High-Intensity Activity Profiles of Elite Soccer Players at Different Performance Levels

Paul S. Bradley,[1] Michele Di Mascio,[1] Dan Peart,[2] Peter Olsen,[2] and Bill Sheldon[1]

[1]*Department of Sport and Exercise, Soccer Research Group, University of Sunderland, Sunderland, United Kingdom; and* [2]*Department of Sport and Exercise, University of Teesside, Middlesbrough, United Kingdom*

Abstract

Bradley, PS, Di Mascio, M, Peart, D, Wooster, B, Olsen, P, and Sheldon, B. High-intensity activity profiles of elite soccer players at different performance levels. *J Strength Cond Res* 24(9): 2343–2351, 2010–The aims of the study were to (a) determine the high-intensity activity patterns of soccer players at different performance levels and playing positions, (b) investigate temporary and end game fatigue in elite domestic and international soccer matches, and (c) quantify acceleration and maximal running speed profiles of elite soccer players. Elite domestic ($n = 100$) and international ($n = 10$) soccer players were analyzed using a multicamera computerized tracking system. No differences were found for high-intensity running distance (2,520 ± 678 vs. 2,745 ± 332 m), mean recovery time (67 ± 15 vs. 71 ± 26 seconds), or maximal running speed (7.76 ± 0.31 vs. 7.66 ± 0.34 $m \cdot s^{-1}$). The distance covered in high-intensity running irrespective of playing level was 18% lower ($p < 0.05$) in the last than in the first 15-minute period of the game (391 ± 117 vs. 478 ± 141 m). The decline in high-intensity running immediately after the most intense 5-minute period was similar between international (222 ± 33 vs. 109 ± 37 m or 51% decline) and elite domestic (243 ± 81 vs. 114 ± 51 m or 53% decline) players. Wide midfielders, central midfielders, fullbacks, and attackers covered a greater ($p < 0.01$) distance in high-intensity running than central defenders (3,243 ± 625, 2,949 ± 435, 2,806 ± 408, 2,618 ± 745 vs. 2,034 ± 284 m). Results demonstrate that high-intensity running is reduced during various periods of elite soccer matches, and high-intensity activity profiles and fatigue patterns are similar between international and elite domestic players but vary markedly between playing positions. These data provide valuable information to the fitness coach regarding the high-intensity active profile of elite soccer players that could be used to develop soccer-specific training drills.

Key Words time-motion analysis, international soccer, positional differences, permanent and temporary fatigue

Address correspondence to Paul S. Bradley, paul.s.bradley@sunderland.ac.uk.

24(9)/2343–2351

Journal of Strength and Conditioning Research

Introduction

An analysis of movement patterns during match play is a useful method for quantifying the physical demands of soccer (6,8). There has been a growing interest in this form of analysis over the last 4 decades as sport-specific needs can be identified and then applied to training (6,7,11,13,21). Although many studies have analyzed activity profiles during elite domestic soccer games (3,6,8,9,13,16,17,19,23), relatively few have investigated international match play (22).

Despite the various methods used to evaluate the activity profiles of elite soccer players, the general consensus is that a distance of 9–14 km is covered per match with the vast majority at low intensity (4). Researchers suggested that distances covered at high intensities are more valid measures of physical performance in soccer because of their strong relationship with training status (12,13). Previous research demonstrated that high-intensity running was a distinguishing characteristic between players at different performance levels, whereby elite players perform 28% more high-intensity running than moderate-standard players (17). No data are available on high-intensity running patterns of soccer players during international matches, although it is generally assumed that the demands of international and elite domestic match play differ. Recent findings suggest that high-intensity running distance was reduced toward the end of the game and temporarily after intense periods (17). Mohr et al. (17) did not investigate temporary fatigue during international match play or for different playing positions. It would also be of interest to examine if any high-intensity running decrements are with or without ball possession. Information regarding recovery times after very high–intensity running bouts is also limited.

Finally, the ability to accelerate and reach maximal speeds quickly is an essential component of game-deciding situations in soccer. Thus, quantifying acceleration and maximal running speed profiles in selected periods of elite soccer matches may provide insight into fatigue-related changes in high-speed performance at different performance levels and playing positions. The aims of the study were to (a) determine the high-intensity activity patterns of soccer players at different performance levels and playing positions, (b) investigate temporary and end game fatigue in elite domestic and international soccer matches, and (c) quantify acceleration and maximal running speed profiles of elite soccer players.

Methods

Experimental Approach to the Problem

A novel, computerized semi-automated tracking system was used to evaluate the match performance of elite domestic and international soccer players. The distance covered, frequency of occurrence, and time spent in each activity category were analyzed at 5-, 15-, and 45-minute periods to identify differences between players at different playing levels of soccer competition.

