2019, *Retos, 35,* 75-79
 ISSN: Edición impresa: 1579-1726. Edición Web: 1988-2041 (www.retos.org)

Individualized thresholds to analyze acceleration demands in soccer players using GPS

Umbrales individualizados para analizar las demandas en la aceleración en futbolistas usando GPS

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Abstract. The aim of the present study was to analyze the number and the % of maximum accelerations, and the distance covered among different soccer players' positions, classifying them with GPS technology according to an individual threshold based on the maximum acceleration capacity. 20 players were observed during four matches (n=80). All players undertook a maximal running speed test to determine the maximal acceleration. Players' activities during the matches were classified into four individual acceleration thresholds: acceleration starting from 0 to 13 km·h^{-1} and never reaching 18 km·h^{-1} (A1); acceleration starting from 0 to 13 km·h^{-1} and reaching 18 km·h^{-1} (A2); acceleration starting from 13 to 18 km·h^{-1} (A3); and acceleration starting above 18 km·h^{-1} (A4). During A1, Full-Backs performed a higher number of accelerations compared to other playing positions and reached a ~95% of the maximum acceleration. During A2, Full-Backs and Wide Midfielder performed a higher number of accelerations than Central Defenders and Forwards, and Central Midfielders reached an estimated intensity of 95% of the maximum acceleration. During A3, CM performed the highest number of accelerations compared to the rest of the groups, while F reached an estimated intensity of 78% of their maximum acceleration. This individualized threshold could help coaches assess players' physical performance and improve it, or to avoid injuries.
Key words: Acceleration, match analysis, soccer, GPS, physical performance.

Resumen. El objetivo del presente estudio fue analizar el número, % de la aceleración máxima y la distancia recorrida por las diferentes posiciones de juego, clasificándolos según un umbral individual para cada jugador basado en la máxima capacidad de aceleraración usando la tecnología GPS. Un total de 20 jugadores fueron evaluados durante 4 partidos (n=80). Todos los participantes realizaron un sprint a la máxima velocidad de carrera para determinar su capacidad máxima de aceleración. La actividad de los jugadores durante los partidos fue dividida en 4 categorías individuales de aceleración: A1, aceleración de 0 a 13 km·h^{-1} y sin llegar a 18 km·h^{-1}; A2, aceleración desde 0 hasta 13 km·h^{-1} y alcanzando 18 km·h^{-1}; A3, aceleración que inicia desde los 13 km·h^{-1} hasta los 18 km·h^{-1}; A4, aceleración que comienza a una velocidad >18 km·h^{-1}. En A1, los defensas laterales realizaron un mayor número de aceleraciones en comparación con las otras demarcaciones de juego y logrando una intensidad ~ 95% de su aceleración máxima. En A2, los defensas laterales y centrocampistas laterales realizaron un mayor número de aceleraciones que los defensas centrales y delanteros, consiguiendo los centrocampistas una intensidad aproximada del 95% de su máxima aceleración. En A3, los centrocampistas realizaron una cantidad superior de aceleraciones que el resto de grupos, mientras que los delanteros lograron una intensidad aproximada del 78% de su máxima aceleración. Estos umbrales individualizados podrían ser de gran utilidad para permitir evaluar a los técnicos de forma más precisa el rendimiento físico de los jugadores, permitiéndoles con ello mejorar su rendimiento y prevenir lesiones en futbolistas.
Palabras clave: aceleración, análisis de partido, fútbol, GPS, rendimiento físico.

Introduction

The Global Positioning System (GPS) has been used to describe the physical profile of the soccer player by distance and speed variables during friendly matches (Casamichana et al., 2012; Buchheit et al., 2014b; Varley et al., 2014) and official matches (Suarez-Arrones et al., 2015). Several researches have indicated that the physical profile can vary in adults because of the playing position (Suarez-Arrones et al., 2015) or the fatigue development during the match (Randers et al., 2010). Normally the activity profile is divided in different speed zones ranging from 0 to 36 km·h^{-1} and no standardized speed zones are observed (Cummins et al., 2013). In this line, most of these studies have categorized efforts as > 13 and > 18 km · h^{-1} as medium and high intensity velocity, respectively (Casamichana et al., 2012; Suarez-Arrones et al., 2015). However, the use of absolute thresholds have two limitations that should be considered. Firstly, an absolute threshold do not consider that the capacity to accelerate is less when the acceleration start from a moderate or high speed than from a standing position (Bradley et al., 2010; Sonderegger et al., 2016). Secondly they are less specifics than an individualized threshold because they do not consider the individual capacity of accelerate of each player (Núñez-Sánchez et al., 2017).

