Half-time and high-speed running in the second half of soccer

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Short title: Half-time and high-speed running in soccer

Abstract

This study investigated if the quantity of high-speed running (movements >15 km.h^{-1}) completed in the first 15 minutes of competitive football matches differed from that completed in the corresponding 15 minutes of the second half. Twenty semi-professional soccer players (age 21.2 ± 3.6 years, body mass 76.4 ± 3.8 kg, height 1.89 ± 0.05 m) participated in the study. Fifty competitive soccer matches and 192 data files were analysed (4 ± 2 files per match) using Global Positioning Satellite technology. Data were analysed using 2-way repeated measures ANOVA and Pearson correlations. No differences were found between the first 15 min of each half for the distance completed at high-speed (>15 km.h^{-1}) or sprinting (>21 km.h^{-1}), or in the number of sprints undertaken (p>0.05). However, total distance covered was shorter (1st half vs. 2nd half: 1746 ± 220 vs. 1644 ± 224 m; p<0.001) and mean speed lower (1st half vs. 2nd half: 7.0 ± 0.9 vs. 6.6 ± 0.9 km.h^{-1}; p<0.001) in the first 15 min of the second half compared to the first. The correlations between the duration of the half-time interval and the difference in the high-speed running or sprinting between first and second halves (0-15 min) were very small (r=0.08 [p=0.25] and r=0.04 [p=0.61] respectively). Therefore, this study did not find any difference between the amount of high-speed running and sprinting completed by semi-professional soccer players when the first 15 minutes of the first and second half of competitive matches were compared The maintenance of high-speed running and sprinting, as total distance and mean speed declined, may be a function of the pacing strategies adopted by players in competitive matches.

Key words: Intermittent exercise, football, GPS, activity profiles

Introduction

Association Football, or ‘soccer’ as it is increasingly labelled, is an intermittent sport involving frequent but brief periods of high intensity movement, interspersed with walking, jogging and lower intensity running [3,21]. To these varying physical requirements can be added the disparate technical requirements of the game such as passing, shooting, heading and tackling [3,21]. Research suggests that a soccer player changes their activity every 4-6s [3,17], and international players may complete 1350 activities per game, of which approximately 220 involve running at what has been categorised as “high-intensity” [17] or, perhaps more correctly, “high-speed” running (>15 $km.h^{-1}$) [1]. Although comprising only a fraction (11%) of the total distance covered by players during a game [22], these short periods of high-speed running are most likely to produce the crucial moments in matches, such as winning possession and scoring or conceding a goal [21]. Also, as the quantity of high-speed running completed by players in a 90 minute match relates to physical characteristics such as maximal oxygen uptake [3,5,20,23,25], and can distinguish high-standard players from those of more moderate standard [17], the ability to sustain high-speed running during a match (or not) is a topic of real interest.

Research indicates that the distances completed at a high to maximal speed are shorter, and the number of discrete sprints fewer, in the second half of a match compared with the first half [3,5]. Given the suggested association between high-speed running and crucial moments during a game [22], any intervention that might attenuate some or all of the decrements evident in high-speed running during the second half of matches, could have important performance outcomes. Some recent studies have investigated the impact of the half-time interval, on high speed running. During 2-7 matches in 18 top class and 24 moderate level professional players, a shorter high-speed running distance was covered in the first 5 minutes of the second half compared with the same period in the first half [17]. In youth players (17 ± 1 years) distance at high-speed was also shorter (-5.8 m) in the first 5 minutes of the second half of play when compared with the first half mean [Lovell 2012]. However, this difference was not evident when the subsequent 5 minute periods (51-55 min and 56-60 min) of each half were compared for the professional players [17] or when compared with the first half mean for the youth players [14]. As elevated muscle temperature is associated with increased power outputs [24] the passive rest typically adopted by players during the half-time interval [4], and the accompanying decline in muscle temperature (by approximately 2 °C [18]), may explain why high-speed running appears to be poorer during the initial part of the second half of matches. Manipulations to prevent this performance decline could have important implications during match play.