Subjects and Match Analysis

With consent and institutional ethics approval, a multicamera computerized tracking system (ProZone Version 3.0; ProZone Sports Ltd., Leeds, United Kingdom) was used to analyze 14 competitive elite domestic matches and 1 noncompetitive international match. All domestic players were competing for elite European teams in one of the strongest leagues in the world. Three of the elite domestic teams were also competing in the European Champions League. All elite international players were sampled from teams that were among the top 10 on the official Fédération Internationale de Football Association (soccer) (FIFA) world rankings list. All players' movements were captured during each game by 8 stable cameras (Vicon surveyor dome SVFT-W23; Oxford, United Kingdom) positioned on the roof of each stadium (Figure 1). To enhance tracking, each area of the pitch was covered by at least 2 cameras. The data captured were analyzed using proprietary match analysis software (Stadium Manager; ProZone Sports Ltd.) to produce individual activity profiles. This system has been validated to verify data accuracy (10).

The games selected for analysis were played at the midphase of the competitive season between teams of a comparable standard (domestic: similar league position and international: similar FIFA ranking) and played at a similar time of day to reduce the influence of circadian variations on performance (20). Matches were played in the same country on a grass surface to control for environmental conditions. To allow direct comparisons to be made with regard to playing time, data were only used from players completing an entire match. This allowed profiling of 100 elite domestic and 10 international players in various playing positions (23 central defenders, 22 fullbacks, 22 central midfielders, 22 wide midfielders, and 21 attackers). All subject identifiers were removed to ensure confidentiality.

Match Activities

Player activities were coded into the following categories and speed thresholds: standing (0–0.6 $km \cdot h^{-1}$), walking (0.7–7.1 $km \cdot h^{-1}$), jogging (7.2–14.3 $km \cdot h^{-1}$), running (14.4–19.7 $km \cdot h^{-1}$), high-speed running (19.8–25.1 $km \cdot h^{-1}$), and sprinting ($\geq$25.2 $km \cdot h^{-1}$).

Match Distances

High-intensity running consisted of running, high-speed running, and sprinting ($\geq$14.4 $km \cdot h^{-1}$). Very high–intensity running consisted of high-speed running and sprinting ($\geq$19.8 $km \cdot h^{-1}$). The speed thresholds for each category are similar to that reported by previous authors (8,17,19).

Other Match Analysis Measures

High-intensity running with ball possession was defined as the high-intensity running distance covered when the players' own team was in possession of the ball. High-intensity running without ball possession was defined as the subtraction of high-intensity running distance with possession of the ball from total high-intensity running distance. Peak distance represented the 5 minutes that contained the most high-intensity running in a game and was specific for each player (17). Mean recovery time was defined as the time that elapsed between very high–intensity running bouts ($\geq$19.8 $km \cdot h^{-1}$). Maximal running speed represented the mean maximal run speed a player reached in all 5-minute periods of the game. Players' accelerations were divided into 2 subsets: medium (2.5–4.0 $m \cdot s^{-2}$) and high ($>$4.0 $m \cdot s^{-2}$). Mean accelerations were also quantified when players moved from low-intensity categories (standing, walking, and jogging) to high-intensity categories (running, high-speed running, and sprinting).

Inter- and Intra-Observer Reliability

An intra- and interobserver reliability analysis was conducted using 5 elite soccer players. Two trained observers tracked each player on 2 occasions, interspersed by 1 week, and the coefficient of variation (CV) was determined to assess reliability (2). The intra- and interobserver CV for total distance, walking, running, high-speed running, high-intensity running, and very high–intensity running was $<$2% with the exception of sprinting that was $<$3%. These reliability values are similar to those previously reported for the same multicamera computerized match analysis system (8).

Statistical Analyses

All statistical analyses were conducted using SPSS for Windows 14.0 (SPSS, Inc., Chicago, IL). Descriptive statistics