Actually, describing the physical profile of the soccer player by distance and speed variables might underestimate the external load during a match (Dalen et al., 2016). Some studies analyzed the acceleration movement profiles of soccer players, arguing that motion analysis that excludes accelerations probably underestimated high-intensity activities of the player (Bradley et al., 2010; Varley & Aughey, 2013). Bradley et al. (2010) quantified the accelerations (> 2.5 m·s^{-2}) of soccer players using a camera computerized tracking system, and no differences were found for elite players between the first and second half for the frequency of accelerations. Ingebrigtsen et al. (2015) (using microwave technology) and Dalen et al. (2016) determined acceleration profiles of elite soccer players and their contribution to the players´ match load. According to these authors, the acceleration has to reach 2 m·s^{-2} for at least a half second to be counted. In soccer, the players' tactical roles and available space on the pitch affect in the possibility of acceleration of the player and that does not need to occur at high velocity to be physically challenging (Varley & Aughey, 2012). Thus, it is essential to know the initial and final velocity to determine the acceleration profile of the player according to their playing position. Varley & Aughey (2013) quantified the number of accelerations using GPS (>2.78 m·s^{-2}), commencement and final velocity of maximal accelerations were also identified to determine an acceleration profile of soccer players. These authors showed that the number of accelerations was position dependent, where wide defenders performed more accelerations than other roles. In addition, the 98 % of the accelerations started from a low velocity, and the 85 % had a final velocity <14,4 km·h^{-1}. These studies have not provided an explanation for the use of an absolute acceleration threshold for all players and all positions. Therefore, they could have a potential error in the measurement of the players' performance and generate the need for an individualized acceleration threshold (Abt & Lovell, 2009). According to this, these absolute thresholds do not consider the velocity where player start to accelerate. Thus, it is necessary to consider that the capacity to accelerate is greater when accelerations are initiated from stand or low velocity than when accelerations are initiated from moderate to high velocity (Sonderegger et al., 2016). Sonderegger et al. (2016) found that an acceleration of 3 m·s^{-2} represents about 50% of the maximal voluntary acceleration when it start from a standing position. However, from an initial speed of 15

Fecha recepción: 09-10-17. Fecha de aceptación: 17-04-18
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km·h^{-1}, just a few young soccer players could reach an acceleration over 3 m·s^{-2}. Then, when the initial speed is considered, the accelerations initiated from high-speed running are not underestimated and those that start from a low-speed running or standing are not overestimated as when absolute acceleration thresholds are used.

Therefore, the aim of the current study was to analyze the number, the % maximum of acceleration, and the distance covered among different soccer players positions, classifying them according to an individual threshold based on the maximum capacity of acceleration (a_{max}) during friendly games using GPS technology.

Materials and Method

Participants

Time-motion analysis activity was collected from 20 semiprofessional soccer players (age 26.6±4.1 years; height 178.5±5.8 cm; body mass 74.4±5.6 kg). The athletes belonged to a Second B Spanish soccer division club. All players participate on average 14 hours combining soccer-specific training and 1-2 strength training sessions per week. This data was obtained from routine monitoring of work-rate in friendly games. Team and players confidentiality were granted and the study followed the Code of Ethics of the World Medical Association (Declaration of Helsinki). The University Human Research Ethics Committee granted the ethical approval for all of the experimental procedures.

Activity Pattern Measurements

Players were required to wear a GPS unit (15 hz SPI-pro W2b, GPSport, Canberra, Australia) fitted to the upper back of each player using a neoprene harness, during 40 m maximal running speed test and in four matches. All the units were activated more than 20 minutes before the match, allowing the acquisition of satellite signals (Duffield et al., 2010). The number of satellites for GPS was satisfactory, over 3 satellites at least (Larsson, 2003), during sprint test and all matches: ranged 4-11, average 7.8±2. GPS data was analyzed with Team AMS-R1-2012.9 software. The use of GPS technology for monitoring a match play provides a reliable and valid measure of the physical profile of the players (Coutts & Duffield, 2010; Varley et al., 2012), instantaneous velocity (Varley et al., 2012) and peak velocity (Buchheit et al., 2014a). Acceleration was calculated using a custom excel spreadsheet.