The performance benefits of a “re-warm-up” during a half-time period have been examined in a controlled (but ecologically invalid) laboratory setting using a soccer specific endurance test [15]. Active submaximal or intermittent sprint-based warm-ups in the half-time interval prevented declines in endurance performance evident when players rested passively or were heated passively in a water bath [15]. During actual match play, when Danish Fourth Division soccer players rested passively at half-time, there was a 2.4% decline in their mean 3 x 30 m sprint performance prior to the second half of play. When they incorporated a “re-warm-up” into the final 7 minutes of the half-time interval this decline was prevented [18]. The study’s authors recommended that moderate intensity activities should be performed in the final 7-8 minutes of the half-time interval to increase the likelihood of high quality performance at the start of the second half of a match, and to reduce the possibility of injury [18]. It may also be that ambient temperature could influence the efficacy of re-warm-up as hotter environmental conditions may attenuate some of the decline in the elevated core and muscle temperature seen following intermittent exercise [19].

While physical activity may produce benefits in terms of high-speed running and sprinting, there may be good tactical reasons why players are inactive prior to the start of a match and at half-time, such as assimilating tactical instructions from managerial or coaching staff. There is also the possibility that players would wish to rest in the half-time interval, or that if they fail to rest, while beneficial in the early part of the second half, performance could be poorer later in the half. Also, in high standard players, the greatest amount of high-speed running in a 5 minute period during a match, was followed by the 5 minutes with the shortest high-speed running distance [17]. This suggests that performing at maximum in one period of a match inevitably impacts on the ability to perform similar activity in the period immediately following such an effort.

Previous studies which have directly examined the effect of the half-time interval on the quantity of high-speed running and sprinting performed in the early part of the second half of soccer matches have been based in the laboratory [15], or have involved friendly matches [18] or youth players [14]. Laboratory studies are often limited by factors such as: the absence of a ball; set patterns of movement, which are not as variable as that seen in match play; and prescribed exercise intensities which limit the opportunity to self-pace physical effort [7]. While much closer to the ‘real’ situation, friendly matches may also fail to induce responses which can only accrue from actual competition. In addition, much of the previous work has used video analysis methodologies and pitch markings to establish distances travelled during match play [17]. Although the reliability of such methods have been established [13], the speed of player movements are not directly determined. Recent technological advances in Global Positioning Satellite (GPS) systems would seem to offer a quick, valid and reliable methodology for analysing game sport activities [9,16,27]. Such quantitative systems provide the opportunity to analyse more players and their performance across a season relatively easily, and hence allow a more thorough and less subjective examination of the extent to which high-speed running and sprinting is reduced in the early part of the second half of a match. Thus, further research investigating the effect of half-time on performance of high-speed running and sprinting during competitive matches would appear to be warranted.

Therefore, using GPS technology, this study sought to examine if the quantity of high-speed running and sprinting completed in the first 15 minutes of competitive football matches differed from that completed in the corresponding 15 minutes of the second half. The study also sought to investigate if the length of half time and the ambient temperatures during competitive matches influenced the amount of high-speed running completed in the first 15 minutes of the second half.

Method

Participants

Twenty, healthy, semi-professional soccer players (age 21.2 ± 3.6 years, body mass 76.4 ± 3.8 kg, stature 1.81 ± 0.05 m) volunteered for the study. These players were undertaking 2-3 training sessions and 1-3 matches per week during the season in which the study was completed. One hundred and ninety-two data files, from 50 soccer matches (39 National League System of English Football games and 11 British Universities and Colleges Sport (BUCS) Premier League games), were analysed (4 ± 2 files per match). All participants were outfield players. Participants were fully informed of any risks and discomforts associated with the study, and completed a health screen and signed informed consent before involvement. The study was approved by the institution's Ethical Advisory Committee and conformed to the ethical standards of the International Journal of Sports Medicine [11].