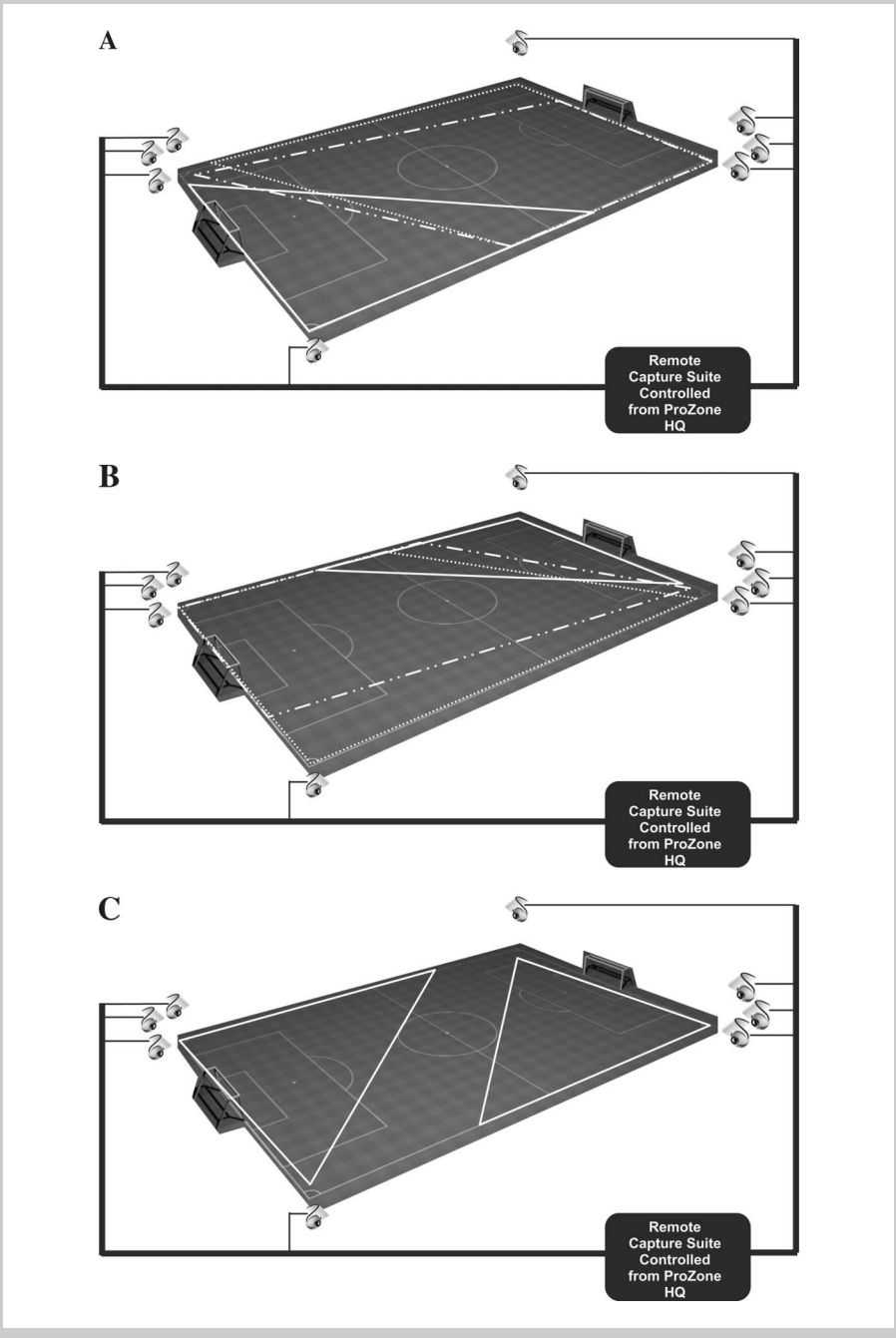

Figure 1. ProZone capture system uses 8 color cameras that cover the entire pitch from all 4 corners of the stadium. (A) Cameras 1–3 positioning in corner 1. (B) Cameras 4–6 positioned in corner 2. (C) Cameras 7–8 positioned opposing one another.

were calculated on each variable, and *z*-scores were used to verify normality. Differences between the first and second half were determined using paired sample *t*-tests. Differences between 5-, 15-, and 45-minute periods within a match were determined using analysis of variance with repeated measures. In the event that a significant difference occurred, Tukey's post hoc tests were used to identify any localized effects. Statistical significance was set at $p \leq 0.05$. Data are presented as mean and *SD*s unless otherwise stated.

Results

Activity Profile

During a typical elite match, players stood for 5.2% of the total time. Low-intensity activity represented 91.0% of total time, which consisted of 59.4% walking and 26.4% jogging. High-intensity running represented 9.0% of total time, which consisted of 6.4% running, 2.0% high-speed running, and 0.6% sprinting. No differences were found between elite domestic and international players in terms of distance covered, frequency of occurrence, and time spent in each activity category (Table 1).

Distances Covered

Total distance covered during a match irrespective of playing level was 10,841 ± 950 m. There was no difference in the total distance covered between international and elite domestic players (10,666 ± 566 vs. 10,859 ± 980 m). Distance covered during the first half was greater ($p < 0.05$) than the second half for players irrespective of playing level (5,469 ± 507 vs. 5,372 ± 498 m). Elite domestic players covered a greater distance ($p < 0.01$) in the first than in the second half (5,482 ± 522 vs. 5,376 ± 510 m), whereas no difference was observed for international players (5,336 ± 302 vs. 5,330 ± 374 m).

High-Intensity Running Profile

The mean distances covered in high-intensity running and very high–intensity running were 2,725 ± 656 and 980 ± 294 m irrespective of playing level. There was no difference in high-intensity running and very high–intensity running distances between international and elite domestic players

Table 1. Distance, frequency, and time spent in different activity categories for international and elite domestic soccer players.

	Standing	Walking	Jogging	Run	HSR	Sprinting	HIR	VHIR
Distance (m)								
International	22.0 ± 5	3,872 ± 196	4,252 ± 566	1,609 ± 185	660 ± 154	251 ± 84	2,520 ± 332	911 ± 238
Domestic	27.3 ± 9	3,803 ± 276	4,284 ± 622	1,758 ± 441	722 ± 215	265 ± 117	2,745 ± 678	987 ± 300
Combined	26.8 ± 8	3,809 ± 270	4,281 ± 615	1,745 ± 426	716 ± 210	264 ± 114	2,725 ± 656	980 ± 294
Time (s)								
International	262 ± 73	3,414 ± 214	1,509 ± 203	349 ± 39	108 ± 25	33 ± 11	490 ± 59	141 ± 34
Domestic	326 ± 144	3,294 ± 449	1,473 ± 267	372 ± 102	117 ± 37	34 ± 16	522 ± 141	151 ± 48
Combined	321 ± 140	3,305 ± 434	1,477 ± 261	370 ± 98	116 ± 36	34 ± 15	519 ± 136	150 ± 47
Frequency (n)								
International	148 ± 26	890 ± 67	1,013 ± 95	365 ± 36	125 ± 22	35 ± 11	525 ± 79	160 ± 33
Domestic	168 ± 47	851 ± 76	969 ± 112	391 ± 82	136 ± 38	36 ± 13	562 ± 126	171 ± 49
Combined	167 ± 46	855 ± 76	973 ± 111	388 ± 80	135 ± 37	36 ± 13	559 ± 121	170 ± 48

HIR = high-intensity running; HSR = high-speed run; VHIR = very high–intensity running.
Values are mean ± *SD*.

