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Comparison of external load in high speed actions between friendly matches and training sessions
Comparación de carga externa en las acciones de alta velocidad en partidos amistosos y sesiones de entrenamientos

*Francisco Javier Toscano Bendala,** Miguel Angel Campos Vázquez, **Luis Jesús Suarez-Arrones, **Francisco Javier Núñez Sánchez

*Universidad Católica San Antonio de Murcia (España), **Universidad Pablo de Olavide (España)

Abstract. The aim of the current research was to analyze the differences in high-velocity actions external load (SP+) between competitions and training sessions in professional soccer team. We considered any action soccer players performed over 23 km·h^{-1} and could be held for at least 1 second as SP+ indicators. A sample of 25 professional soccer players belonging to the first team of a first Spanish soccer division team were monitored using 10 GPS devices (SPI, ELITE model, GPSport, Canberra, Australia). These GSPORT transmitters have a sampling frequency of 1 Hz. The results of our study showed how players performed a substantially higher number of SP+ of 1 s, 2s, 3s y 4 s (per minute of activity) during matches than during training.
Key words: Monitoring, GPS, distance traveled, maximum speed, football.

Resumen. El objetivo esta investigación fue encontrar las diferencias que existen entre la carga externa en acciones de alta velocidad (SP+) en paridos amistosos de pretemporada y las sesiones de entrenamientos en un equipo de fútbol profesional. Tomamos como indicadores SP + aquellas acciones que realizan los jugadores de fútbol por encima de 23 km·h^{-1} y pudiendo ser mantenidas durante al menos 1 segundo. Se monitorizaron 25 jugadores profesionales pertenecientes a la primera plantilla de un equipo de la primera división de futbol español, y se utilizaron 10 dispositivos GPS (SPI, ELITE model, GPSport, Canberra, Australia). Estos transmisores GPSORT, tienen una frecuencia de muestreo de 1 Hz. Los resultados de nuestro estudio manifestaron como durante el partido, los jugadores realizaron de manera sustancial más en número de SP+ de 1 s, 2s, 3s y 4 s (por minuto de actividad) que durante los entrenamientos.
Palabras clave. Monitorización, GPS, distancias recorrida, velocidad máxima, fútbol.

Introduction

In recent years, the concern about improving performance at individual and team levels in players has propelled an increasing interest in the analysis of behavior in players when training and playing matches (Sarmento et al., 2014). The practical value of these analyses is focused on how to properly select the liability of the indicators. This can help coaches to identify good and bad performance both in individuals and teams (Di Salvo et al., 2007), and then in technology, such as the one we can find in GPS devices, which has played a major role when collecting data about monitoring and analyzing the external load carried by soccer players (Aughey, 2011; Jennings, Cormack, Coutts, & Aughey, 2012; Varley, Fairweather, & Aughey, 2012).

Soccer is mainly an aerobic sport that includes lapses of time in which high intensity movements take place (Suarez-Arrones et al., 2014). During the match, a soccer player performs more than 75 actions in high-intensity races (Newman, Tarpenning, & Marino, 2004). These sprints actions rarely reach 20 m distance and last no more than 4 s (Sánchez, Blazquez, Gonzalo, & Yagüe, 2005). They usually coincide with those movements that are meant to catch the ball and with those actions that require agility in defensive maneuvers (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Stolen, Chamari, Castagna, & Wisloff, 2005), being all of them considered as variables of sport performance prediction (Kaplan, Erkmen, & Taskin, 2009; Mujika, Santisteban, & Castagna, 2009). Faude, Koch, & Meyer (2012) show that most of the goals scored were preceded by an intense activity straight line sprints performed by the player that was going to score the goal or by the team mate that assisted him to score.

Through time, the task of planning training sessions has taken a step forward towards specificity. It has evolved from having the ball as an essential element in every training activity implying, then, the typical features we can find in a collective challenge, which results into collaboration-opposition action traditionally performed on a common space (Reilly, Morris, & Whyte, 2009), and engaging simultaneous participation (Casamichana, Castellano, González-Morán, García-Cueto, & García-López, 2011; Parlebas, 2001). Small side games (SSG) are a way of training in which the dimensions of the playing field, the number of players and its rules are altered with the aim to achieve technical, tactical and physical targets (Hill-Haas, Coutts, Dawson, & Rowsell, 2010; Little & Williams, 2005). Despite players only cover 1.2 - 2.4% of the distance of the playing field when they carry the ball (Cometti, Maffiuletti, Pousson, Chatard, & Maffulli, 2001; Di Salvo et al., 2007; Hinojosa, 2017), at a conditional level, such means show physiological values which are similar to the ones required in a match (Casamichana, Castellano, & Castagna, 2012); nevertheless, the lack of a solid criteria about establishing the dimensions of the space, where the activities must take place, brings into question its usefulness in the development of all the movements the player has to perform (Fradua et al., 2013).

