Nakamura, FY, Pereira, LA, Loturco, I, Rosseti, M, Moura, FA and Bradley, PS

Repeated-sprint sequences during female soccer matches using fixed and individual speed thresholds.

Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000001659

ORIGINAL RESEARCH

Repeated-sprint sequences during female soccer matches using fixed and individual speed thresholds

Repeated sprints in female soccer matches

FÁBIO Y. NAKAMURA[1,2*], LUCAS A. PEREIRA[1], IRINEU LOTURCO[1], MARCELO ROSSETI[3], FELIPE A. MOURA[2,4], & PAUL S. BRADLEY[5]

[1]*Nucleus of High Performance in Sport, São Paulo, Brazil;*

[2]*State University of Londrina, Brazil;*

[3]*Grêmio Osasco Audax, Osasco, Brazil;*

[4]*Laboratory of Applied Biomechanics, Londrina, Brazil;*

[5]*Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom.*

*Fabio Y. Nakamura

NAR – Nucleus of High Performance in Sport,

Av. Padre José Maria, 555, Santo Amaro, 04753-060, São Paulo, SP, Brasil.

e-mail: fabioy_nakamura@yahoo.com.br

ABSTRACT

The main objective of this study was to characterize the occurrence of single sprint and repeated-sprint sequences (RSS) during elite female soccer matches, using fixed (20 $km \cdot h^{-1}$) and individually based speed thresholds (>90% of the mean speed from a 20 m sprint test). Eleven elite female soccer players from the same team participated in the study. All players performed a 20 m linear sprint test, and were assessed in up to 10 official matches using Global Positioning System (GPS) technology. Magnitude-based inferences were used to test for meaningful differences. Results revealed that irrespective of adopting fixed or individual speed thresholds, female players produced only a few RSS during matches (2.3 ± 2.4 sequences using the fixed threshold and 3.3 ± 3.0 sequences using the individually based threshold), with most sequences composing of just two sprints. Additionally, central defenders performed fewer sprints (10.2 ± 4.1) than other positions (full backs: 28.1 ± 5.5; midfielders: 21.9 ± 10.5; forwards: 31.9 ± 11.1; with *likely* to *almost certainly* differences associated with effect sizes ranging from 1.65 to 2.72) and sprinting ability declined in the second half. The data do not support the notion that RSS occurs frequently during soccer matches in female players, irrespective of using fixed or individual speed thresholds to define sprint occurrence. However, repeated sprint ability development cannot be ruled out from soccer training programs due to its association with match-related performance.

Keywords: *football, fitness, time-motion analysis, women.*

INTRODUCTION

Interest in match analysis has increased in the last few decades, since this allows sport scientists to determine the current demands of match play in order to translate this data into specific training and testing protocols (11). Although elite soccer players require a number of physical characteristics such as peak speed reached during the incremental field test (30) and speed associated with the ventilatory threshold (25), repeated-sprint ability (RSA) is arguably one of the most important physical qualities in team sports, presumably owing to the frequency of its occurrence during matches (13, 18, 35). Additionally, research demonstrates that the ability to perform successive sprints with minimal recovery during matches demarcates players in different competitive standards and positions (3, 31). Recently, studies have questioned the occurrence of repeated-sprint bouts during soccer matches showing that only a few repeated-sprint sequences (RSS) occur during matches (10, 33). Due to concerns regarding the validity of RSS in team sports, some researchers have redefined it as "repeated acceleration ability", as this may describe the demands of a soccer match more accurately (4). This is especially true as metabolically taxing accelerations do not always reach fixed sprinting thresholds (14, 36), but are more likely to hit an individualized sprinting threshold (i.e., a percentage speed relative to the individual's maximal sprinting performance). However, the accurate quantification of accelerations seems to demand tracking technologies with higher sampling frequency (34). Therefore, more studies are necessary to better understand the profile of sprinting activities during official soccer matches and to provide additional information about the occurrence of RSS using individualized speed thresholds. The importance of such studies lies on the fact that previous research used different methods (some lacking accuracy) to profile sprint occurrences during matches without taking into account the individual differences in physical capacities, by applying fixed sprint thresholds to all players.

Female soccer has become popular worldwide, and this has resulted in an increased number of investigations examining the physical demands of matches (8). Surprisingly, limited information exists on the occurrence of single and RSS in elite female players' during official matches. Gabbett, et al. (18) found that 2 consecutive sprints interspersed with ≤20 s recovery occurred ~5 times per player per match, with repeated sprint episodes progressively decreasing as the number of sprints per sequence increased. However, the use of video-based analysis may lead to inherent errors due to the subjective judgment of the observer when characterizing the type of effort performed (32). Possibly, this "subjective technology" leads to the overestimation of RSS in previous research (35). Therefore, the frequency and the characteristics of single and repeated-sprint efforts during female soccer matches require further investigation, preferably using more objective (i.e., not relying on researchers' subjective classification of the locomotor activities) and precise technologies. This knowledge may provide coaches with useful information to assess the sprint capacity and the RSA of their players, and also enables them to create specific testing protocols and prescribe training sessions to improve these capacities.

