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011).

The studies that analyze the variable number of touches have been made with a small number of players per team. However, it was demonstrated that the increase in the number of players, the pitch ratio per player and the type of SSG (large, medium or small sided-game) induced an alteration of physiological and physical characteristics. However, this issue has not been studied in large-sided games (LSGs). This is a very interesting topic because coaches constantly use LSGs in their training. Therefore, the main purpose of this study was to examine how the modification of the number of ball touches authorized per individual possession (1-touch, 2-touch and free-touch) affects the physical and physiological demands of soccer playing during the practice of LSGs (7 vs. 7) with goalkeepers and official goals under standardized conditions (e.g. pitch dimensions, orientation, game duration, presence of balls around the pitch and coach encouragement).

Methods

Subjects

Fourteen amateur male soccer players (age: 24.4±4.7 years; height: 180±5.6 cm; weight: 77.9±5.6 kg; Yo-Yo Intermittent Recovery Test level 1 (YYIRT1): 2394±621.1 m), playing in the same team (senior division) at regional level took part in this study. They had been playing soccer for an average of 12.5 years prior to the study. Their standard training involved 3-4 sessions per week (each lasting around 90 minutes), in addition to a competitive match. All the players were notified of the research design and its requirements, as well as the potential benefits and risks, and they each gave their informed consent for participation prior to the start. The Ethics Committee of the University of the Basque Country (CEISH) also gave its institutional approval of the study.

Variables

Independent variables: number of ball touches

The independent variable was the number of ball touches authorized per individual possession. Each session involved a seven-a-side LSG with a different format: 1) large-sided game played in 1-touch form (LSG1); 2) large-sided game played in 2-touch form (LSG2); and 3) large-sided game played in free-touch form (LSGFT). The pitch size was the same for all LSGs (60 x 49 m) with ≈210 m^2 of relative area per player (≈245 m^2 excluding goalkeepers). Except for the offside rules, the standard rules of eleven-a-side soccer were followed.

Dependent variables: physiological and physical profiles

Physiological profile: heart rate

The physiological profile was assessed on the basis of the players heart rates (Espósito, et al., 2004), which were recorded every five seconds using a telemetric device (Polar Team Sport System, Polar Electro Oy, Finland). HR appears to be suitable for an indirect estimation of the aerobic energy production in soccer (Bangsbo, Mohr, & Krustrup, 2006). The maximum HR (HR_{max}) of each player was determined by the YYIRT1 (Bangsbo, Iaia, & Krustrup, 2008). Similarly to previous studies (Casamichana & Castellano, 2010; Hill-Haas, Dawson, Coutts, & Rowsell, 2009) we established six HR intensity zones: <50%HR_{max}, 50–60%HR_{max}, 60–70%HR_{max}, 70–80%HR_{max}, 80–90%HR_{max} and 90–100%HR_{max}. The variables used were: percentage of time spent in each intensity zone during the LSGs, absolute (bpm) and relative (%) values in relation to the mean and maximum HR obtained in the YYIRT1 (%HR_{mean}, %HR_{max}). The percentage of the total time spent in each zone for each player during all LSGs was recorded. The data were categorized into HR zones using the software *Logan plus* v.4.5.0 (Catapult Innovations, 2010).

Physical profile: distance covered, speed and number of accelerations performed

The physical profile was measured using portable global positioning system (GPS) devices operating at a sampling frequency of 10 Hz (MinimaxX v.4.0, Catapult Innovations). This technology has been previously determined as reliable and has been validated for monitoring the players' high-intensity activities (Castellano, Casamichana, Calleja-González, San Román, & Ostojic, 2011; Varley, Fairweather, & Aughey, 2012). After recording, the data were downloaded to a PC and analyzed using the software package *Logan Plus v.4.5.0* (Catapult Innovations, 2010).