So, the aim of this research was to make an analysis about the high velocity actions that a player performs during a competition match, so they could be compared with the training sessions that are carried during a whole training season. This was intended to create a new vision of the suitability of the current training tasks based on Reduced Games, something that is nowadays taken as the main stimulus of external load for professional soccer players.

Method

Subjects

Twenty five soccer players took part in this study, with an average (±DT) of age 26.5 ± 4.1 years, height 180.6 ± 7.2 cm, weight of: 77.3 ± 7.7 kg and maximal oxygen consumption (VO_{2max}) 49.6 ± 4.6 ml/kg/min, respectively. The goalkeeper were excluded from the investigation. All of them belonged to the main staff of a Spanish premier league team on that played on season 2008-2009. All these participants gave their consent to participate in this study and they were informed about the details of this project. This research has been developed under the ethic laws of the University Pablo de Olavide of Seville.

Experimental procedure

The training routine of the soccer players was divided into two parts: a period of preparatory season and an official competition period. The preseason lasted 6 weeks, a time in which the team performed from 6 to 12 weekly training sessions and played from 1 to 2 weekly friendly matches. The training sessions in this period lasted from 60 to 90

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Francisco Javier Toscano Bendala
fjtoscano@ucam.edu

minutes and the working structure was being modified throughout these 6 weeks. The volume of these training sessions was progressively being reduced from the 4th week onwards.

During the competitive season, the team performed from 5 to 6 training sessions and one official competition match per week. Each week the same 10 players were monitored and corresponded to the specific positions that complete a soccer team. Each player complete at least 8 weeks of full training (Table 1). The training sessions in this period lasted from 90 to 120 minutes. The first sessions of the week (Wednesday and Thursday) were destined to improve physical conditions (by using strength circuits, physical-technical circuits and SSG) and to the technical-tactical preparation of the following match. The last sessions of the week (Friday and Saturday) were dedicated to recover from the efforts made throughout the week and the activation prior to the match —from the conditional point of view— and to the strategic work. The structure of the training weeks was the same throughout the season, following a model of tactical periodization (Frade, 2013).

Table 1:
Number of weeks and players who were monitored

Players	Week	S/W
22	9.5 ± 17	5,4 ± 1.0

S/W: Number of sessions per week

Finally, were recorded 9 friendly matches played in the preseason. The playing system used in them followed this scheme: 1 (goalkeeper), 4 (2 central backs + 1 right back and 1 left back), 2 (midfielders), 3 (2 side midfielders and 1 attacking midfielder), 1 (striker) and 41 weeks of training without missing any session.

All the players were monitored with 10 GPS (global positions system) devices (SPI, ELITE model, GPSPORT, Canberra, Australia). These GPSPORT transmitters have a sampling frequency of 1 Hz. These devices have been validated by prior studies whose purpose was to determine the position of players and to estimate their motion and velocity (Coutts & Duffield, 2010; Portas, Harley, Barnes, & Rush, 2010), demonstrating, therefore, a good precision (Barbero-Alvarez, Coutts, Granda, Barbero-Alvarez, & Castagna, 2010) and liability (Barbero-Alvarez et al., 2010; Coutts & Duffield, 2010) when assessing the peak velocity.

Data was downloaded into a laptop once the training sessions or the matches were over (ACER Travel Mate 7720). All the analysis of the data was done by using the software of GPSPORT TEAM AMS Version 1.2, Canberra, Australia. The GPS receptors were given to the players when they were in the locker room, before the match or the training session started. These devices were located in the upper part of the back, between the scapulas and the lower part of the cervical spine, and were attached to a harness that could be adjusted to the size of every player and included a small bag pack containing the GPS.

In order to be monitored during the matches, the 10 players that were participating in the soccer match wore the GPS; all of them had it, but the goalkeeper.

The 10 players also wore it at the training sessions for a whole week. These soccer players formed a team where every position was covered; they wore the GPS receivers throughout the training sessions for a whole week. Once the week had finished, the devices were delivered to another 10 players that formed part of a different team.

In some occasions, some players had to wear the receivers in consecutive weeks, since they had to replace those mates who couldn't train because they were injured, ill or because of any other reason. When every session was over, the data registered were daily transferred to the computer.