(2,520 ± 678 vs. 2,745 ± 332 and 911 ± 226 vs. 987 ± 300 m). The distance covered in high-intensity running irrespective of playing level was 18% lower ($p < 0.05$) in the last than in the first 15-minute period of the game (391 ± 117 vs. 478 ± 141 m). Elite domestic players covered 12% less ($p < 0.05$) very high–intensity running distance in the last 15 minutes of the first half and second half than in the first 15-minute period of the game (141 ± 68 and 141 ± 61 vs. 160 ± 66 m), whereas no difference was found for international players. Elite domestic players covered greater ($p < 0.05$) high-intensity running distance than international players in the second 15-minute period of the second half (420 ± 115 vs. 339 ± 51 m). No differences were observed between international and elite domestic players for high-intensity running and very high–intensity running with and without possession (Table 2).

The decline in high-intensity running immediately after the most intense 5-minute period was similar between international (222 ± 33 vs. 109 ± 37 m or 51% decline) and elite domestic (243 ± 81 vs. 114 ± 51 m or 53% decline) soccer players. Elite domestic players demonstrated a 25% higher final 5-minute period (130 ± 66 vs. 97 ± 35 m) than international players (Figure 2). Independent of playing level, the peak distance covered in high-intensity running in a 5-minute period was 241 ± 78 m. In the next 5-minute period, the amount of high-intensity running was 114 ± 57 m, which was 12% lower ($p < 0.05$) than the mean distance covered during all 5-minute periods minus the peak 5-minute period (129 ± 31 m).

Mean Recovery Time, Maximal Running Speed, and Acceleration Profile

The mean recovery time between very high–intensity running bouts was 70 ± 25 seconds irrespective of playing level (Table 3). International players demonstrated a similar mean recovery time than elite domestic players (67 ± 15 vs. 71 ± 26 seconds). Elite domestic players' mean recovery times during the second half were 7% longer ($p < 0.05$) than the first half (73 ± 33 vs. 68 ± 28 seconds) and 24% longer ($p < 0.01$) during the last 15 minutes than the first 15 minutes of the game (78 ± 48 vs. 63 ± 34 seconds), whereas no difference was observed for international players. Independent of playing level, recovery times were 14% higher ($p < 0.05$) in the last 15 minutes of the first half (74 ± 41 seconds) and 17% higher in the last 15 minutes of the second half (76 ± 47 seconds) compared with the first 15-minute period (65 ± 36 seconds).

No differences were apparent for maximal running speed between international and elite domestic players (7.76 ± 0.31 vs. 7.66 ± 0.34 $m \cdot s^{-1}$). No differences were found for elite players between the first and second half or the first and last 15 minutes for the frequency of discrete bouts of medium (53 ± 6 vs. 53 ± 6 and 18 ± 6 vs. 18 ± 7) or high (6 ± 2 vs. 7 ± 2 and 2 ± 2 vs. 3 ± 2) accelerations. Accelerations were highest ($p < 0.01$) when elite players moved from any low-intensity

Table 2. High-intensity profile with and without ball possession for international and elite domestic players.*†