Match Analysis

Match data were collected across an entire season (August 2009-May 2010) using a 1 Hz portable GPS system, integrated with output from a 100 Hz accelerometer to improve calculation of distance and speed (SPI Elite, GPSports, Fyshwick, Australia). The GPS unit was located between a participant's shoulder blades during matches, with the unit housed in a custom made vest. Participants used the same GPS unit throughout the season and 15 units in all were used in the study. The GPS system used in the study has previously been validated specifically for research into team sport match movements at latitudes employed in the present study ([6]; mean difference ± 95% limits of agreement: 0.0 ± 0.9 $km.h^{-1}$ and 2.5 ± 15.8 m; [16]), including high-speed running and sprinting (linear distance percentage bias: 2.5% and non-linear distance percentage bias adjusted for lean: -4.3% [10]; mean difference ± 95% limits of agreement: 0.2 ± 1.2 $km.h^{-1}$; [16]). During the testing period 8 ± 1 satellites were used for the position fix by the GPS units with a mean horizontal dilution of precision of 1.17 ± 0.26 ([26]; 1 is regarded as ideal for the highest possible precision at all times and 1-2 as excellent). Motion categories (zones) were set at walking (0-6 $km.h^{-1}$), jogging (6-12 $km.h^{-1}$), running (12-15 $km.h^{-1}$), high-speed running (>15 $km.h^{-1}$) and sprinting (>21 $km.h^{-1}$) [1]. Time slots for analysis focussed on 0-5, 5-10, 10-15 min periods of the first half of competitive play and on the 45-50, 50-55, 55-60 min of matches which represented the corresponding time points at the start of the second half of play. The length of the half-time interval was measured using a stop watch and was regarded as the time immediately following the referee's whistle to end the first half of play up to the referee's whistle to start the second half. The length of half-time was not controlled by the researcher and was dependant on the referee and the players returning to the field. Players returned to the changing rooms at half-time and recovered passively. On four occasions players remained on the pitch for the duration of half-time but recovered passively. Ambient temperature and humidity were measured using a Thermohygrometer (Electronic Temperature Instruments Ltd, Worthing, UK) to determine if temperature had an effect on activity profile statistics.

Statistical Analyses

Data were analysed using SPSS statistical software (Version 17.0, SPSS Inc. Chicago IL, USA) and Microsoft Office Excel 2007 (Microsoft, USA). A 2–way analysis of variance (ANOVA) with repeated measures on both factors (half x 5 min time period) was used to investigate high speed running distance, sprinting distance, the number of sprints, total distance covered and mean speed during specific periods of the first half of matches (0-5, 5-10, 10-15 min) compared to the same time periods in the second half (45-50, 50-55, 55-60 min). Bonferroni post hoc analyses were employed when significant differences were found. Data for the complete match for the variables above were also analysed using Student's t-test (first vs. second half). Pearson correlation was used to examine relationships between the match activity variables noted above (and the difference in performance between the 1st and 2nd half for these variables), and the duration of the half-time interval, and with ambient temperature. Correlations were defined as small (r = 0.1-0.29), medium (r = 0.3-0.49) or large (r = 0.50-1.0) [8]. Statistical significance was accepted at P <0.05 level. Results are presented as mean ± standard deviation (SD).

Results

Match Analysis: Complete match (2 x 45 minutes)

Players covered 10163 ± 1183 m during matches, at a mean speed of 6.5 ± 0.7 km.h^{-1}. Sixteen per cent of the total distance, or 1635 ± 530 m, was completed through high speed running, while 3%, or 320 ±173 m, was completed via 22 ± 10 sprints. The total distance covered in the first half of matches was greater than that completed in the second half (5188 ± 617 vs 4975 ± 723 m respectively; $p<0.001$). High speed running was reduced in the second half (1st half vs 2nd half: 837 ± 294 vs 797 ± 289 m; $p=0.03$), but there were no differences in the distance sprinted (1st half vs 2nd half: 159 ± 100 vs 161 ± 93 m; $p=0.79$) or in the number of sprints (1st half vs 2nd half: 11 ± 6 vs 11 ± 6; $p=0.68$) when the two playing periods were compared.

Match Analysis: 0-15 min period of each half

When the first 15 minutes of the first and second half were compared, the distance covered, when running at high-speed or sprinting, was not different (Table 1). A similar number of sprints were performed during each of these time periods (1st half 0-15 min vs 2nd half 0-15 min: 4.0 ± 2.7 vs. 3.8 ± 2.5; main effect, half, $p=0.197$). However, the total distance completed was less (5.8%) in the first fifteen minutes of the second half (main effect, half, $p<0.001$), and as such mean speed was slower (1st half 0-15 min vs 2nd half 0-15 min: 7.0 ± 0.9 vs. 6.6 ± 0.9 km.h^{-1}, main effect, half, $p<0.001$).