Variables

In this research, all those actions performed by players which implied movements over 23 km·h^{-1} and were held for at least 1 second (s) were identified and categorized, as well as the high velocity sprints, by Di Salvo et al. (2007). The analyzed variables were:

·Number of high-velocity actions (SP+) performed by the soccer player both in competition matches and training sessions.

· Maximal velocity obtained both in competition matches and training sessions.

· Distance covered at SP+ both in competition matches and training sessions.

All these variables were likewise studied and classified into different duration periods: 1 s, 2 s, 3 s, 4 s and 5 s.

In our case, we find more suitable to link the distance to the minutes that the game had lasted, since the duration of a match may vary depending on the minutes the referee decides to add to the competition; this way we could to compare the effort that a player makes when facing a match with a different duration.

Statistical analysis

Data were presented as the average results obtained and the standard deviations (±DS) and trying to establish a relation between the team in its competitive phase and its training sessions. Those inferences based on degrees of magnitude in the differences between variables were made by normalization differences after the process reported by (Batterham & Hopkins, 2006). Standardized units 0.20 (that is, a fraction of the standard deviation between participants at the beginning of this research) were selected as the least significant change (Cohen, 1988). The size of the effect quantifies the size of the difference that exists between both groups; so, according to this, we could say that this is a true measure of the significance for such a difference (Coe & Merino, 2003). The threshold values for the Cohen effect sizes (ES) would be, then, trivial: 0.0 to 0.19; small, 0.2 to 0.5; moderate, 0.6 to 1.1; large, 1.2 to1.9; and very large, >2.0. The qualitative terms and the defect values are: hardly probable <0.5%; hardly probable 0.5-5%; not very probable, 5-25%; possible 25-75%; probable 75-95%; very probable 95–99.5%; highly probable, > 99.5% (Hopkins, Marshall, Batterham, & Hanin, 2009).

Results

During the competition matches, every player performed SP+ both for 1 s duration as for 2 s duration (Fig 1). In every entire training session that took place throughout the whole season, just 87.5% of the players carried SP+ for 1 s and 77.7% of them for 2 s. The number of players that did SP+ for 3 s. plummeted in matches (48.3% of those who were monitored) The same happened for SP + of 4 s where only 24.2% of the registered players in the match and 20.6% of the registered players during training contribute data for the analysis. However, in the SP + analysis of 5 s more records were obtained during training (12.8% of the monitored) than during the match (5.7% of the monitored)

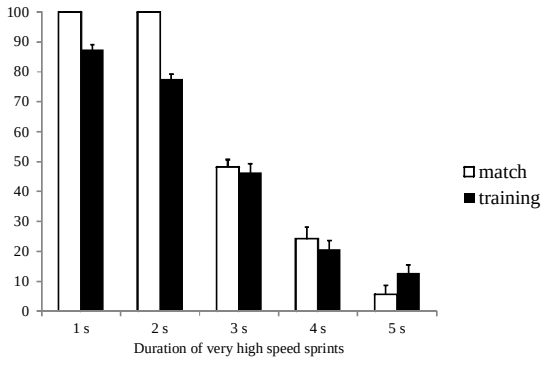

Figure 1. Descriptive information. Percentage of players that did SP+ in a match and in training weeks.

The number of SP+ both in competition as in training is reflected on Table 2. The results of our study showed how, during this period, players substantially more in number of SP+ for 1 s than in longer training (large ES). The same happened with the SP+ for 2 s, more of them in matches than training (large ES). No differences in SP+ for 3 s. were found. Substantial differences were reflected again in SP+ for 4 and 5 s. Regarding to 4 s, there were more actions in the match than in

Table 2.
Number of sprints over 23 km·h^{-1} per minute Friends Match (FM) and Training Sessions (TS), of activity exerted by a player when competing and training, in lapses of 1 s, 2 s, 3 s and 4 s (average ± DE).

Sprint duration	Number of sprints per minute (FM)	Number of sprints per minute (TS)	ES (90% LC)	Qualitative assessment
1 s.	0.07 ± 0.04	0.03 ± 0.01	1.5 (1.7-1.2)	AC (0/0/100)
2 s.	0.04 ± 0.02	0.02 ± 0.01	1.1 (1.5-0.8)	AC (0/0/100)
3 s.	0.01 ± 0.01	0.01 ± 0.00	0.1 (0.6-0.2)	NC (6/45/49)
4 s.	0.01 ± 0.01	0.01 ± 0.01	0.7 (1.5-0.1)	P (3/10/87)

ES: size of the effect. LC: Confidence limits: AC: Almost Certainly NC: Not clear P: Probable.

Table 3.
Maximal velocity reached in SP+ (>23 km·h^{-1}) in lapses of 1 s, 2 s, 3 s and 4 s Friends Match (FM) and Training Sessions (TS) (average ± DE).