	Match time (min)								
	0–15	15–30	30–45	45–60	60–75	75–90	First half	Second half	Full game
HIR with possession (m)									
International	183 ± 61	157 ± 64	171 ± 101	162 ± 100	138 ± 50‡	193 ± 83	511 ± 195	493 ± 220	1,004 ± 411
Domestic	202 ± 94	193 ± 96	197 ± 99	188 ± 92	171 ± 86‡	198 ± 101	592 ± 250	557 ± 238§	1,148 ± 468
Combined	200 ± 91	190 ± 94	194 ± 99	186 ± 93	168 ± 83‡	197 ± 99	584 ± 246	551 ± 236§	1,135 ± 463
HIR without possession (m)									
International	273 ± 69	250 ± 42	258 ± 79	247 ± 68	201 ± 44‡	287 ± 96	782 ± 155	735 ± 164	1,516 ± 273
Domestic	279 ± 106	248 ± 106‖	273 ± 110	252 ± 90‖	250 ± 97‖	296 ± 125	799 ± 278	797 ± 260	1,597 ± 504
Combined	278 ± 103	248 ± 102‖	272 ± 108	251 ± 87‖	245 ± 94‖	295 ± 123	798 ± 268	791 ± 253	1,590 ± 488
HIR total (m)									
International	456 ± 95	407 ± 63	429 ± 80	409 ± 106	339 ± 51‡¶	480 ± 121	1,292 ± 187	1,228 ± 200	2,520 ± 332
Domestic	480 ± 145	441 ± 125#	470 ± 153	440 ± 126#	420 ± 115‡	493 ± 166	1,392 ± 374	1,354 ± 348	2,745 ± 678
Combined	478 ± 141	438 ± 121	466 ± 148	437 ± 124	413 ± 113‡	492,162	1,383 ± 362	1,342 ± 338	2,725 ± 656
VHIR with possession (m)									
International	58 ± 37	59 ± 43	72 ± 67	63 ± 53	53 ± 32	79 ± 59	189 ± 126	195 ± 135	384 ± 260
Domestic	74 ± 52	76 ± 60	73 ± 59	71 ± 55	65 ± 51‡	74 ± 57	223 ± 145	210 ± 136§	433 ± 268
Combined	72 ± 51	74 ± 59	73 ± 60	70 ± 55	64 ± 50‡	74 ± 57	220 ± 143	209 ± 135§	428 ± 267
VHIR without possession (m)									
International	79 ± 36	84 ± 53	94 ± 59	89 ± 32	66 ± 20‡	109 ± 37	257 ± 101	264 ± 74	521 ± 155
Domestic	88 ± 50#	84 ± 34#	91 ± 52	92 ± 50	90 ± 51#	101 ± 51	261 ± 123	283 ± 119	544 ± 219
Combined	86 ± 49#	84 ± 51#	91 ± 52	92 ± 48	88 ± 50#	102 ± 49	261 ± 120	281 ± 115	542 ± 214
VHIR total (m)									
International	136 ± 59#	143 ± 48	166 ± 56	153 ± 46	119 ± 29¶#	187 ± 58	445 ± 139	459 ± 110	904 ± 230
Domestic	160 ± 68#	160 ± 67#	165 ± 76	163 ± 68#	155 ± 60#	175 ± 73	484 ± 171	493 ± 159	977 ± 301
Combined	160 ± 67#	160 ± 65#	169 ± 73	162 ± 66#	152 ± 60#	177 ± 72	489 ± 163	490 ± 156	980 ± 294

*HIR = high-intensity running; VHIR = very high–intensity running.
†Values are mean ± *SD*.
‡Significantly different for all other 15-minute period ($p < 0.05$).
§Significantly different from first half ($p < 0.05$).
‖Different from 0- to 15-minute period ($p < 0.05$).
¶Different from international players ($p < 0.05$).
#Different from 75- to 90-minute period ($p < 0.05$).

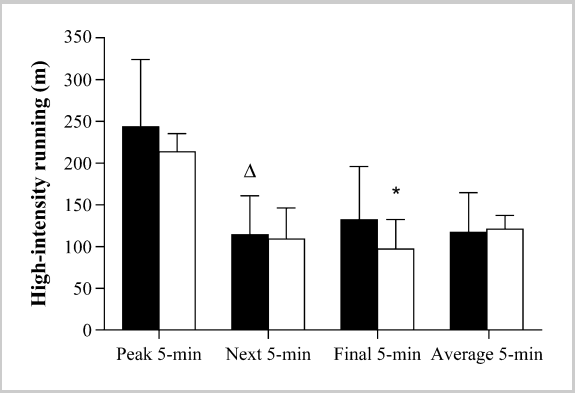

Figure 2. Temporary fatigue in elite domestic and international soccer players. High-intensity running in the most intense 5-minute period during the game (peak 5-minute period), the following 5-minute period (next 5-minute period), the final 5-minute period, as well as the game average 5-minute period (minus the peak value) for elite domestic players (■) and international players (□). *Different from the average 5-minute period ($p < 0.05$). Δ Different from the average 5-minute period ($p < 0.01$). Values are mean ± *SD*.

category (standing, walking, or jogging) to sprinting (3.8 ± 0.3 $m \cdot s^{-2}$) compared with high-speed running (3.1 ± 0.5 $m \cdot s^{-2}$) or running (2.2 ± 0.2 $m \cdot s^{-2}$).

Positional Differences

Wide and central midfielders covered a greater ($p < 0.05$) total distance than fullbacks, attackers, and central defenders (11,491 ± 996, 11,411 ± 486 vs. 10,763 ± 627, 10,504 ± 1,090, and 10,057 ± 582 m). Wide midfielders, central midfielders, fullbacks, and attackers also covered a greater ($p < 0.01$) distance in high-intensity running than central defenders (3,243 ± 625, 2,949 ± 435, 2,806 ± 408, 2,618 ± 745 vs. 2,034 ± 284 m). Wide midfielders covered a greater ($p < 0.01$) distance in very high–intensity running than central midfielders, fullbacks, attackers, and central defenders (1,273 ± 257 vs. 941 ± 235, 1,046 ± 196, 996 ± 268, and 638 ± 154 m).