In a study using a Global Positioning System (GPS) to quantify single sprinting actions (>18 $km \cdot h^{-1}$) in elite female soccer players (37), forwards performed more sprints (43 ± 10) than midfielders (31 ± 11) and defenders (36 ± 12). The mean time between consecutive sprints was >2 min. Although valuable, these data do not report the occurrence of RSS. Moreover, the threshold of 18 $km \cdot h^{-1}$ to define a sprint was set arbitrarily, and has been recently revised by the same author, who updated it to 20 $km \cdot h^{-1}$ (8). Owing to the great variability in sprinting ability among female players (38), it seems logical to individualize the sprinting thresholds, since these values are particular to the sprint data collected from a respective player during a given period. This individualized approach is desirable in match analytics, as it quantifies the individual engagement in high-speed running, while taking into account the ability of each player to reach high running speeds during matches. Furthermore, this approach reduces the risk of under or overestimating the effort of team sports players, with distinct levels of sprinting ability (17). Thus, this study aimed to: [1] characterize single sprint and RSS of elite female players in official matches using fixed and individually based thresholds; [2] compare playing positions regarding the engagement in sprinting and RSS and; [3] identify possible changes in sprinting ability between playing halves.

METHODS

Participants

Eleven highly trained female soccer players from the same team participated in the present study (age: 21.0 ± 3.0 yr, stature: 163.8 ± 4.5 cm and body mass: 59.7 ± 8.0 kg). Data were collected during the 2015 São Paulo State Championship in which the investigated team reached the semi-final stage. Prior to the study, all players signed an informed consent form, with all procedures approved by the Local Ethics Committee.

Experimental approach to the Problem

This is a cross-sectional observational study aimed at characterizing the sprinting activities during elite female soccer matches. Prior to the State Championship, all players performed a 20 m sprint test (a common sprint distance observed during matches (15)) that was used to individualize the sprinting speed thresholds for matches. Sprint performance data were collected from a total of 10 official matches, and players were only included in the analysis if they completed the entire 90 min; this resulted in 61 player observations (19 for central defenders [CD]; 12 for forwards [FW]; 13 for full-backs [FB]; and 17 for midfielders [MD]). All matches were performed on an outdoor field with a dimension of 100 × 75 m. The GPS units were switched on before the warm-up to enable the devices to locate the necessary satellites (between 4 and 12). All units were fitted prior to each match, with players using the same unit in all observations in order to eliminate inter-unit errors (9).

Sprint Testing

All players sprinted along a 20 m linear track on two occasions, starting from a standing position 0.3 m behind the start line. In order to reduce the influence of the weather on performance, all sprints were performed indoors. A 5 min rest interval was allowed between each attempt and the fastest time was considered for the analyses. Sprint times were recorded by photocells (Smart Speed, Fusion Equipment, AUS) adjusted to a height of 1 m.

Match Sprinting Performance

Sprint profiles during matches were obtained from GPS units operating at 5 Hz (SPI Elite, GPSports Systems, Australia). When compared to a radar system set as a criterion, the typical error for total distance of these devices was reported to be 2.8% and 7.5% for high-speed running (> 4.17 $m.s^{-1}$) (29, 34). Regarding reliability, the devices used presented coefficient of variation values ranging from 8.4 to 20% for peak speed measurements (29, 34). Units were fitted to the upper back of each player using an adjustable neoprene harness. The fixed sprint speed threshold was set at >20 $km \cdot h^{-1}$ and players needed to spend >1 s above this threshold for a sprint to be registered. The individualized sprint speed threshold was set at >90% of the mean speed obtained in the 20 m sprint test and players also needed to spend >1 s above this threshold for a sprint to be registered. Of note, 90% of the 20-m maximal speed can be considered a very intense sprint stimulus eliciting ≈ 80% of the kinetic energy of the maximal sprint (19, 20). In addition, this criterion resulted in a mean individual speed threshold (19.37 ± 0.48 $km \cdot h^{-1}$) very close to the fixed threshold (20 $km \cdot h^{-1}$), which was previously calculated "to better equate the relative amount of sprinting between men's and women's matches" (8). This fact permitted the "unbiased" comparison between the two criteria to define RSS occurrences. Each RSS consisted of at least 2 sprints performed within 60 s. This interval was based on Buchheit et al. (10) who used intervals of 15, 30, 45 and 60 s, being the latter the most inclusive criterion. The total number of sprints, the total distance sprinting (m), the distance per sprint (m) and duration (s) of each sprint, in addition to the average interval between consecutive sprints (s) were recorded.

Statistical Analysis

Data were presented as means ± standard deviation. Due to the between-player variability in all parameters, data were log transformed before analysis. Magnitude-based inferences were used to identify differences between the fixed and individually based sprinting thresholds to detect sprint occurrences, playing positions, and the 1st and 2nd halves in all variables analyzed (5). The quantitative chance of finding differences in the variables tested were assessed qualitatively as follows: <1%, almost certainly not; 1% to 5%, very unlikely; >5% to 25%, unlikely; >25% to 75%, possible; >75% to 95%, likely; >95% to 99%, very likely; >99%, almost certain. If the chances of having better and poorer results were both >5%, the true difference was assessed as unclear. The magnitudes of the differences for the comparisons in all variables were analysed using the Cohen's *d* effect size (ES) (12). The magnitudes of the ES were qualitatively interpreted using the following thresholds: <0.2, trivial; >0.2 – 0.6, small; >0.6 – 1.2, moderate; >1.2 – 2.0, large; >2.0 – 4.0, very large and; >4.0, nearly perfect (21). All analyses were conducted using the spreadsheets available on http://www.sportsci.org/.