Experimental Procedures

All players undertook two 40 m maximal running speed to determine a_{max} each 0.5 s. The best sprint time was selected for the analysis. This test was performed in an outdoor natural grass field. Players wore soccer boots during the test. Players started the sprint from a standing start with their front foot 0.5 m behind the start line and were instructed to sprint as fast as possible over the 40 m distance (Mendez-Villanueva et al., 2011). The test was preceded by standardized 20 min warm-up consisting of 5 minutes of mobility, stretches in active tension, 7 minutes of jogging, two progressions of 40m and a maximum acceleration of 10m. Match analyses were performed 4 times in all players during a total of 4 friendly matches played over a period of four weeks. Only the first half was included in our analysis and goalkeepers and players in the rehabilitation process were excluded. All matches were played on the same 100 x 70 m outdoor natural grass field, with no dismissal occurred. Tactically, the team employed a regular 1-4-4-2 formation.

Match running demands analysis

In order to classify intensity of actions based on percentage acceleration, a moderate-high intensity zone that included actions with a percentage of the accelerations (acceleration >50% of the a_{max}) was used (Sonderegger et al., 2016). The following locomotors categories were selected: the acceleration started from 0 to 13 km·h^{-1} and did not reach 18 km·h^{-1} (A1); the acceleration started from 0 to 13 km·h^{-1} and reached 18 km·h^{-1} (A2); the acceleration started from 13 to 18 km·h^{-1} (A3); the acceleration started >18 km·h^{-1} (A4). The number of accelerations, the % of individual maximal accelerations, and mean distance covered, were analyzed for each category. All players were assigned to 1 of 5 positional groups: Full Backs (FB, n=4), Central Defenders (CD, n=4), Central Midfielders (CM, n=4), Wide Midfielder (WM, n=4), and Forwards (F, n=4).

Statistical Analysis

Variables are presented as mean (± SD). Possible differences between players' position were analysed (pairwise comparisons) for practical significance using magnitude-based inferences (Hopkins, 2007). Data were log-transformed prior to the analysis to reduce non-uniformity of error (Hopkins et al., 2009). The standardised differences or effect sizes (90% confidence interval) between players' position were calculated. The threshold values for the Cohen effect size (ES) statistics were: trivial (0.0 – 0.19), small (0.2 – 0.59), moderate (0.6 – 1.1), large (1.2 – 1.9) and very large (> 2.0) (Batterham & Hopkins, 2006; Hopkins et al., 2009). Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile differences (0.2 multiplied by the between-subject standard deviation, based on Cohen's effect size principle). The quantitative chances of higher or lower differences were evaluated qualitatively as follows: <1%, almost certainly not; <5%, very unlikely; <25%, unlikely/probably not; 25–75%, possibly/possibly not; >75%, likely/probably; >95%, very likely; >99%, almost certainly (Batterham & Hopkins, 2006; Hopkins et al., 2009). A substantial effect was established as >75%. If the likelihood of higher or lower differences was >75%, the true difference was assessed as clear (substantial) (Aughey, 2011; Jennings et al., 2012). If the chance of having beneficial/better or detrimental/poorer was >5%, the true difference was considered unclear (Suarez-Arrones et al., 2014).

Results

The individual maximal acceleration every 0.5 seconds during the 40m test is present for each playing position in Table 1. The total number of accelerations, and the number of accelerations, the % a_{max}, and mean distance covered during A1, A2, A3, and A4 actions are present for each position group in Table 2.

FB performed a higher number of total accelerations, obtaining substantial differences with F (%: +37%, ES= 1.26 [90%CL:2.03; 0.49], 99/1/0% with changes for greater/similar/lower values, respectively) and CD (%: +31%, ES= 1.09 [90%CL:1.84; 0.33], 97/2/1% with changes for greater/similar/lower values, respectively). The F were the players who performed a smaller number of total accelerations, obtaining substantial differences with WM (%: -23.7%, ES= 0.62 [90%CL:1.46; -0.22], 81/14/5% with changes for greater/similar/lower values, respectively) too. During A1 FB performed a substantially higher number of accelerations than CD (%: +28%, ES= 1.04 [90%CL:1.8; 0.29], 96/3/1% with changes for greater/similar/lower values, respectively), WM (%: +25.7%, ES= 0.64 [90%CL:1.44; -0.17], 82/14/4% with changes for greater/similar/lower values, respectively) and F (%: +39.3%, ES= 1.26 [90%CL:2.03; 0.48], 99/1/0% with changes for greater/similar/lower values, respectively), but no than CM. During A2 FB

Table 1.
The individual maximal acceleration ($m \cdot s^{-2}$) during A1, A2, A3 and A4 situations for each position group.