Sprint Duration	FM average	TS average	ES (90% LC)	Qualitative assessment
1 s.	24.36 ± 0.35	24.66 ± 0.76	1.5 (0.5– .4)	VP (96/4/0)
2 s.	25.06 ± 1.02	24.52 ± 0.45	0.1(0.2–0.6)	NC (46/65/9)
3 s.	25.98 ± 0.68	26.24 ± 0.41	0.3 (0.1-0.8)	NC (71/26/3)
4 s.	26.25 ± 0.52	26.13 ± 0.44	0.2 (0.8-0.4)	NC (13/35/52)

ES: Size of the effect. . LC: Confidence limits. VP: Very probable. NC: Not clear.

Tabla 4.
Average distance (m) covered at SP+ by players Friends Match (FM) and Training Sessions (TS) in lapses of 1 s, 2 s, 3 s and 4 s (Average ± DE).

Sprint duration	FM average	TS average	ES (90% LC)	Qualitative assessment
1 s.	6.14 ± 0.19	6.33 ± 0.09	0.1 (0.5-0.2)	NC (7/53/38)
2 s.	13.45 ± 0.45	13.36 ±0.22	0.1 (0.5-0.2)	NC (6/48/46)
3 s.	20.83 ± 0.48	20.80 ± 0.47	0.1 (0.5-0.4)	NC (20/50/30)
4 s.	27.86 ± 1.16	27.09 ± 1.60	0.6 (1.2-0)	P (2/10/88)

ES: Size of the effect. . LC: Confidence limits. NC: Not clear. P: Probable

training (large ES), while as far as 5 s is concerned, there were more actions substantially in training than in the match, since the occurrence in this kind of actions was practically inexistent (~ 0.27 SP+ > 5 s / match).

Table 3 reflects the maximal velocities reached by players when competing and training during SP+. For the SP+ for 1 s duration, the velocity reached was substantially higher in training rather than in matches (1.2% moderate ES). Maximal velocities reached by players, both in matches and training, for the rest of durations showed no substantial differences.

Table 4 reflects the distance covered in SP+ in competitions and training. In lapses of 1 s, 2 s and 3 s there were no substantial differences. In SP+ of 4 s duration, the distance covered by players was shorter in training than in matches (2.8%; moderate ES). Actions of 5 s couldn't be analyzed because of the lack of data recorded, since players didn't have as many opportunities as to hold 5 s at a velocity that exceeded 23 km·h^{-1}.

Discussion

The aim of this work was to find the differences between the SP+ actions that a player executes when competing and the ones that performs in training sessions throughout a whole season. There hasn't been any similar studies published by now, in which data extracted from the training sessions in a whole season of professional soccer were recorded. The main finding in this study was to confirm that in a competition there is more SP+ per minute of activity than in any of the training weeks in a season, which demonstrates an evident shortfall of stimulation in this conditional manifestation at the training process of a professional soccer.

Faude, Koch, & Meyer, (2012) and Kaplan, et al., (2009) indicate in their studies that 83% of the goals scored in a soccer match are preceded by a straight line sprint performed by the player that scores that goal, or by the team mate that uses such a high velocity sprint to assist the goal scorer. Despite the importance of this kind of movements in the action of a game, the current study shows that really high velocity actions have a very scarce occurrence indeed, adding a total of 0.15 SP+·min^{-1}, a little higher than the record of ~ 0.08 SP+·min^{-1}, as demonstrated by Varley et al., (2013). In our research, the total of the sprint actions generated in a single match stands for approximately ~ 2% of the total of actions performed. These results coincide with prior researches where sprint actions didn't's stand for more than 10% in a match (Carling, Bloomfield, Nelsen, & Reilly, 2008), investing in these actions from 0.5 to 3 % of the playing time (Stolen et al., 2005).

There is a lack of consensus in current literature about categorizing SP+ actions. Thus, Varley et al.,(2013) classify this sort of movement as actions that exceed 24.85 km·h^{-1}, showing this way that there is an average of 0.08 SP+·min^{-1} in a soccer match. In our study, where we have categorized SP+ as actions that take place at velocity e»23 km·h^{-1}, the results achieved have been slightly superior, (~ 0.15 SP+·min^{-1}), probably because of a velocity threshold to categorize these movements, likewise inferior (24.9 vs. 23.0 km·h^{-1}). Sánchez et al., (2005) prove that predominant actions last from 1 s to 4 s, where those efforts that exceed 5 s are rare. According to this study, our results indicate that those actions that are frequently repeated in SP+ don't last more than 2 s, as showed in previous studies. Nevertheless, there is no proof about the existence of studies that show the quantification of this kind of actions in different training sessions. Our results showed how —except for the actions that are less demanded in the game (4-5 s), and in every week of training in a whole season— the number of SP+ actions is substantially smaller than required in a competition match.