The decline ($p < 0.05$) in high-intensity running immediately after the most intense 5-minute period was more evident in attackers (256 ± 142 vs. 102 ± 61 m or 60% decline) than in central defenders (189 ± 31 vs. 101 ± 44 m or 47% decline), fullbacks (245 ± 42 vs. 124 ± 64 m or 44% decline), wide midfielders (273 ± 55 vs. 125 ± 72 m or 54% decline), and central midfielders (245 ± 50 vs. 118 ± 35 m or 52% decline). Central defenders demonstrated a higher mean recovery time ($p < 0.01$) than wide midfielders, central midfielders, fullbacks, and attackers (98 ± 21 vs. 52 ± 15, 63 ± 16, 70 ± 29, and 70 ± 23 seconds). Maximal running speed was higher ($p < 0.05$) for wide midfielders, attackers, and fullbacks than central midfielders and central defenders (7.94 ± 0.29, 7.71 ± 0.31, 7.74 ± 0.25 vs. 7.55 ± 0.31 and 7.37 ± 0.30 $m \cdot s^{-1}$).

Table 3. Maximal running speed and mean recovery time in 15-minute periods, half by half, and full game for international and elite domestic players.*

	Match time (min)								
	0–15	15–30	30–45	45–60	60–75	75–90	First half	Second half	Full game
Maximal running speed ($m \cdot s^{-1}$)									
International	7.62 ± 0.54	7.74 ± 0.67	7.99 ± 0.44	8.02 ± 0.22	7.35 ± 0.52	7.84 ± 0.63	7.79 ± 0.44	7.78 ± 0.29	7.76 ± 0.31
Domestic	7.74 ± 0.67	7.79 ± 0.58	7.53 ± 0.59	7.68 ± 0.59	7.66 ± 0.57	7.65 ± 0.59	7.65 ± 0.42	7.67 ± 0.41	7.66 ± 0.34
Combined	7.64 ± 0.55	7.79 ± 0.58	7.57 ± 0.59	7.71 ± 0.57	7.64 ± 0.57	7.67 ± 0.59	7.67 ± 0.42	7.68 ± 0.40	7.67 ± 0.34
Mean recovery time (s)									
International	80.8 ± 48.5	59.1 ± 17.5	79.6 ± 26.5	61.1 ± 27.8	69.5 ± 26.8	52.2 ± 16.4	73.2 ± 26.03	61.0 ± 12.5	67.1 ± 15.1
Domestic	63.0 ± 34.1	67.3 ± 38.1†	73.7 ± 42.7‡	67.4 ± 44.4	73.5 ± 42.1‡	77.8 ± 48.2‡	68.0 ± 27.8	72.9 ± 33.4	70.5 ± 25.9
Combined	64.6 ± 35.7	66.6 ± 36.7	74.2 ± 41.4‡	66.8 ± 43.1	73.2 ± 40.9	75.5 ± 46.8‡	68.5 ± 27.5	71.8 ± 32.2	70.2 ± 25.1

*Values are mean ± *SD*.
†Different from 75- to 90-minute period ($p < 0.01$).
‡Different from 0- to 15-minute period ($p < 0.05$).

Discussion

The present data depict the high physical demands of modern elite soccer and that high-intensity running, mean recovery time, and maximal running speed were similar between elite domestic and international players over the course of the full game. Changes in high-intensity running after intense periods were similar for both performance levels but different toward the end of the game. Irrespective of performance level, high-intensity running after the most intense period was lowered by ~50% below the game mean. No fatigue-related changes were evident in acceleration and maximal running speed profiles during elite soccer matches. It was also clear that the high-intensity activity profile of elite players is closely related to their positional role in the team.

The amount of high-intensity running in both international and elite domestic matches is similar to the elite domestic Spanish league (9) but different from the same level of play in Danish and Swedish leagues (1,17). The present data suggest that the amount of high-intensity running performed by elite domestic and international players is ~40% more than elite domestic Danish and Swedish leagues. It should be noted that different technologies used to measure activity patterns and variations in the classification of movements probably account for the majority of the high-intensity running differences between studies. This finding could also be because of differences in playing style. The elite domestic players in this study were sampled from a league where teams are required to maintain a high level of activity when not directly involved in play to create space to receive passes or to pressure opponents into mistakes to regain possession. Taken together, these observations demonstrate that the physical demands from the matches studied were high and are representative of modern elite soccer.

Research shows that soccer work-rate profiles are dependent on level of play (6). Rienzi et al. (22) found that elite domestic players covered a greater total distance than international players. While Mohr et al. (17) demonstrated that elite domestic players performed 28% more high-intensity running than moderate-playing level domestic players the present data suggest that total (10,666 vs 10,859 m) and high-intensity running distances (2,520 vs 2,745 m) are similar between international and elite domestic players. This finding is in contrast to previous research and the general assumption that elite domestic and international soccer differ in terms of tempo. Elite domestic match play is traditionally played at a very fast tempo and requires players to perform high levels of activity, in contrast to the international match play whereby the emphasis is placed on retaining possession until decisive opportunities arise. The elite domestic players used in this study were sampled from a league consisting of a large proportion of international players, which could account for the similarity between the two performance levels. Activity profiles could have been further influenced by motivational factors, such as the competitive importance placed on the game or the tactical restrictions placed on the teams and players. Another reason could be that the small sample of international players used may not provide an accurate depiction of the physical demands of international match play because of variability in movement patterns both among and within players (3,17). The only difference found between performance levels for high-intensity running occurred in the second 15-minute period of the second half, where elite domestic players covered ~20% more high-intensity running distance. This high-intensity distance deficit was roughly similar when subdivided into with or without ball possession, indicating that all elements of play are influenced proportionately. This finding could be attributed to the noncompetitive nature of the international match in which high-intensity running declined toward the end in contrast to elite domestic matches that remained competitive until the end. This was further supported by the finding that elite domestic players demonstrated a 25% higher final 5-minute period than international players (130 ± 66 vs. 97 ± 35 m). No differences were found between performance levels for very high–intensity running. However, where no difference was found between time periods for international players, elite domestic players covered 12% less very high–intensity running distance in the last 15-minute period of the first half and second half than in the first 15-minute period of the game. The decline in very high–intensity running distances could be a change in style of play as the elite domestic league is renowned for continuous high-tempo match play rather than retaining possession.