	CD	FB	CM	WM	F
A1 -A2	5.81±0.38[b]	4.59±0.11	3.81±2.94	6.22±0.15[b]	5.24±0.9
A3	3.33±0.24	2.84±0.47[a]	3.02±0.16[ae]	3.13±0.39[e]	2.63±0.31[a]
A4	2.66±1.05	2.70±0.02	2.33 ±0.01[b]	2.46±0.06[b]	2.53±0.83[b]

CD: Central Defenders; FB: Full Backs; CM: Central Midfielders; WM: Wide Midfielder; F: Forwards. [a]. Substantial differences with CD; [b]. Substantial differences with FB; [c]. Substantial differences with CM; [d]. Substantial differences with W; [e]. Substantial differences with F.

Table 2.
Number of accelerations (nº Acc), percentage of individual maximal acceleration (% Acc Max) and mean distance covered in meters during A1, A2, A3 and A4 situations for each position group.

	CD	FB	CM	WM	F
nº Acc					
Total	73.7±4[eb]	106.9±39.4[e]	86.9±48.7[e]	88.3±47.1[e]	63.3±24.6
A1	57.3±3.4[e]	79.6±27.5[ade]	65.4±34.6[e]	59.13±33.3	48.25±19.1
A2	15.8±3.3[bd]	25.6±12.9	20.2±13.6	27.7±17.1	14.1±7.6[bd]
A3	1±0 [c]	1.89±1.27[ac]	4±1.73	1.7±0.5 [ac]	1.5±0.5 [ac]
A4		1(only 1)			1(only 1)
% Acc Max					
A1	69.2±8.8[bce]	95.5±5.2[c]	98.4±1.5	75.1±16.4[bc]	80.4±7.5[bc]
A2	73.2±6.8[bcd]	88.5±10.5[c]	96.4±6.8	81.4±14.6[bc]	75.8±12.1[bc]
A3	50.4±11.4	62±19.2[ad]	57.2±22.5[a]	58.3±10.6[a]	78.2±22.5[abcd]
A4		51.21			54.45
Distance					
A1	10.3±2.2	10±2.4	10.7±1.7	10.3±1.3	10.2±1.5
A2	21.5±5.5	22.4±2.5	22.6±5.6	21±5.3[bc]	22.5±5.3
A3	10.9±2	17.4±6.5[a]	14.6±3[abd]	19.9±7.7[a]	25.1±24[a]
A4		15.8			15.8

CD: Central Defenders; FB: Full Backs; CM: Central Midfielders; WM: Wide Midfielder; F: Forwards. [a]. Substantial differences with CD; [b]. Substantial differences with FB; [c]. Substantial differences with CM; [d]. Substantial differences with W; [e]. Substantial differences with F.

and WM performed a substantial higher number of acceleration than CD and F (from +38.2% to +49.1%, ES= from 0.87 to 1.02, 91-96% with changes for greater values). During A3 CM and CD performed a higher and lower number of accelerations than all groups (From ±52.7% to ±75%, ES= from 0.89 to 1.54 ES, 86-98% with changes for greater values respectively). During A4, only FB and F performed an acceleration.

CM and FB reached 95% a_{max} during A1 actions, and obtained substantial differences with all groups (ES= from 1.44 to 3.93, 100% with changes for greater values) that no reached 80% a_{max}. During A2 CM reached values above 95% a_{max} with substantial differences with all groups (ES= from 0.85 to 3.19, 92-100% with changes for greater values) that no reached 88% a_{max}. During A3 F reached 78% a_{max} and obtained substantial differences with all groups (ES= from 0.70 to 1.93, 79-97% with changes for greater values) that no reach 62% a_{max}. During A4 only FB and F performed an acceleration and reached a 51% and 54% of a_{max} respectively.