Match Analysis: 0-5, 5-10 and 10-15 min period of each half

There were no differences in the high-speed running or sprinting distance when the 0-5, 5-10 and 10-15 minutes of the first and second half of play were compared (Table 2). The number of sprints decreased over time, but was not different between halves (main effect, time, p=0.03; 0-5 vs. 10-15 min, post hoc, p=0.04). The total distance completed was less and the mean speed was slower in the second half of play in the 0-5 and 10-15 min time periods (both variables - main effect, half, p<0.001; main effect, time, p<0.001 [0-5 vs. 10-15 min, post hoc, p<0.001]; interaction, half x time, p=0.05 (1st half vs. 2nd half, 0-5 and 10-15 min, post hoc, p<0.001] Table 2).

Correlation: Duration of the half-time interval with various match activities

The mean duration of half-time during the 50 matches examined in this study was 14.2 ± 2.3 min (range 7.2 - 21.7 min). The correlations between the duration of the half-time interval and the match activities examined were small. As Table 3 shows, for the 15 min match activities, no Pearson correlation was greater than 0.11 and none reached statistical significance. The correlations between the duration of half-time and match activities at 45-50 min of play were 0.10 or less and not statistically significant.

Correlation: Ambient temperature with various match activities

The mean dry bulb temperature and humidity during the 50 matches examined in this study was 11.4 ± 5.7 ^{o}C (range: 1.8 to 24.3 ^{o}C) and 75.8 ± 17.5 % (range: 38.8 to 100.0 %) respectively. Correlations between temperature and high-speed running or sprinting or the number of sprints were small (Pearson ‘r’ ranging from -0.15 to 0.05) and none attained statistical significance (Table 4). Small negative correlations (-0.24 to -0.29, p<0.001) were found between temperature and total distance or mean speed in the first 15 min of matches, and between temperature and difference in distance or difference in speed between the first 15 min of each half (Table 4). There were small negative correlations between temperature and high-speed running in the first 5 min of each half (1st half 0-5 min: r=-0.233, p=0.002; 2nd half 0-15 min: r=-0.222, p =0.002). There were large correlations between temperature and number of sprints (1st half 0-5 min: r=0.638, p<0.001; 2nd half 0-15 min: r = 0.616, p<0.001) and temperature and total distance covered (1st half 0-5 min: r = -0.767, p<0.001; 2nd half 0-15 min: r = 0.763, p<0.001) in the first 5 min of each half. No association was evident between temperature and the difference in the various match activities in the first 5 min of each half.

Discussion

The aim of the present study was to examine if the quantity of high-speed running and sprinting completed in the first 15 minutes of competitive football matches differed from that completed in the corresponding 15 minutes of the second half. The key finding was that no difference was found between the amount of high-speed running or sprinting completed by semi-professional soccer players when the first 15 minutes of the first and second half of competitive matches were compared (this was the case whether the 15 min periods of play were examined as a single block or in sub-segments of 5 minutes). However, the total distance completed by players was less and their mean speed slower in the first 15 minutes of the second half when compared with the same time period in the first half of competitive matches. No correlation was found between the duration of the half-time interval (which ranged from 7.2 - 21.7 min) and the difference between first and second half performance (0-15 min) for any of the match activities examined. However, small correlations were found between dry bulb temperature and total distance completed or mean speed maintained, suggesting that perhaps 5% of the difference observed in these match activities between the first and second half (0-15 min) could be due to ambient temperature.

In agreement with previous research, when the first 15 minutes of each half of match play were compared, the distance completed by high-speed running was comparable [2,14,17]. However, the finding in the present study that high-speed running did not differ when the first 5 minutes of the first and second half of competitive matches were compared, is in contrast to previous research, which found reductions in high-speed running of just under 19% when the first 5 minutes of the first half of matches was compared with the comparable time period in the second half [17]. It is possible that this lack of agreement between studies is a function of the different methods used to analyse the movement patterns in the matches they examined. Mohr and colleagues [17] used a video based approach which is reliant on the subjective categorisation of player movements into speed categories; the present study used a GPS based method which has been validated [16] and gives a more direct quantification of the speed of movement of players during match play. Therefore it may well be that the match analysis methodology may be a key issue explaining the discrepancy between the findings. However, it is interesting to note that the semi-professional soccer players in the present study were performing about one third of the high-speed running in a 5 minute period compared with the top-class and moderate standard professional players that were studied previously using video based methods (160 vs. 49 m in the 1st half; 130 vs 42 m in the 2nd half), and therefore the contrasting findings may be a function of playing standard and 'fitness'. Though not directly comparable, recent research in youth players has also demonstrated that high-speed running distance is shorter when the first 5 min of the second half of a match is compared with the first half mean [14]. Therefore, as players of all playing standards and ages seem to be unable to maintain high levels of performance throughout matches it has to be acknowledged that the differing observations described above may simply be indicative of differing strategies adopted by players and their team managers during competitive match play.