RESULTS

The mean speed of the 20 m sprint test was 21.5 ± 0.5 $km \cdot h^{-1}$ (range: 20.7 to 22.3 $km \cdot h^{-1}$). The distance covered sprinting using the fixed and individually based thresholds corresponds, on average to 3% and 4% of the total distance covered during matches, respectively. Figure 1 depicts the comparisons between the occurrence of sprints using both the fixed and individually based sprint thresholds. The total number of sprints, mean duration of each sprint, total distance sprinting, number of sequences of 2, ≥3, and the total number of sprinting sequences were *likely* to *very likely* higher using the individual threshold in comparison to the fixed threshold. The comparison of the distance covered per sprint using each threshold was rated as *very likely trivial*. The mean interval between sprints was *likely* longer using the fixed threshold than using the individually-based speed threshold.

*****INSERT FIGURE 1 HERE*****

Table 1 displays position specific differences in variables using fixed sprint thresholds. The central defenders (CD) demonstrated *very likely* to *almost certain* differences in the total number of sprints, total distance sprinting, mean interval between sprints, number of sequences of 2, ≥3, and the total number of sprinting sequences when compared to all other playing positions (ES: ranging from 1.22 to 3.42). The comparisons among the other playing positions in the aforementioned variables were all rated as *unclear* (ES: ranging from 0.01 to 0.19). The mean duration of each sprint in CD was *possibly* lower than in the midfielders (MD) (ES: 0.30) and the differences between CD and forwards (FW), and between MD and FW was rated as *unclear* (ES: 0.20 and 0.15, respectively). The full-backs (FB) demonstrated *likely* to *very likely* greater sprint durations than CD, MD, and FW (ES: 0.56, 0.44, and 0.55, respectively). Finally, the mean distance of each sprint was *likely* higher in the FB in comparison to the CD and FW (ES: 0.64, and 0.55, respectively). The comparisons between CD and FW, CD and MD, MD and FW, and FB and MD were all rated as *unclear* (ES: 0.03, 0.38, 0.30, and 0.27, respectively).

*****INSERT TABLE 1 HERE*****

Table 2 displays position specific trends using individualized sprint thresholds. The CD demonstrated *very likely* to *almost certain* differences in the total number of sprints, total distance sprinting, mean interval between sprints, number of sequences of 2, ≥3, and the total number of sprinting sequences in relation to the other playing positions (ES: ranging from 1.25 to 3.64). The MD illustrated *likely* to *very likely* differences in comparison to the FB and FW in the aforementioned variables (ES: ranging from 0.43 to 1.02). The comparison between FB and FW in the total number of sprints, total distance sprinting, mean interval between sprints, number of sequences of 2, ≥3, and the total of sprinting sequences were all rated as *unclear* (ES: ranging from 0.08 to 0.28). For the mean duration of each sprint, CD demonstrated *likely* to *almost certain* differences in comparison to the FB, MD and FW (ES: 1.38, 0.68, and 0.51, respectively). The FB displayed *likely* and *very likely* greater mean durations for each sprint than the MD (ES: 0.61) and FW (ES: 0.88), respectively. The comparison between MD and FW in the aforementioned variables was rated as *unclear* (ES: 0.17). Finally, the mean distance of each sprint were *likely* and *almost certainly* higher in the FB in comparison to the CD (ES: 1.14) and FW (ES: 0.75), respectively. The MD demonstrated *very likely* higher mean distance per sprint than CD (ES: 0.78). The following comparisons between CD and FW, MD and FW, and FB and MD in the aforementioned variables were all rated as *unclear* (ES: 0.36, 0.41, and 0.32, respectively).

*****INSERT TABLE 2 HERE*****

Table 3 compares all sprinting variables in the 1st and 2nd halves. Using the fixed threshold, the mean duration of each sprint, distance per sprint, sequences of 2 sprints, and total of sequences were *possibly* to *very likely* lower in the 2nd half in comparison to the 1st half (ES: 0.23, 0.24, 0.40, and 0.41, respectively). The comparisons of the total number of sprints, total distance sprinting, and sequences ≥3 sprints were all rated as *possibly trivial* (ES: 0.11, 0.18, and 0.19, respectively). The mean interval between sprints was *possibly* higher in the 2nd half than in the 1st half (ES: 0.25). Meanwhile, for the individually based threshold, the comparisons of the total number of sprints and the total distance sprinting were rated as *very likely trivial* (ES: 0.01) and *likely trivial* (ES: 0.09), respectively. The mean duration of each sprint, distance per sprint, and the sequences of 2, ≥3, and the total of sequences were *possibly* to *very likely* reduced in the 2nd half in comparison to the 1st half (ES: 0.26, 0.29, 0.30, 0.32, and 0.37, respectively). Finally, the mean interval between sprints was *likely* higher in the 2nd half than in the 1st half (ES: 0.33).

*****INSERT TABLE 3 HERE*****

DISCUSSION

This study demonstrated that: [1] irrespective of adopting fixed or individual speed sprinting thresholds, female players produced only a few RSS during matches, with most sequences composing of just two sprints; [2] position-specific sprinting trends were evident, with CD performing the lowest number of sprints (in comparison with the other positions); and [3] female players sprinting ability declined in the second half.