Similarly to previous studies, five speed categories ($km \cdot h^{-1}$): 0–6.9, 7.0–12.9, 13.0–17.9, 18.0–20.9 and >21 (Di Salvo, et al., 2007; Hill-Haas, Dawson, et al., 2009; Impellizzeri, et al., 2006) and three acceleration ranges ($m \cdot s^2$) were established (1.0–1.5, 1.5–2.0 and ≥2.0), similar to Varley, Aughey, and Pedrana (2011). The total distance covered (TD), the distance covered in each of the speed categories and in each of the acceleration categories were also recorded. Global load indicators were also includ-

ed: the maximum speed reached (V_{max}), work:rest ratio and the player load, through accelerometry (Casamichana, Castellano, Calleja-González, San Román, & Castagna, 2012), has been calculated by 100 Hz accelerometer incorporating GPS devices by combining accelerations in three axes of movement. The device has shown high levels of inter- and intra-device reliability (Boyd, Ball, & Aughey, 2011), and has been established as a valid indicator for monitoring training load in soccer players (Casamichana, et al., 2012).

Procedure

The study was conducted over a 3-week period (January) during the 2010/2011 competitive season. In the weeks before the experiment, the players were familiarized with both the type of the LSGs and the material used. During the week immediately before the study, they performed the YYIRT1 to determine their HR_{max}. It was done on an outdoor artificial pitch with the players wearing football boots, and all the tests were performed on the same day.

Six training sessions were held considering an interval of at least 48 hours between them to avoid the influence of fatigue. In order to avoid the effects of the circadian rhythms on the results (Drust, Waterhouse, Atkinson, Edwards, & Reilly, 2005), the sessions took place on an outdoor artificial grass pitch at similar times of the day. Each session began with a 15-min standard warm-up, followed by LSGs involving the same number of players per side (7 vs. 7 plus goalkeepers) but with a different game format (LSG1, LSG2 and LSGFT) and a duration of 12 minutes. The order in which the resulting six LSGs (3 levels of different game formats × 2 sessions) were played and recorded is shown in Table 1. This order of play was established randomly in advance. In order to avoid potential imbalances between the two teams, and to ensure their equivalence, according to Casamichana and Castellano (2010), the players were classified according to the following variables: the number of minutes of competitive play, performance on the YYIRT1, playing position, and subjective appraisal of the coach.

During all the LSGs, the coaches were present in order to offer encouragement to the players (Rampinini, et al., 2007). In addition, eight balls were distributed around the edge of the pitch to maximize the effective playing time (Casamichana & Castellano, 2010). All the participants were advised to maintain their normal diet habits; a special emphasis was placed on a high intake of water and carbohydrates.

Statistical analysis

The data are presented as means and standard deviations (means±SD). The homogeneity of variances was examined by means of Levene's test. The presence of significant differences was determined by a one-way repeated measures analysis of variance (ANOVA), applied to each of the dependent variables. *Post-hoc* Bonferroni test was applied to make a pairwise comparison between the different levels of within-player factors. Effect sizes (ES) were also calculated (Rhea, 2004) for physiological responses and time-motion characteristics. All the statistical analyses were performed using a Windows PC program, version 17.0 (SPSS Inc., Illinois USA), with the significance level being set at $p<.05$.

Results

Physiological profile: heart rate

Table 2 shows the mean and maximum HR, in absolute (bpm) and relative (%HR_{mean} and %HR_{max}) values in relation to the ones obtained in the YYIRT1. It shows significant differences in HR_{mean} (bpm) ($F_{(2,21)}=4.46$; $p<.05$ and ES=1.30) and in HR_{mean}(%) ($F_{(2,21)}=7.72$; $p<.05$ and ES=1.76).

Figure 1 shows the time spent (%) in each physiological category. The players spent significantly more time in the zone of 50–60% HR_{max} ($F_{(2,21)}=4.47$; $p<.05$ and ES=1.54) during the LSG2 as compared with LSGFT.

Table 1. Protocol followed for the different small-sided games played over a three-week period in six sessions

Week	Session/Day	Task
1	1st/Tuesday	12' 7 vs. 7-LSG1
	2nd/Thursday	12' 7 vs. 7-LSG1
2	3rd/Tuesday	12' 7 vs. 7-LSG2
	4th/Thursday	12' 7 vs. 7-LSG2
3	5th/Tuesday	12' 7 vs. 7-LSGFT
	6th/Thursday	12' 7 *vs.* 7-LSGFT

Note. 7 vs. 7: number of on-field players of one team against on-field players of the other team; LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 2-touch form; LSGFT is the large-sided game with no limitations in reference to ball touches per individual possession.