While no differences were found in in the amount of high-speed running or sprinting completed when the 0-5, 5-10 and 10-15 minutes of the first half and second half of competitive match play were compared, the total distance completed was less and the mean speed maintained was lower in the second half of play in these time periods. If one accepts that the high-speed and sprinting elements in a match may be associated with crucial incidents [21], and that fatigue occurs in the course of the game [17], the decline observed in total distance and mean speed, but not in high-speed running and sprinting, in the second half of matches, could be indicative of conscious pacing strategies in players.

No associations were found between the duration of the half-time interval and the amount of high-speed running or sprinting. However, ambient temperature did appear to have an effect on performance. As dry bulb temperature increased the total distance completed by players in the 0-5 min and 45-50 min periods declined, and approximately 50% of the variance was common. Yet at the same time perhaps 5% of the variation in high-speed running and sprinting was associated with ambient temperature. The fact that the negative correlations between dry bulb temperature and total distance were large, while those with high-speed running were small, may again support the assertion that players consciously preserve their ability to perform high-speed running at the expense of the lower speed, and perhaps ultimately less important movements.

The present study investigated competitive match play over the course of a season in semi-professional soccer players and found no evidence for a decline in high-speed running or sprinting post the half-time interval (in terms of either 15 minute or 5 minute time segments), suggesting that re-warm-up strategies may be unnecessary. They could even be counterproductive, as Mohr and colleagues [17] noted that in the 5 minute period following that in which the peak high-speed running distance was achieved, 12 % less high-speed running was completed than the average distance completed in a 5 min segment of a match. The implication being that the peak bout of high-speed running induced sufficient fatigue that in the subsequent 5 min bout the distance completed by high-speed running had to be lowered. The benefits of elevated muscle temperature on high speed or sprint performance are clear [12,24], and therefore the theoretical reasoning behind "re-warm-up" seems sound. However, in the key paper in this area [18] it is interesting that, while a 10 minute period of passive rest at half-time was sufficient to result in a 1.4 °C drop in muscle temperature (from 39.4 to 38 °C), prior to the start of the friendly match (and following a warm-up ending 5 minutes before the start of play) muscle temperature did not drop and was maintained at 39.4 °C. The ability to have only a short delay between the end of a pre-match warm-up and the start of a match (thus maintaining a high muscle temperature) seems unlikely in many actual high-level competitive circumstances. Even at the highest level of soccer players are required to wait in tunnels, go through handshaking formalities and stand for anthems among other things. In the present study the delay between the end of the pre-match warm-up and the start of the match was typically 10-15 minutes and this may explain why the amount of high-speed running and sprinting did not differ when the first 5 or 15 minutes of the first and second half of competitive matches were compared. The likelihood is if the period of passive rest prior to the start of the first half of play is not short and muscle temperature not high then it is unlikely any difference will be seen in high-speed running and sprinting performance. The implications of the observations from the present study and the findings from other published research suggest that focussing on the half-time interval alone is far too simplistic.

Therefore in summary, using automated match analysis technology (GPS) for the first time for this purpose, this study did not find any difference between the amount of high-speed running and sprinting completed by semi-professional soccer players when the first 15 minutes of the first and second half of competitive matches were compared, although the total distance completed by players was less and their mean speed lower in the first 15 minutes of the second half of matches. The maintenance of high-speed running and sprinting, as total distance and mean speed declined, may be a function of the pacing strategies adopted by players in competitive matches.

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Table 1. Total distance (m) covered, high-speed running and sprinting distance (m) in the 0-15 minute period of the first and second half of matches (mean ± SD).