The sprinting distance covered by elite female players typically makes up approximately 1-3% of the total distance covered and the findings from the present study thus fall in line with previous literature (2, 6, 23, 26) – although these relative values might substantially differ, according to the speed threshold adopted in the analysis (20-25 $km \cdot h^{-1}$). The present study is the first to directly compare fixed versus individual speed thresholds in elite female players to quantify the differences between their sprint performances. The differences between sprint variables (e.g., number of single sprints and RSS) during matches using fixed or individual speed thresholds were deemed to be less meaningful from a practical perspective (ES: ranging from 0.2 to 0.6). This finding can be attributed to the similarity between the individual threshold to define sprint occurrence using performance tests (>19.4 ± 0.5 $km \cdot h^{-1}$) and the fixed speed threshold (>20 $km \cdot h^{-1}$) defined by the literature (8, 18). However, sports scientists should advocate the use of individual thresholds, as selected players can have substantially higher or lower sprint velocities compared to the average velocities attained by the squad, resulting in the over- or under-estimation of sprint performance

(8). In this case, it is important to mention that this choice requires at least one sprint test, turning the procedure less practical than the fixed threshold approach.

The present study demonstrated that female players produced a low number of RSS during matches, irrespective of the position or the type of speed threshold used to define sprints. For instance, despite using a conservative criteria to establish the occurrence of a RSS (consecutive sprints interspersed with <60 s), players produced just three sequences when using individually based thresholds. This finding was in contrast to previous research that reported 5.1 ± 5.1 RSS per player per match in elite female players (18). This is even more surprising as this research used a very stringent criterion to define a RSS compared to the present study (consecutive sprints interspersed with <20 s). The discrepancy between the findings is probably related to the technique used to capture sprinting profiles. Gabbett, et al. (18) examined the occurrence of sprints by means of video-based analysis, which partly depends on the subjective judgment of intense actions while the present study used GPS technology. Sprinting is defined as a maximal effort whereby a greater extension of the lower leg during the forward swing and a higher heel lift relative to striding occurs. Although this technique for identifying sprinting is reproducible in experienced observers (18), this pattern of locomotion does not necessarily lead the players to reach the threshold speed to define a sprint when quantified by GPS or optical tracking technologies (e.g., Amisco and Prozone) (11). This is especially evident during short-distance sprints with high accelerations, which are extremely prevalent throughout the games (36). Therefore, it seems that video-based analysis over-estimates the number of sprints during matches, and that GPS-based analysis reveals the occurrence of only a few RSS in female players. It is important to emphasize that GPS cannot be considered the gold standard to measure the distances covered by players during the matches. As aforementioned, the typical error for total distance of these devices was reported to be 2.8% and 7.5% for high-speed running (> 4.17 $m.s^{-1}$) (29, 34). Hence, errors in recording the sprint occurrences in our study cannot be ruled out.

In partial agreement with the present results, previous literature found that youth male players displayed large inter-individual variation in the number of RSS (10). While this variation was less pronounced in our study, Buchheit, et al. (10) found RSS varied from 0-43 RSS, which is probably related to the wide age ranges investigated (U13 to U18) and the criteria used to define sprints (61% of peak speed recorded as the fastest 10-m split measured during a maximal 40-m sprint). Research has also demonstrated that male German national team players performed just two RSS per game for all outfield players when using individual speed thresholds varying from 23-27.2 $km \cdot h^{-1}$ (33). The criteria used for RSS in the referred study was a minimum of three consecutive sprints with a recovery of < 30. This reiterates that RSS registration appears to be highly dependent on the sprint speed threshold and recovery duration criterion used to define its occurrence (33), although studies demonstrate that the ability to perform repeated intense actions with minimal recovery during matches demarcates players in different competitive standards and positions (3, 31). However, based on the findings presented herein and that reported on elite male players, some could question the RSS occurrence during soccer matches (10, 33). Although players may not reach sprinting velocities during each intense action due to player density in selected areas of the pitch or tactical and technical constraints but may in fact produce very high accelerations and decelerations during matches (1, 36). Thus, the literature may need to redefine this as repeated acceleration ability, since this may describe the demands of soccer match-play more accurately as these efforts are metabolically taxing (28) but do not register as sprints (4). The present data collected from elite female players points in the same direction, and thereby bring into question the great deal of effort used to assess and develop RSA in elite players. Nonetheless, some findings in the literature still need to be highlighted to contextualize this statement. For instance, RSA has been shown to positively correlate with physical performance during soccer matches (30), discriminate between players of different competitive levels and positional roles, and be able to detect training-induced changes (22). Further, RSA is impaired post-match (24), indicating that the physical demands of soccer place specific stress on determinants of RSA (e.g., neuromuscular system and H^+ buffering). Therefore, although it is evident that RSS, as they are currently defined, do not occur very often during soccer matches, the stochastic alternation between activities (including high-intensity running and single sprints) seems to acutely deteriorate RSA. In fact, although RSA is an important physical capacity related to match performance, it does not mean that RSS, as they are currently defined, actually occurs during soccer matches. This calls for additional studies to be conducted to elucidate whether the physiological factors related to RSA performance are or are not related to the match physical demands and players' fatigue. More importantly, research needs to indicate whether a better RSA can ameliorate the tolerance to fatigue throughout the match, manifested as the reduction in the distance covered during repeated accelerations and decelerations (1).