The exercises that were proposed during the training didn't supposed an external load as challenging as the competitive exigency required, especially for the number of SP+ efforts of 1 and 2 s. One of the possible explanations to this evidence is the exaggerated use of training structures that are based on a globalized methodology and playing in short spaces. Such reduced playing situations may reproduce the internal load, or even external loads, that a player undergoes throughout a competition (Casamichana & Castellano, 2011; Casamichana et al., 2012; Casamichana et al., 2011; Hill-Haas, Coutts, Dawson, & Rowsell, 2010; Hill-Haas, Rowsell, Dawson, & Coutts, 2009), but they don't help to develop SP+, not as required in a competition at least.

As a consequence of the importance that velocity may have in decisive moments in a match, the estimation of maximal velocity in a sprint (V_{max}) or the peak velocity has received a growing interest in recent years (Buchheit, Simpson, Peltola, & Mendez-Villanueva, 2012). Mendez-Villanueva et al., (2011) show how $V_{máx}$ expressed by a player in a match is highly influenced by the tactical necessities of the game at every moment, but optimizing or even keeping this V_{max} will allow us to answer in a more efficient way to the requirements of the game. It is even spread the idea that it has be a physical prerequisite for professional soccer players (Cometti et al., 2001; Gissis et al., 2006; Mendez-Villanueva et al., 2011; Stolen et al., 2005). In our study, the average V_{max} reached in SP+ ranges from ~ 24 km·h^{-1} in efforts with durations of 1 s to ~ 26 km·h^{-1} in actions of 4 s. These values are a little smaller than the ones that appear in different studies (Suarez-Arrones et al., 2014), however, in our investigation they appear as average of SP+ and not as maximal value reached. The explanation about why there are no differences in training and competitive matches can be found in sprints made by players once they reach maximal values in SP+, but the deficit lies on the fact that the number of SP+ is not reached at the same level in training as when competing.

Regarding to the distance that a player covers when is competing in SP+, we must agree with the work done by Sánchez et al., (2005), where the average number of actions in SP+ hardly exceeds 20 m. Similar investigations show that, in a soccer match, 90% of the sprints take place on a distance that ranges from 5 m to 15 m (Bangsbo, Mohr, & Krustrup, 2006; Carling et al., 2008; Di Salvo et al., 2007; Newman et al., 2004). That dates are similar to the data we reflect in this study (6 and 13 m, respectively). The differences that lay in those actions that last 4 secs. are higher in competitions, something that can be explained by a fast progressive action towards the rival goalmouth with the purpose to achieve the most successful end possible.

Finally, we must point out that there were some drawbacks we bore in mind when we were working on this study. It would have been rather interesting to be able to register the accelerations and decelerations exerted by players, but it was not possible because the devices that players used were not still equipped with accelerometers that would enable to develop that study. In addition, the fact that we only were able to carry this research with just one soccer team, despite being a professional one, made impossible to extrapolate the results to any

more teams. Furthermore, the Spanish Professional Soccer League bans the use of any kind of unauthorized or unapproved equipment to play soccer in official competitions, so it would be really interesting to have had the possibility to record data in such competitions, since we think that the dynamics in them may be different to the ones we can find in friendly matches.

As a practical application, we can say that, by means of the SSG, we can have an approximation to most of the conditional factors of soccer players; we can even reproduce certain SP+ actions that soccer players do in competitions, but the search of how to improve a certain skill leads us to more controlled training structures, under a more analytical methodology and less globalised. That way, we can make sure that such determinant efforts, from the point of view of physical performance and prevention of injuries, are trained as well.

Conclusions

Enlightened by the results of our investigation, we can extract the following conclusions: from all the SP+ actions that a soccer player exerts in a match, the ones that are more frequently repeated have a duration of 1 and 2 s, reaching a maximal velocity of 24.6 km·h^{-1} (rank 23.6 24.6 km·h^{-1}) and a maximal distance of 6.7 m (rank 6 – 6.7 m.) in actions of 1 s, at maximal velocity of 26.1 km·h^{-1} (rank 21.2 26.1 km·h^{-1}) and a maximal distance of 14.1 m (rank 12.2 – 14.1 m) in actions of 2 s. Finally, we conclude that, considering that SP+ training exercises have a deficit in reference to the competitive request, we must think about how to adapt the exercises selected to the training process in these specific actions.

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