	1st half 0-15 min	**2nd half 0-15 min**	**Statistical analysis**
Total distance (m)	1746 ± 220	1644 ± 224	main effect, half, $p<0.001$
High-speed running (m) (>15 km.h^{-1})	137 ± 75	127 ± 69	main effect, half, $p=0.072$
Sprinting (m) (>21 km.h^{-1})	60 ± 46	55 ± 43	main effect, half, $p=0.165$

Table 2. Distance (m) covered in total, at high-speed and sprinting, and mean speed and number of sprints in the 0-5, 5-10 and 10-15 minute periods of the first and second half of matches (mean ± SD).

	1st half			**2nd Half**		
	0-5 min	**5-10 min**	**10-15 min**	**0-5 min**	**5-10 min**	**10-15 min**
Total distance (m)	592 ± 102	582 ± 101	571 ± 86	553 ± 96	562 ± 91	528 ± 108
	main effect, half, p<0.001; main effect, time, p<0.001 (0-5 vs. 10-15 min, post hoc, p<0.001); interaction, half x time, p=0.05 (1st half vs. 2nd half, 0-5 and 10-15 min, post hoc, p<0.001)					
Mean speed (km.h^{-1})	7.1 ± 1.2	7.0 ± 1.2	6.9 ± 1.0	6.6 ± 1.2	6.8 ± 1.1	6.3 ± 1.3
	main effect, half, p<0.001; main effect, time, p<0.001 (0-5 vs. 10-15 min, post hoc, p<0.001); interaction, half x time, p=0.05 (1st half vs. 2nd half, 0-5 and 10-15 min, post hoc, p<0.001)					
High-speed running distance (m) (>15 km.h^{-1})	49 ± 37	46 ± 31	42 ± 32	42 ± 33	45 ± 33	40 ± 30
	main effect, half, p=0.07; main effect, time, p=0.06; interaction, half x time, p=0.13.					
Sprinting distance (m) (>21 km.h^{-1})	22 ± 26	20 ± 19	19 ± 20	17 ± 20	20 ± 20	17 ± 20
	main effect, half, p=0.17; main effect, time, p=0.37; interaction, half x time, p=0.10.					
Number of sprints	1.5 ± 1.4	1.3 ± 1.1	1.2 ± 1.1	1.3 ± 1.2	1.3 ± 1.2	1.1 ± 1.1
	main effect, half, p=0.197; main effect, time, p=0.03 (0-5 vs. 10-15 min, post hoc, p=0.04); interaction, half x time, p=0.15.					

Table 3. Pearson correlations (r) between the duration of the half-time interval and various match activities, in the 0-15 minute period of the second half of matches, and with respect to the difference between these match activities in the 0-15 min period of the first and second half of matches.

	2nd half 0-15 min	**Difference between 1st half 0-15 min and 2nd half 0-15 min**
Total distance	-0.09 (p=0.22)	0.11 (p=0.13)
Mean speed ($km.h^{-1}$)	-0.09 (p=0.24)	0.11 (p=0.12)
High-speed running (>15 $km.h^{-1}$)	-0.10 (p=0.18)	0.08 (p=0.25)
Sprinting (>21 $km.h^{-1}$)	-0.06 (p=0.42)	0.04 (p=0.61)
Number of sprints	-0.10 (p=0.18)	0.04 (p=0.25)

Table 4. Pearson correlations (r) between dry bulb temperature during matches and various match activities in the 0-15 minute period of the first and second half of matches, and with respect to the difference between these match activities in the 0-15 min period of the first and second half of matches.

	1st half 0-15 min	2nd half 0-15 min	Difference between 1st half 0-15 min and 2nd half 0-15 min
Total distance	-0.29 (p<0.001)	-0.09 (p=0.24)	-0.24 (p=0.001)
Mean speed ($km.h^{-1}$)	-0.29 (p<0.001)	-0.09 (p=0.24)	-0.24 (p=0.001)
High-speed running (>15 $km.h^{-1}$)	-0.15 (p=0.036)	-0.11 (p=0.13)	0.05 (p=0.49)
Sprinting (>21 $km.h^{-1}$)	-0.10 (p=0.20)	-0.10 (p=0.18)	0.00 (p=0.98)
Number of sprints	-0.06 (p=0.40)	-0.12 (p=0.12)	0.05 (p=0.55)