Irrespective of the sprint speed threshold, the mean duration of each sprint, distance per sprint, sequences of 2 sprints, and total number of sequences were lower in the 2nd half in comparison to the 1st half. Additionally, the mean interval between sprints was longer in the 2nd half than in the 1st half. These results agree with those previously reported by Vescovi (37), who found fewer sprints and sprint distance in the 2nd half compared to the 1st half in elite female players, especially in forwards, and with Gabbett, et al. (18), who reported increased recovery durations between sprints during the 2nd half than in the 1st half. The present findings corroborate the idea that fatigue ensues throughout the match duration (27), possibly impairing the ability to perform sprints and repeated sprints (24). This is supported by game-induced fatigue patterns in elite female players that illustrated a 60% drop in Yo-Yo Intermittent Test performance and 4% slower repeated sprint test time after games compared with before (24). Substituting fatigued players at halftime is an effective means of avoiding a reduction in players' high-intensity running profile, since the substitutes perform better than themselves when tracked from the start of the match, the players who completed the entire match or the players who were replaced (7). It is important to emphasize that fatigue may not be the only reason sprint performance is reduced during the later stages of a soccer match. Other match-specific contextual factors (such as current match scoreline, holding possession and slowing the game down) may have also contributed to the reduction in sprint performance. Future studies should determine whether substitutes perform more sprints and RSS (than their replaced peers), and if this feature will increase the chances of scoring goals (16).

In general, using both speed thresholds, CD performed less sprints, covered lower distance sprinting and were involved in fewer sequences than other playing positions. Additionally, MD were also less involved in single sprinting activities and sprint sequences than the FW and the FB (when using the individually based threshold). These results are consistent with the literature, since Vescovi (37) found that the number of sprints performed by female FW was greater than those performed by MD and defenders (which included both central defenders and full-backs). In our opinion, in this kind of comparison, data should never be collapsed for CD and FB, due to their contrasting participation in sprinting activities during the matches. Additionally, CD were shown to perform fewer repeated high-intensity bouts (> 19.8 $km \cdot h^{-1}$ over a minimum duration of 1 s, with >61 s recovery) than the other positions. The present findings add to the literature by demonstrating that the choice of fixed or individual speed thresholds produces small but important differences in the number of RSS per positional subsets. Possibly, the use of individually-based velocities should be preferred by coaches and sports scientists to account/search for differences in the sprinting ability among players, providing more detailed information about the physical demands of each playing position.

The main findings of this study were that using either fixed or individually based thresholds to define sprinting during the matches resulted in a very limited number of RSS, with most of them composed of only 2 sprints. In addition, some differences in the performance of sprints and RSS were found among playing positions, with the CD performing less sprint efforts than the other players in other positions do. Finally, impairment in the ability to repeat sprints was observed in our sample of elite female soccer players during the second half compared to the first half, suggesting that fatigue-related mechanisms may compromise performance in decisive playing actions (e.g., counterattack and goal scoring) across the match.

In summary, the data presented herein demonstrate that elite female players perform only a few RSS regardless of the type of sprint threshold used. Additionally, the individually based threshold was more sensible at demarcating between position differences. Our results do not support the notion that RSS occurs frequently during soccer matches, especially for female players, but do not imply that this ability should not be included in training programs. The RSA is positively correlated with match physical performance as measured by the very-high intensity running and sprinting distance (30). Finally, the findings from this study suggest the use of individually based thresholds in order to better/properly analyze the activities profile during the matches according to the physical performance of each player, keeping in mind the necessity of an additional sprint test to implement it.

PRACTICAL APPLICATIONS

For practical training related purposes, it is important to determine whether repeated sprint sequences occur during female soccer matches. Interestingly, our approach of adopting >90% of the mean speed obtained in the 20 m sprint resulted in a threshold defined to identify a sprint occurrence (>19.4 ± 0.5 $km \cdot h^{-1}$) which was quite close to the fixed threshold determined in the literature (>20 $km \cdot h^{-1}$). Therefore, we suggest this method to individualize the counting of sprint efforts in this population. This is especially critical to players largely deviating from the average sprint performance. Although it is recognized that the repeated-sprint ability is an important determinant of high-level match physical performance, our results confirm previous reports on male soccer that few repeated sprint sequences are performed by the players. This means that match-related physical performance reduction is probably caused by other efforts (e.g., accelerations and decelerations, high-intensity runs, etc) or even modulated by contextual factors (such as current match scoreline and slowing the game down). However, the role of a well-developed RSA cannot be ruled out in soccer players since it does influence match physical performance during high-intensity activities. In fact, its determining factors (neuromuscular capacity and H^+ buffering) might protect players against transient fatigue typical of soccer matches. Finally, the central backs are the players least demanded to perform sprints during matches (compared to full-backs, midfielders and forwards) and this information can help in prescription of more specific training drills to each playing position, especially in teams having access to GPS-based data in both training and matches.