Table 2. Means and standard deviations (mean±SD) of mean HR (HR_{mean}) and maximal HR (HR_{max}), HR_{mean} in relative values to an individual maximal HR, (%HR_{mean}) and $HR_{máx,}$ in relative values to an individual maximal HR, (%HR_{max}) in different format of LSGs

	LSG1	LSG2	LSGFT	Mean
HR_{mean} (bpm)	145.5±14.5	146.9±8.4	159.4±10.7[a]	151.9±11.9
HR_{mean} (%)	75.6±5.9	74.3±5.3	82.2±3.5[a]	77.8±5.9
HR_{max} (bpm)	171.2±13.0	174.5±7.6	179.7±10.9	176.1±10.1
HR_{max} (%)	89.0±6.1	88.2±4.9	92.7±2.9	90.2±4.7

Note. LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 2-touch form; LSGFT is the large-sided game with no limitations in reference to ball touches per individual possession. Bonferroni *post hoc* test, [a]>LSG2, in any cases; $p<.05$.

Physical profile: distance covered, speed and number of accelerations performed

The global load indicators (distance covered, player load, maximal speed and work:rest ratio) presented no significant differences in either of the studied variables (Table 3).

Figure 2 shows the distance covered (m) in different ranges of speed categories depending on the number of maximal ball touches authorized per individual possession. The players covered significantly more distance ($F_{(2,22)}$=5.86, p<.05 and ES=1.50) in the LSGFT than in the LSG2 in the speed range from 13.0 to 17.9 km·h^{-1}, but in the lowest speed category (<7.0 km·h^{-1}) the players covered more distance ($F_{(2,22)}$=4.29, p<.05 and ES=1.18) in LSG2 than in LSGFT.

Figure 3 shows the distance covered expressed in percentage of the TD, showing the significant differences in the same dependent variables. The soccer players covered less distance in the speed range of <7 km·h^{-1} in the LSGFT in comparison with LSG2 ($F_{(2,22)}$=4.37, p<.05 and ES=1.34), while greater distances were covered in the speed range of 7.0–12.9 km·h^{-1} ($F_{(2,22)}$=6.95, p<.05 and ES=1.55).

Figure 4 shows the distance covered (m) with accelerations depending on their intensity for each

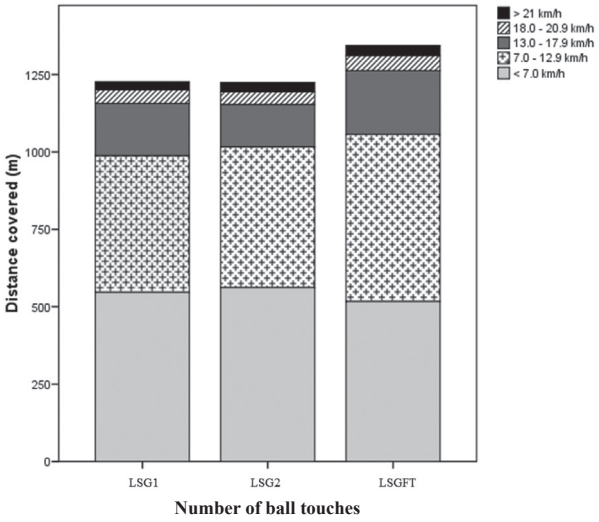

Figure 2. Distance covered (m) in each speed category. LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 2-touch form; and LSGFT is the large-sided games with no limitations in reference to ball touches per individual possession.

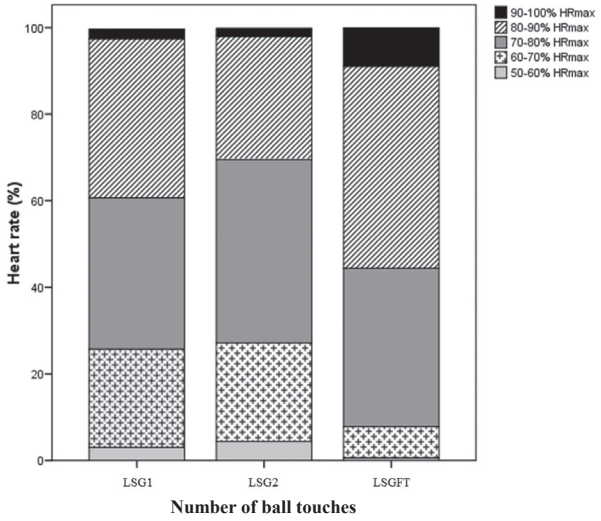

Figure 1. Time (%) spent in each physiological category. LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 2-touch form; LSGFT is the large-sided game with no limitations in reference to ball touches per individual possession.