During A1 the players covered 10 m of distance without differences between groups. In A2 actions, the distance was duplicated. WM covered a substantial smaller distance than CM (%: -7%, ES= 0.71 [90%CL:1.55; -0.12], 85/11/4% with changes for greater/similar/lower values, respectively) and FB (%: -6.2%, ES= 0.53 [90%CL:1.32; 0.27], 76/18/7% with changes for greater/similar/lower values, respectively). During A3 CD were the players who covered a smaller distance, obtaining substantial differences with the other groups (from -25.3% to -56.5%, ES= from 0.61 to 1.32, 76-98% with changes for greater values respectively).

Discussion

The aim of the current study was to analyze the number, the % maximal acceleration, and the distance covered among different soccer players' positions, classifying them according to an individualized threshold based on a_{max}, during friendly matches, with the same tactical system and monitoring with a GPS technology. The main findings of the present study were: a) FB performed a substantially higher number of accelerations A1 (the acceleration started from 0 to 13 $km \cdot h^{-1}$ and no reached 18 $km \cdot h^{-1}$) than CD, WM and F. b) FB and CM reached above 95% a_{max} for A1 with substantial differences with all groups; c) FB and WM performed a substantially higher number of accelerations A2 (the acceleration started from 0 to 13 $km \cdot h^{-1}$and reached 18 $km \cdot h^{-1}$) than CD and F; d) CM reached above 95% a_{max} for A2 with substantial differences with all groups; e) CM performed a substantially higher number of accelerations A3 (the acceleration started from 13 to 18 $km \cdot h^{-1}$), compared to the other groups; f) F reached above 78% a_{max} for A2 with substantial differences with all groups; g) During A1 all players covered the same distance, but during A2 WM covered a substantial smaller distance than CM, and during A3 CD cover a smaller distance than other groups.

The analysis of the accelerations, based on a_{max} of the players, generated an average of 83 accelerations during the first half of a match for each players. This value represents a 54 % more accelerations than those obtained by Dalen et al. (2016) and Ingebrigtsen et al. (2015), and a 28 % lower than those obtained by Varley & Aughey (2013) and a 30 % less than those obtained by Bradley et al. (2010) using absolute thresholds for analyzing the number of accelerations for all players. In our study, the 74 % of total accelerations were in A1, while the 24 % were A2, and the 2 % were in A3. This distribution is similar to that obtained in other studies (Varley & Aughey, 2012). These differences may have been for several issues. First, these authors have used an absolute threshold, which may not adapt to the maximum capacity to accelerate of each player. In addition, these studies have not considered the initial speed before acceleration, which affects the maximum capacity to accelerate (Sonderegger et al., 2016).

The acceleration started from 0 to 13 $km \cdot h^{-1}$and no reached 18 $km \cdot h^{-1}$ (A1), is the most repeated action along the first half of the match, in all playing positions, and which requires higher acceleration relative intensity (see Table 2). These results agree with those obtained in other studies which indicated that 98 % of the accelerations that occur in a match are of this nature (Varley & Aughey, 2012), and that the accelerations were the highest when players moved from any low-intensity running (Bradley et al., 2010). In our study, FB and CM produced the highest number of accelerations A1, performing an average of 79 and 65 accelerations during the first half of the match and reaching 94 % a_{max} and 80 % a_{max}. This is partly in line with the results obtained by Varley & Aughey (2013) and Dalen et al. (2016), both indicated that FB produced a greater number of accelerations during the first half of the match. These authors also agreed with Ingebrigtsen et al. (2015) when concluded that players in lateral positions in the team accelerate more compared to players in more central positions during the first half of the match. However none of these authors mentions that CM have high records in such actions as in our study. This could be caused by two reasons: first, the tactical intentions proposed to CM made them develop a greater capacity for acceleration than those obtained by Varley & Aughey (2013) where CM and CD got few accelerations; Second, the lower absolute acceleration capacity of the CM group and the relativity of accelerations, have to respond adequately to game actions to increase both the number of records, as % a_{max} respect to the other groups. Dalen et al. (2016) state that WM and FB produced more accelerations than other groups during the first half of the match. In our study WM have the least accelerations A1 produced and reached 75% a_{max}. One possible explanation for these results could be based on our study. WM are those who have greater capacity of acceleration A1 obtaining substantial differences with respect to FB. The analysis of the number of accelerations based on an absolute criterion (2 $m \cdot s^{-2}$) (Dalen et al., 2016) may overestimate the number of accelerations of players who have a greater capacity for acceleration and underestimate the capacity of smaller players. The analysis based on the capacity of acceleration of each player allowed seeing that a FB with less capacity of acceleration, reached to 94 % a_{max} to resolve situations that WM, with more capacity of acceleration, do it with the 75 % a_{max}. CD showed the least intensity in accelerations A1 reached 69 % a_{max}. However, they performed a greater number of accelerations than WM and F. For all groups during acceleration A1 the player covered around 10 m of distance. These findings could provide useful information for coaches because it is known that accelerations produce high mechanical demands that cause muscle damage due to the forces produces (Proske & Morgan, 2001) as well as an increase in the creatine kinase concentration and of the perception of muscle soreness (Young et al., 2012; Varley et al., 2017). Then, knowing the acceleration demands of an activity will help to coaches to design training programs for improve the players´ performance and avoid injuries.