REFERENCES

1. Akenhead R, Hayes PR, Thompson KG, and French D. Diminutions of acceleration and deceleration output during professional football match play. *J Sci Med Sport* 16: 556-561, 2013.
2. Andersson HA, Randers MB, Heiner-Moller A, Krustrup P, and Mohr M. Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *J Strength Cond Res* 24: 912-919, 2010.
3. Aziz AR, Mukherjee S, Chia MY, and Teh KC. Validity of the running repeated sprint ability test among playing positions and level of competitiveness in trained soccer players. *Int J Sports Med* 29: 833-838, 2008.
4. Barbero-Alvarez JC, Boullosa D, Nakamura FY, Andrin G, and Weston M. Repeated Acceleration Ability (RAA): A New Concept with Reference to Top-Level Field and Assistant Soccer Referees. *Asian J Sports Med* 5: 63-66, 2014.
5. Batterham AM and Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform* 1: 50-57, 2006.
6. Bradley PS, Dellal A, Mohr M, Castellano J, and Wilkie A. Gender differences in match performance characteristics of soccer players competing in the UEFA Champions League. *Hum Mov Sci* 33: 159-171, 2014.
7. Bradley PS, Lago-Penas C, and Rey E. Evaluation of the match performances of substitution players in elite soccer. *Int J Sports Physiol Perform* 9: 415-424, 2014.

8. Bradley PS and Vescovi JD. Velocity thresholds for women's soccer matches: sex specificity dictates high-speed running and sprinting thresholds - Female Athletes in Motion (FAiM). *Int J Sports Physiol Perform* 10: 112-116, 2015.

9. Buchheit M, Al Haddad H, Simpson BM, Palazzi D, Bourdon PC, Di Salvo V, and Mendez-Villanueva A. Monitoring accelerations with GPS in football: time to slow down? *Int J Sports Physiol Perform* 9: 442-445, 2014.

10. Buchheit M, Mendez-villanueva A, Simpson BM, and Bourdon PC. Repeated-sprint sequences during youth soccer matches. *Int J Sports Med* 31: 709-716, 2010.

11. Castellano J, Alvarez-Pastor D, and Bradley PS. Evaluation of research using computerised tracking systems (Amisco and Prozone) to analyse physical performance in elite soccer: a systematic review. *Sports Med* 44: 701-712, 2014.

12. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Hillsdale (NJ): Lawrence Erlbaum Associates, 1988.

13. Di Mascio M, Ade J, and Bradley PS. The reliability, validity and sensitivity of a novel soccer-specific reactive repeated-sprint test (RRST). *Eur J Appl Physiol* 115: 2531-2542, 2015.

14. di Prampero PE, Fusi S, Sepulcri L, Morin JB, Belli A, and Antonutto G. Sprint running: a new energetic approach. *J Exp Biol* 208: 2809-2816, 2005.

15. Di Salvo V, Baron R, Gonzalez-Haro C, Gormasz C, Pigozzi F, and Bachl N. Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *J Sports Sci* 28: 1489-1494, 2010.

16. Faude O, Koch T, and Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci* 30: 625-631, 2012.

17. Gabbett TJ. Use of Relative Speed Zones Increases the High-Speed Running Performed in Team Sport Match Play. *J Strength Cond Res* 29: 3353-3359, 2015.

18. Gabbett TJ, Wiig H, and Spencer M. Repeated high-intensity running and sprinting in elite women's soccer competition. *Int J Sports Physiol Perform* 8: 130-138, 2013.

19. Haugen T, Tonnessen E, Leirstein S, Hem E, and Seiler S. Not quite so fast: effect of training at 90% sprint speed on maximal and repeated-sprint ability in soccer players. *J Sports Sci* 32: 1979-1986, 2014.

20. Haugen T, Tonnessen E, Oksenholt O, Haugen FL, Paulsen G, Enoksen E, and Seiler S. Sprint conditioning of junior soccer players: effects of training intensity and technique supervision. *PLoS One* 10: e0121827, 2015.

21. Hopkins WG, Marshall SW, Batterham AM, and Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41: 3-13, 2009.

22. Impellizzeri FM, Rampinini E, Castagna C, Bishop D, Ferrari Bravo D, Tibaudi A, and Wisloff U. Validity of a repeated-sprint test for football. *Int J Sports Med* 29: 899-905, 2008.

23. Krustrup P, Mohr M, Ellingsgaard H, and Bangsbo J. Physical demands during an elite female soccer game: importance of training status. *Med Sci Sports Exerc* 37: 1242-1248, 2005.

24. Krustrup P, Zebis M, Jensen JM, and Mohr M. Game-induced fatigue patterns in elite female soccer. *J Strength Cond Res* 24: 437-441, 2010.

25. Lovell R and Abt G. Individualization of time-motion analysis: a case-cohort example. *Int J Sports Physiol Perform* 8: 456-458, 2013.

26. Mohr M, Krustrup P, Andersson H, Kirkendal D, and Bangsbo J. Match activities of elite women soccer players at different performance levels. *J Strength Cond Res* 22: 341-349, 2008.

27. Mohr M, Krustrup P, and Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519-528, 2003.

28. Osgnach C, Poser S, Bernardini R, Rinaldo R, and di Prampero PE. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc* 42: 170-178, 2010.

29. Rampinini E, Alberti G, Fiorenza M, Riggio M, Sassi R, Borges TO, and Coutts AJ. Accuracy of GPS devices for measuring high-intensity running in field-based team sports. *Int J Sports Med* 36: 49-53, 2015.

30. Rampinini E, Bishop D, Marcora SM, Ferrari Bravo D, Sassi R, and Impellizzeri FM. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *Int J Sports Med* 28: 228-235, 2007.

31. Rampinini E, Sassi A, Morelli A, Mazzoni S, Fanchini M, and Coutts AJ. Repeated-sprint ability in professional and amateur soccer players. *Appl Physiol Nutr Metab* 34: 1048-1054, 2009.