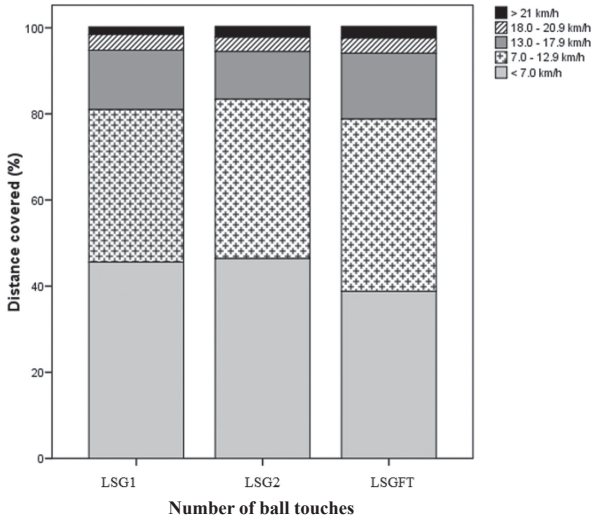

Figure 3. Distance covered (%) in each speed category established for each situation. LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 2-touch form; LSGFT is the large-sided game with no limitations in reference to ball touches per individual possession.

Table 3. The values are means and standard deviation (±SD) of distance covered (DC), player load (PL), maximal speed (MS) and work:rest ratio (WR) of different LSGs.

	LSG1	LSG2	LSGFT	Mean
DC (m)	1226.8±171.5	1224.9±133.3	1345.2±110.4	1273.4±140.4
PL (AU)	136.2±34.5	127.9±19.0	147.8±23.8	137.5±25.1
MS (km·h^{-1})	22.9±2.2	23.7±2.5	23.4±2.5	23.4±2.4
WR	2.5±0.9	2.5±0.9	3.2±0.9	2.8±0.9

Note. LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 1-touch form; LSGFT is the large-sided game with no limitations in reference to ball touches per individual possession.

of the LSGs. Total distance covered by accelerations did not show any significant differences even when analyzed by intensity ranges.

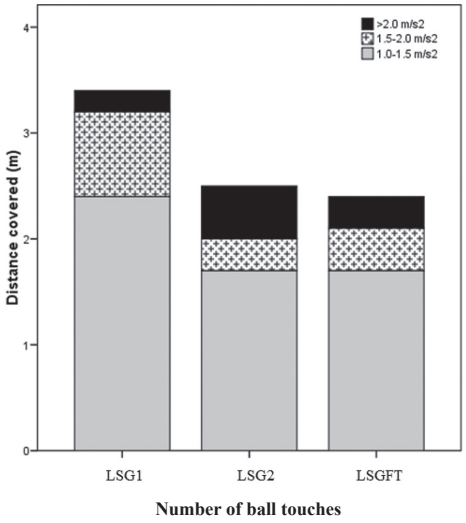

Figure 4. Distance of accelerations from each intensity category established. LSG1 is the large-sided game played in 1-touch form; LSG2 is the large-sided game played in 2-touch form; and LSGFT is the large-sided game with no limitations in reference to ball touches per individual possession.

Discussion and conclusions

The main aim of this investigation was to examine if the modification of the variable *number of ball touches* allowed per individual possession (1-touch, 2-touch or free-touch) provoked variations in physical and physiological responses in amateur soccer players. To the best of our knowledge, no study has examined the effects of this variable during LSGs of 7 vs. 7, in the same relative area per player, with goalkeepers, official soccer goals and without a floater. The main finding of this study was that the LSGs with the unlimited number of touches lead to the increased physiological and physical demands compared with LSG1 or LSG2, whereas no differences were observed in physical demands on the observed amateur soccer players.