It has been shown that high-intensity running decreases after the most intense period of the game and at the end of the game, indicating temporary and permanent forms of fatigue (8,17,18). After the most intense 5-minute period, high-intensity running was lowered to a similar extent to values below the game mean for elite domestic (53% decline) and international (51% decline) players. The ~50% decline found for high-intensity running after the most intense period for elite soccer players was strikingly similar to elite domestic Italian (17) and English league players (8). However, the temporary drop in high-intensity running may not be a true measure as these values are based on predefined 5-minute periods from semi-automated match analysis software; thus, this drop could be over- or underestimated. Despite this, these data indicate that the anaerobic energy turnover of elite soccer is high in selected periods when players have to perform repeated intense bouts during a game.

The present study is the first to report mean recovery times between very high–intensity bouts within international match play. No differences were found in recovery times between performance levels over the course of the game. However, recovery times were found to be lower in the last 15 minutes of the first and second half, when compared with the first 15 minutes, within domestic match play. Moreover, no differences were found within international match play, possibly because of the low number of international players

analyzed or the slower tempo used throughout. Irrespective of playing level, the mean recovery time increased markedly over the duration of the game. Bradley et al. (8) reported 28% longer recovery times from the first to the last 15-minute period compared with 17% longer recovery times in this study. The underlying mechanism responsible for increases in recovery time during games is debatable and could be attributed to fatigue manifesting over the course of the game. However, caution is necessary when interpreting recovery times as the tempo of play could be slowing down as the game progresses and thus recovery may proceed. It could also be argued that increased recovery times during the last 15-minute period of a game are related to the fact that the outcome of the game had been decided. Further studies are required to investigate if the increase in mean recovery time between very high–intensity running bouts is fatigue or tempo related.

The number of international players analyzed was insufficient to allow for differences in playing positions to be elucidated between performance levels. Independent of playing level, this study revealed that total and high-intensity running distances were higher for wide and central midfielders than fullbacks, attackers, and central defenders (11,491 and 3,243, 11,411 and 2,949 vs. 10,763 and 2,806, 10,504 and 2,618, and 10,057 and 2,034 m). The speed category for high-intensity running used in this study is similar to a recent large-scale study of elite domestic Spanish players ($>$14.4 vs. $>$14.1 km·h^{-1}) (9). Comparable values for high-intensity running were obtained for elite domestic Spanish league fullbacks (2,806 vs. 2,784 m), wide midfielders (3,243 vs. 3,171 m), central midfielders (2,949 vs. 2,991 m), attackers (2,618 vs. 2,708 m), and central defenders (2,034 vs. 1,869 m). Our mean values for high-intensity running are in accordance with values from the elite domestic Spanish league (9) using a similar multicamera computerized tracking system (2,725 vs. 2,710 m). The present data suggest that the high-intensity running profile of wide and central midfielders is superior to other positions and the mean high-intensity running distance of elite players is ~2,700 m independent of position. Midfield players have been found to have higher maximal oxygen uptake ($\dot{V}o_2max$) values than other playing positions (4), and the superior high-intensity running profile found in this study for certain positions could be related to a higher endurance capacity. In support of this notion, midfielders performed more favorably than other positions in the soccer-specific Yo-Yo intermittent recovery tests 1 and 2 (12,14). It seems reasonable to conclude that players in different playing positions have unique physical and bioenergetic characteristics, and thus, specific conditioning should be tailored to meet these requirements.

The present study demonstrated that maximal running speeds during games were similar between elite domestic and international players (7.76 vs. 7.66 m·s^{-1}) but markedly different between playing positions. Specifically, maximal running speeds reached during games were higher for wide midfielders, fullbacks, and attackers than for central midfielders and central defenders. In support of this finding, attackers, fullbacks, and wide midfielders have the highest running speed as shown by sprint tests (5). For wide midfielder and fullbacks, the higher running speeds may also be related to the fact that these players have more space and time along the flanks, allowing for full acceleration. Thus, large differences in maximal running speeds are present between playing positions. No differences in the frequency of discrete bouts of medium or high accelerations were evident between halves or the first and last 15 minutes for elite players. This implies that the fatigue patterns observed for high-intensity running do not influence acceleration capacity. Accelerations were highest when players moved from any low-intensity category to sprinting compared with high-speed running or running, presumably as more effort was required to overcome inertia. Future research should identify deceleration profiles as the loading of eccentric contraction during a rapid deceleration may affect the rate of fatigue in the muscles and have a detrimental effect on sprinting performance during an extended number of efforts (15).