32. Randers MB, Mujika I, Hewitt A, Santisteban J, Bischoff R, Solano R, Zubillaga A, Peltola E, Krustrup P, and Mohr M. Application of four different football match analysis systems: a comparative study. *J Sports Sci* 28: 171-182, 2010.

33. Schimpchen J, Skorski S, Nopp S, and Meyer T. Are "classical" tests of repeated-sprint ability in football externally valid? A new approach to determine

in-game sprinting behaviour in elite football players. *J Sports Sci* 34: 519-526, 2016.

34. Scott MT, Scott TJ, and Kelly VG. The Validity and Reliability of Global Positioning Systems in Team Sport: A Brief Review. *J Strength Cond Res* 30: 1470-1490, 2016.

35. Spencer M, Lawrence S, Rechichi C, Bishop D, Dawson B, and Goodman C. Time-motion analysis of elite field hockey, with special reference to repeated-sprint activity. *J Sports Sci* 22: 843-850, 2004.

36. Varley MC and Aughey RJ. Acceleration profiles in elite Australian soccer. *Int J Sports Med* 34: 34-39, 2013.

37. Vescovi JD. Sprint profile of professional female soccer players during competitive matches: Female Athletes in Motion (FAiM) study. *J Sports Sci* 30: 1259-1265, 2012.

38. Vescovi JD. Sprint speed characteristics of high-level American female soccer players: Female Athletes in Motion (FAiM) study. *J Sci Med Sport* 15: 474-478, 2012.

FIGURE CAPTION

Figure 1. Comparisons of the sprinting activities between fixed (20 $km{\cdot}h^{-1}$) and individually based thresholds to identify sprint occurrences presented by effect sizes and 90% confidence intervals. The magnitudes of the ES were qualitatively interpreted using the following thresholds: <0.2, trivial; >0.2 – 0.6, small; >0.6 – 1.2, moderate; >1.2 – 2.0, large; >2.0 – 4.0, very large and; >4.0, nearly perfect.

Table 1. Comparisons of the sprint variables in the different playing positions using the fixed threshold (20 $km \cdot h^{-1}$) to identify sprint occurrences. Data are presented as means ± standard deviations.

	CD	**FB**	**MD**	**FW**	**All Players**
Number of sprints	8.2 ± 3.3*	21.4 ± 4.8	21.9 ± 9.7	22.8 ± 7.8	17.7 ± 9.3
Mean duration (s)	2.4 ± 0.6#	2.7 ± 0.4	2.5 ± 0.4+	2.5 ± 0.4	2.5 ± 0.5
Total distance in sprints (m)	124.5 ± 61.3*	358.5 ± 97.6	359.1 ± 174.0	352.0 ± 144.5	284.5 ± 163.5
Distance per sprint (m)	15.0 ± 2.3	16.7 ± 2.6¥	16.0 ± 2.6	15.1 ± 2.8	15.7 ± 2.6
Mean interval between sprints (s)	533.3 ± 251.4*	264.8 ± 55.0	283.2 ± 161.3	247.3 ± 57.7	350.1 ± 206.7
Sequences of 2 sprints	0.4 ± 0.8*	2.7 ± 1.7	2.5 ± 2.1	2.7 ± 2.3	1.9 ± 2.0
Sequences ≥3 sprints	0*	0.5 ± 0.5	0.7 ± 0.8	0.7 ± 1.0	0.4 ± 0.7
Total number of sprint sequences	0.4 ± 0.8*	3.2 ± 1.8	3.0 ± 2.6	3.3 ± 2.6	2.3 ± 2.4

*Note: CD: central defenders; FB: fullbacks; MD: midfielders; FW: forwards. *Almost certain different from FB, MD, FW; #possibly different from MD; +likely and very likely different from CD, MD FW; ¥likely different from CD, FW.*

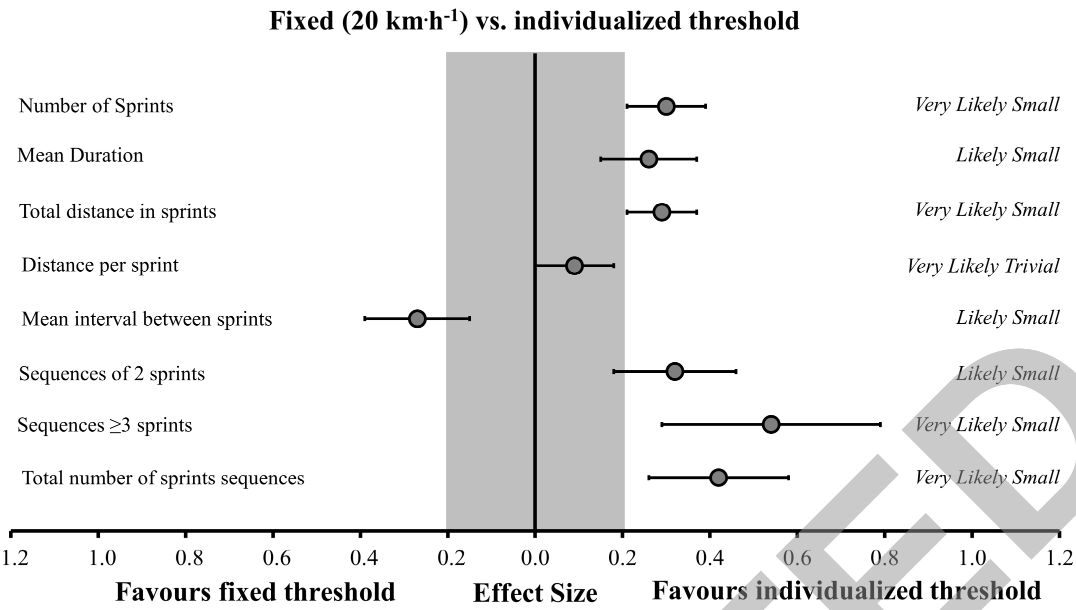
Table 2. Comparisons of the sprint variables in the different playing positions using the individually based threshold (>90% of 20-m maximal sprint velocity) to identify sprint occurrences. Data are presented as means ± standard deviations.