The results have to be interpreted carefully when they are compared with the findings of other works because the touch limitation appears to have a heterogeneous influence on physiological responses, technical and time-motion activities in relation to the expertise level of players (Dellal, Hill-Haas, et al., 2011). According to this, our results may be different from the ones in previous investigations (Aroso, et al., 2004; Dellal, Chamari, et al., 2011; Dellal, Hill-Haas, et al., 2011; Dellal, Lago-Penas, et al., 2011; Sampaio, et al., 2007) that generally found a higher intensity in activities (RPE, lactate concentrations, total distance, total distance in high speed) when the authorized number of touches was reduced. This contrast could be due to the players' expertise level; namely, a lower play quality could cause more technical mistakes and more balls lost, so a good dynamic of passing game could not be maintained (Dellal, Hill-Haas, et al., 2011).

Although the $\%HR_{mean}$ was around 80% in all three types of LSGs, there were significant differences based on the number of authorized touches. These values, as well as those in the previous investigations (Dellal, Chamari, et al., 2011; Dellal, Hill-Haas, et al., 2011; Dellal, Lago-Penas, et al., 2011; Sampaio, et al., 2007) in which intensities in which intensities over 80%, and sometimes even near 90%, were observed are considered, are considered appropriate for the improvement of endurance in soccer (Castagna, Impellizeri, Chaouach, & Manzi, 2013; Chamari, et al., 2005; Hill-Haas, Coutts, et al., 2009). These lower values could be caused by a larger number of players in a team, which affects the intensity of the game (Brandes, Heitmann, & Müller, 2011; Castellano, Casamichana, & Dellal, 2013; Dellal, Jannault, Lopez-Segovia, & Pialoux, 2011; Hill-Haas, Dawson, et al., 2009). The format used in this investigation was 7 vs. 7, while Sampaio et al. (2007) used the 2 vs. 2 and 3 vs. 3 formats, and Dellal, Chamari, Owen et al. (2011) used the 4 vs. 4 format. However, in this investigation we studied the LSGs with goalkeepers and official soccer goals which obviously induce a lower physiological response when compared to the games in which the goal was to maintain collective possession of the ball (Castellano, et al., 2013; Mallo & Navarro, 2008).

On the other hand, taking into account the number-of-touches-authorized formats, a higher percentage of HR_{mean} was recorded during the LSGFT (82.2±3.5%) when compared with LSG2 (74.3±5.3%), and a higher HR_{mean} was recorded during LSGFT (159.4±10.7) in comparison to LSG2 (146.9±8.4). In contrast, other authors did not find any differences between the formats (Dellal, Chamari, Owen, et al., 2011; Sampaio, et al., 2007), or they even found higher percentage of HR_{mean} in 4 vs. 4 game formats when 1-touch form was allowed as compared to the free-touch modification (Dellal, Chamari, Owen, et al., 2011).

In reference to the physical demands, no significant differences were found among the global load indicators (TD, player load, V_{max} and work:rest ratio), although the greater distance covered and the higher player load were found in the LSGFT (1345.2±110.4 m and 147.8±23.8 AU) with respect to the LSG2 (1224.9±133.3 m and 127.9±19.0 AU) and LSG1 (1226.8±171.5 m and 136.2±34.5 AU). In contrast, Dellal, Chamari, Owen et al. (2011) in their research done on professional players, estimated larger distances covered in SSGs with 1-touch form allowed in comparison to 2-touch and free-touch SSGs in 2 vs. 2, 3 vs. 3 and 4 vs. 4 game formats. Once again, we think that the players' quality level

could have influenced these results because the players with a higher level of expertise would be able to play more fluidly.

Regarding different speed categories, the players covered significantly more distance and obtained higher percentage of time spent in speed range of 13.0–17.9 km·h^{-1} during the LSGFT (206.5 m and 15.3%) when compared to the LSG2 (137.9 m and 11.1%). On the contrary, the players covered a greater distance and spent more time in the speed zone of <7.0 km·h^{-1} in the LSG2 (561.8 m and 46.4%) when compared to the LSGFT (517.1 m and 38.8%). For high (18-20.9 km·h^{-1}) and very high-intensity actions (>21 km·h^{-1}), greater distances covered were found in LSGFT compared to the LSG1 and LSG2, but no significant differences were observed. On the contrary, Dellal, Chamari, Owen et al. (2011) observed a greater distance covered in high-intensity (13–17 km·h^{-1}) and very high-intensity speed zone (>18 km·h^{-1}) in 2 vs. 2, 3 vs. 3 and 4 vs. 4 game formats played with 1-touch allowed in comparison with two touches allowed form and free-touch form. Also, greater permanence in high intensity and very high-intensity speed zones were observed during formats where only 1-touch was allowed (Dellal, Chamari, Owen et al., 2011). It is possible that these contradictions were due to the LSGs formats used in the present investigation in which the goalkeepers and official goals were used and the players were forced to organize as to defend a particular area of the side (Castellano, et al, 2013; Mallo & Navarro, 2008). Otherwise, as we have previously commented, the quality level of the players could have influenced the results, i.e. amateurs participated in our study versus professionals in the project of Dellal, Chamari, Owen et al. (2011).