During accelerations which started from 0 to 13 $km \cdot h^{-1}$ and reached 18 $km \cdot h^{-1}$ (A2), the players covered the double distance than they did in A1. This may be a determining factor. Thus FB and WM, those who performed the greatest distance displacements, were the players that produced the highest number of accelerations A2 (25 and 27 accelerations, respectively) without substantially differences with CM. These results agree with those obtained by Varley & Aughey (2013) and Dalen et al. (2016) which they showed that FB and WM covered a greater distance of acceleration than other playing positions. In our study during A2 accelerations, WM covered a shorter distance than FB unclear. However, FB required a higher percentage of their maximum capacity of acceleration (88 %) than WM (81 %). One possible explanation could be that FB had more distance to accelerate on the pitch and a smaller capacity of accelerate comparing with their teammates. Then, they needed to use a higher percentage of their full potential acceleration. CD and F were the players who produced the lowest number of accelerations in A2 and used less percentage of their maximum capacity of accelerate (73 % and 75 %, respectively). It is possible that the spatial delimitation involving its location within the game system does not allow them regularly to perform such actions.

Our results showed a small number of accelerations that started from 13 to 18 $km \cdot h^{-1}$ (A3). CM are the players who produced the highest number of accelerations A3 (4 accelerations per a half of a match), reaching a 57 % a_{max}. F reached the highest percentage of their maximum capacity of acceleration (78 %) and covered the highest distance (25 m).

The findings presented here are limited by the data which was collected from friendly matches and from all players who participated in the entire first half. Due to the impossibility of using the GPS during official matches at the time of measurement, we could not take data from official matches instead of friendly matches. These friendly matches are played to a greater extent in the preseason period. During the preseason, in the second half of the match, there are many player changes, so the analysis of only the first half allowed us to register the player during all the minutes played and under the same conditions. There may be an accuracy error in the measurement of all possible maximum acceleration, because during the A1, the acceleration which started during the match could be from 0 to 13 $km \cdot h^{-1}$. When registering the maximum acceleration over the 40 m maximal running speed test, this maximal acceleration will always be achieved starting from 0, and this acceleration capacity may not be totally representative of the acceleration capacity starting from any other initial velocity. Likewise, we can make an estimation error of the maximum acceleration if we consider that during the game, the player can remain several seconds at a speed before accelerating, when our proposal of measurement of the maximum acceleration is always in a continuous upward acceleration until reaching the maximum. With all this, this proposal of evaluation of the different types of acceleration guarantees that the evaluation of A1, A2, A3 and A4 will obtain the maximum records of each player for the different established criteria.

Conclusion

To conclude, this study supports the use of an individualized threshold to assess the acceleration according to the maximum capacity of acceleration instead of an absolute threshold. Furthermore, this approach reports useful information to understand the physical demands during a soccer match in function of the playing positions. This allows the coaches to design more accurate programs of training according to the number of accelerations, the % of their maximal acceleration or the distance covered during the acceleration by players. The traditional approach of assessment through the running speed does not consider the intensity of some actions that are developed in short distance and does not reach a high speed running. We have to consider the efforts at medium or low intensity while they have been done at high intensity. So, an individualized threshold based on the % of maximum acceleration could be a good tool to quantify these kind of physical demands in soccer.

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