	CD	**FB**	**MD**	**FW**	**All Players**
Number of Sprints	10.2 ± 4.1*	28.1 ± 5.5	21.9 ± 10.5#	31.9 ± 11.1	21.5 ± 11.6
Mean duration (s)	2.4 ± 0.3*	3.0 ± 0.4+	2.7 ± 0.4	2.6 ± 0.4	2.6 ± 0.4
Total distance in sprints (m)	150.0 ± 71.0*	496.0 ± 135.8	371.5 ± 191.2#	492.6 ± 179.2	352.9 ± 205.7
Distance per sprint (m)	14.5 ± 2.3	17.5 ± 2.4¥	16.6 ± 2.7¶	15.4 ± 2.5	15.9 ± 2.7
Mean interval between sprints (s)	490.3 ± 212.2*	201.6 ± 38.5	278.0 ± 140.0#	191.0 ± 50.7	310.7 ± 188.3
Sequences of 2 sprints	0.7 ± 1.0*	3.8 ± 1.7	2.4 ± 2.2#	4.1 ± 1.9	2.5 ± 2.2
Sequences ≥3 sprints	0.2 ± 0.4*	1.2 ± 0.7	0.7 ± 0.8#	1.6 ± 1.8	0.8 ± 1.1
Total number of sprint sequences	0.9 ± 1.2*	4.9 ± 2.0	3.1 ± 2.9#	5.7 ± 3.2	3.3 ± 3.0

*Note: CD: central defenders; FB: fullbacks; MD: midfielders; FW: forwards. *Likely, very likely and almost certainly different from FB, MD, FW; #likely and very likely different from FB and FW; +likely and very likely different from MD and FW; ¥likely and almost certainly different from CD and FW; ¶very likely different from CD.*

Table 3. Comparisons of the sprinting activities between first and second halves using fixed (20 $km \cdot h^{-1}$) and individually based (>90% of 20-m maximal sprint velocity) thresholds to identify sprint occurrences. Data are presented as means ± standard deviations.

	Thresholds	**1st half**	**2nd half**	**% chances of higher/trivial/lower values comparing the two halves**
Number of sprints	Fixed	9.4 ± 5.3	8.3 ± 5.0	20/80/00 *Likely trivial*
	Individual	11.4 ± 7.2	10.2 ± 5.2	01/98/01 *Very likely trivial*
Mean duration (s)	Fixed	2.6 ± 0.6	2.4 ± 0.7	57/42/01 *Possibly*
	Individual	2.7 ± 0.6	2.6 ± 0.6	63/36/01 *Possibly*
Total distance in sprints (m)	Fixed	154.3 ± 98.4	130.3 ± 87.5	44/56/00 *Possibly*
	Individual	189.5 ± 126.7	163.4 ± 99.9	15/85/00 *Likely trivial*
Distance per sprint (m)	Fixed	16.2 ± 4.3	15.1 ± 3.5	58/41/01 *Possibly*
	Individual	16.5 ± 4.0	15.3 ± 3.8	70/30/00 *Possibly*
Mean interval between sprints (s)	Fixed	330.2 ± 239.9	361.2 ± 298.2	00/34/66 *Possibly*
	Individual	280.1 ± 213.8	330.1 ± 202.5	00/10/90 *Likely*
Sequences of 2 sprints	Fixed	1.2 ± 1.3	0.7 ± 1.1	94/06/00 *Likely*
	Individual	1.5 ± 1.4	1.1 ± 1.3	76/24/00 *Likely*
Sequences >3 sprints	Fixed	0.3 ± 0.5	0.2 ± 0.4	48/51/01 *Possibly*
	Individual	0.6 ± 1.0	0.3 ± 0.5	82/18/00 *Likely*
Total number of sprint sequences	Fixed	1.5 ± 1.5	0.8 ± 1.3	99/01/00 *Very Likely*
	Individual	2.0 ± 2.0	1.3 ± 1.5	93/07/00 *Likely*


Fixed (20 km·h-1) vs. individualized threshold
Number of Sprints
Mean Duration
Total distance in sprints
Distance per sprint
Mean interval between sprints
Sequences of 2 sprints
Sequences ≥3 sprints
Total number of sprints sequences
Very Likely Small
Likely Small
Very Likely Small
Very Likely Trivial
Likely Small
Likely Small
Very Likely Small
Very Likely Small
1.2 1.0 0.8 0.6 0.4 0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2
Favours fixed threshold
Effect Size
Favours individualized threshold