Practical Applications

In summary, the present results suggest that the physical load placed on elite players is high and that the high-intensity profile, mean recovery time, and maximal running speed are similar between performance levels, over the course of the game, but vary markedly between playing positions. These data provide valuable information to the fitness coach about the high-intensity activity profile of elite soccer players at different performance levels and playing positions. These data not only serve as normative values that will allow comparisons to be made with other elite soccer populations but also provide the framework for the development of soccer- and position-specific training regimes. It is recommended that fitness coaches incorporate speed endurance and anaerobic drills within training to allow players to cope with multiple cycles of high-intensity running during matches. These high-intensity drills should try to simulate the peak distances covered during intense periods. This should be in the form of running interspersed by recoveries of ~70 seconds or alternatively drills requiring the ball to increase the motivation of the players. One could speculate that this type of training could improve the physical capabilities of the team, whereby players can maintain high-intensity running and recovery between intense periods.

Acknowledgments

The authors would like to thank Steven Anderson for the additional help on data analysis and the University of Sunderland for kindly funding the study.

References

1. Andersson, H, Ekblom, B, and Krustrup, P. Elite football on artificial turf versus natural grass: Movement pattern, technical standard and player opinion. *J Sports Sci* 8: 1–10, 2008.

2. Atkinson, G and Nevill, AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med* 26: 217–238, 1998.
3. Bangsbo, J. The physiology of soccer: With special reference to intense intermittent exercise. *Acta Physiol Scand* 151(Suppl): 619, 1994.
4. Bangsbo, J and Michalsik, L. Assessment and physiological capacity of elite soccer players. In: *Science and Football IV.* Spinks, W, Reilly, T, and Murphy, A, eds. London, United Kingdom: Routledge, 2002. pp. 53–62.
5. Bangsbo, J, Mohr, M, and Krustrup, P. Physical and metabolic demands of training and match play in the elite football player. *J Sports Sci* 24: 665–674, 2006.
6. Bangsbo, J, Norregaard, L, and Thorsoe, F. Activity profile of competition soccer. *Can J Sports Sci* 16: 110–116, 1991.
7. Bloomfield, J, Polman, R, and O'Donoghue, P. Physical demands of different positions in FA Premier League soccer. *J Sports Sci Med* 6: 63–70, 2007.
8. Bradley, PS, Sheldon, W, Wooster, B, Olsen, PD, Boanas, P, and Krustrup, P. High-intensity running in English FA Premier League soccer matches. *J Sports Sci* 27: 159–168, 2009.
9. Di Salvo, V, Baron, R, Tschan, H, Calderon Montero, FJ, Bachl, N, and Pigozzi, F. Performance characteristics according to playing position in elite soccer. *Int J Sports Med* 28: 222–227, 2007.
10. Di Salvo, V, Collins, A, McNeill, B, and Cardinale, M. Validation of ProZone®: A new video-based performance analysis system. *Int J Perform Anal Sport* 6: 108–119, 2006.
11. Ekblom, B. Applied physiology of soccer. *Sports Med* 3: 50–60, 1986.
12. Krustrup, P, Mohr, M, Amstrup, T, Rysgaard, T, Johansen, J, Steensberg, A, Pedsersen, PK, and Bangsbo, J. The yo-yo intermittent recovery test: Physiological response, reliability, and validity. *Med Sci Sports Exerc* 35: 697–705, 2003.
13. Krustrup, P, Mohr, M, Ellingsgaard, H, and Bangsbo, J. Physical demands of elite female soccer games: Importance of training status. *Med Sci Sports Exerc* 37: 1242–1248, 2005.
14. Krustrup, P, Mohr, M, Nybo, L, Jensen, JM, Nielsen, JJ, and Bangsbo, J. The Yo-Yo IR2 test: Physiological response, reliability and application to elite soccer. *Med Sci Sports Exerc* 38: 1666–1673, 2006.
15. Lakomy, J and Hayden, DT. The effects of enforced, rapid deceleration on performance in a multiple sprint test. *J Strength Cond Res* 18: 579–583, 2004.
16. Mayhew, SR and Wenger, HA. Time-motion analysis of professional soccer. *J Hum Mov Stud* 11: 49–52, 1985.
17. 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.
18. Mohr, M, Krustrup, P, and Bangsbo, J. Fatigue in soccer: A brief review. *J Sports Sci* 23: 593–599, 2005.
19. Rampinini, E, Coutts, AJ, Castagna, C, Sassi, R, and Impellizzeri, FM. Variation in top level soccer match performance. *Int J Sports Med* 28: 1018–1024, 2007.
20. Reilly, T and Brooks, GA. Exercise and the circadian variation in body temperature measures. *Int J Sports Med* 7: 358–368, 1986.
21. Reilly, T and Thomas, V. A motion analysis of work-rate in different positional roles in professional football match play. *J Hum Mov Stud* 2: 87–89, 1976.
22. Rienzi, E, Drust, B, Reilly, T, Carter, EL, and Martin, A. Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *J Sports Med Phys Fitness* 40: 162–169, 2000.
23. Withers, RT, Maricic, Z, Wasilewski, S, and Kelly, LO. Match analysis of Australian professional soccer players. *J Hum Mov Stud* 8: 159–176, 1982.