Finally, no significant differences were found between the accelerations in the function of the number of touches allowed. Therefore, it appears that the number of ball touches authorized does not affect the acceleration actions, even though a greater number of accelerations of low (1.0-1.5 m·s^{-2}) and medium (1.5-2.0 m·s^{-2}) intensity during the LSG1 was observed, while there was a higher number of accelerations of high intensity (>2.0 m·s^{-2}) in the LSG2 and LSGFT.

The main application of this investigation is that the modification of the number of authorized ball touches for individual possession induces different physical and physiological demands during LSGs (LSG, 7 vs.7) played with the goalkeepers and with the official goals. Specifically, a high physiological intensity was registered during activities played in free-touch format, with no differences observed in the physical profile. Coaches could influence the intensity of exercise by manipulating the number of touches allowed. These results should help coaches and trainers to design training sessions during the competitive season by improving the knowledge regarding exercise intensity and allowing the training load alternation depending on the phase of the season. The utilization of LSGs is common in the process of training in soccer and the present study provides an essential piece of information for better control of player's activities during this specific training aiming at the design of the training schedule.

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Acknowledgements

We gratefully acknowledge the support of the Spanish Government to the project Observation of the Interaction in Sport and Physical Activity: Technological and Methodological Advances in Qualitative-Quantitative Computerized Records (Dirección General de Investigación, Ministerio de Ciencia e Innovación) [Grant number DEP2012-32124] over the period 2012-2015. We are also grateful to the University of the Basque Country (UPV/EHU) and the Department of Physical Education and Sport for funding provision. There are no conflicts of interest in relation to this research.

UTJECAJ BROJA DODIRA S LOPTOM NA FIZIČKE I FIZIOLOŠKE ZAHTJEVE VELIKIH POMOĆNIH NOGOMETNIH IGARA

Glavni je cilj ovog istraživanja bio vrednovati odnos između broja dodira s loptom tijekom pojedinog posjeda te fizičkih i fizioloških zahtjeva igranja velikih pomoćnih nogometnih igara u kojima igra po sedam igrača i vratar u svakoj ekipi. Tijekom igre su istraživači mijenjali broj zadanih dodira s loptom tijekom svakog pojedinačnog posjeda (jedan dodir, dva dodira, slobodan broj dodira). U istraživanje je bilo uključeno četrnaest nogometaša amatera (dob: 24,4 ± 4,7 godina; visina: 180 ± 5,6 cm; težina: 77,9 ± 5,6 kg) koji su tijekom igre bili praćeni pomoću GPS uređaja (10 Hz) i monitora srčane frekvencije. Zabilježene su sljedeće varijable: frekvencija srca, ukupna pretrčana udaljenost, udaljenost prevaljena različitim brzinama (0–6.9, 7.0–12.9, 13.0–17.9, 18.0–20.9 i >21 km·h^{-1}), opterećenje igrača te broj ubrzanja. Istraživanje je pokazalo da broj dodira s loptom predstavlja različite fizičke i fiziološke zahtjeve igre. Veća frekvencija srca i veća prevaljena udaljenost bile su zabilježene tijekom igre sa slobodnim brojem dodira ($p<0,05$). Nisu zabilježene značajne razlike između protokola u kojima su igračima bili dopušteni jedan ili dva dodira s loptom. Rezultati ovog istraživanja mogli bi pomoći trenerima u modifikaciji pomoćnih nogometnih igara u kontekstu izazivanja odgovarajućeg fizičkog i fiziološkog odgovora.

Ključne riječi: *intenzitet vježbe, specifični trening, vremenske karakteristike gibanja, GPS uređaj, frekvencija srca, broj dodira s loptom*

Submitted: August 30, 2012
Accepted: November 18, 2013

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