Journal of Sports Sciences, 2003, **21**, 519–528

Taylor&Francis
healthsciences

Match performance of high-standard soccer players with special reference to development of fatigue

MAGNI MOHR, PETER KRUSTRUP and JENS BANGSBO*

Institute of Exercise and Sport Sciences, August Krogh Institute, Department of Human Physiology, University of Copenhagen, Universitetsparken 13, DK-2100 Copenhagen Ø, Denmark

Accepted 18 December 2002

The aim of this study was to assess physical fitness, match performance and development of fatigue during competitive matches at two high standards of professional soccer. Computerized time–motion analyses were performed 2–7 times during the competitive season on 18 top-class and 24 moderate professional soccer players. In addition, the players performed the Yo-Yo intermittent recovery test. The top-class players performed 28 and 58% more ($P < 0.05$) high-intensity running and sprinting, respectively, than the moderate players (2.43 ± 0.14 *vs* 1.90 ± 0.12 km and 0.65 ± 0.06 *vs* 0.41 ± 0.03 km, respectively). The top-class players were better (11%; $P < 0.05$) on the Yo-Yo intermittent recovery test than the moderate players (2.26 ± 0.08 *vs* 2.04 ± 0.06 km, respectively). The amount of high-intensity running, independent of competitive standard and playing position, was lower (35–45%; $P < 0.05$) in the last than in the first 15 min of the game. After the 5-min period during which the amount of high-intensity running peaked, performance was reduced ($P < 0.05$) by 12% in the following 5 min compared with the game average. Substitute players ($n = 13$) covered 25% more ($P < 0.05$) ground during the final 15 min of high-intensity running than the other players. The coefficient of variation in high-intensity running was 9.2% between successive matches, whereas it was 24.8% between different stages of the season. Total distance covered and the distance covered in high-intensity running were higher ($P < 0.05$) for midfield players, full-backs and attackers than for defenders. Attackers and full-backs covered a greater ($P < 0.05$) distance in sprinting than midfield players and defenders. The midfield players and full-backs covered a greater ($P < 0.05$) distance than attackers and defenders in the Yo-Yo intermittent recovery test (2.23 ± 0.10 and 2.21 ± 0.04 *vs* 1.99 ± 0.11 and 1.91 ± 0.12 km, respectively). The results show that: (1) top-class soccer players performed more high-intensity running during a game and were better at the Yo-Yo test than moderate professional players; (2) fatigue occurred towards the end of matches as well as temporarily during the game, independently of competitive standard and of team position; (3) defenders covered a shorter distance in high-intensity running than players in other playing positions; (4) defenders and attackers had a poorer Yo-Yo intermittent recovery test performance than midfielders and full-backs; and (5) large seasonal changes were observed in physical performance during matches.

Keywords: high-intensity intermittent exercise, playing positions, seasonal changes, standard of competition, time–motion analysis, Yo-Yo intermittent recovery test.

Introduction

Time–motion analysis is useful for examining the activity pattern and physical aspects of soccer (Reilly and Thomas, 1976; Mayhew and Wenger, 1985; Bangsbo *et al.*, 1991; Bangsbo, 1994). Several authors have examined low-standard and amateur players (Saltin, 1973; Whitehead, 1975; Van Gool *et al.*, 1988; Ohashi *et al.*, 1988); others have observed players at the top of their national league (Bangsbo *et al.*, 1991; Bangsbo, 1994). These studies have suggested that the amount of high-intensity exercise is a valid measure of physical performance in soccer. It has also been observed that players at a higher standard of competition perform significantly more high-intensity running than those at a lower standard (Ekblom, 1986; Bangsbo *et al.*, 1991). It is unclear whether elite international players perform even more high-intensity exercise. Furthermore, most previous studies were performed more than 10 years ago and it is unclear how the exercise intensity in professional soccer has developed over the last decade. Information about the physical performance of players in different playing positions

* Author to whom all correspondence should be addressed.
e-mail: jbangsbo@aki.ku.dk

Journal of Sports Sciences ISSN 0264-0414 print/ISSN 1466-447X online
DOI: 10.1080/0264041031000071182

and at various stages of a season is also limited. To examine these aspects of soccer, it would be necessary to have a large number of participants representing all playing positions, since considerable variations in activity patterns have been found from game to game and between players within each position (Bangsbo, 1994; Reilly, 1997).

It is also unclear to what extent the players experience fatigue during a high-standard soccer game. Several researchers have observed a reduction in total distance covered in the second half compared with the first (Reilly and Thomas, 1976; Van Gool *et al.*, 1988; Bangsbo *et al.*, 1991). This reduction may indicate the development of fatigue in the second half, although total distance covered appears not to be a perfect indicator of physical performance in a match (Bangsbo, 1994). Rebelo *et al.* (1998) reported that soccer players had a reduced ability to perform repeated sprints after than before a soccer match, indicating that fatigue had developed before the end of a soccer game. The extent to which fatigue occurs among soccer players during elite competitive games could be assessed by analysing high-intensity exercise throughout a match and by comparing the performance of substitute players, who only participate in parts of the second half, with the performance of players taking part in the entire match. An assumption would be that the demand and opportunity to engage in high-intensity runs is constant during a game.

The aims of the present study were: (1) to examine the activity pattern of high-standard soccer players in relation to positional role and performance level; (2) to establish whether fatigue occurs during a high-standard soccer match; and (3) to examine players' match performance at different stages of the season.

Materials and methods

Participants

Eighteen professional top-class soccer players (age 26.4 ± 0.9 years, body mass 75.4 ± 1.5 kg, height 1.80 ± 0.01 m; mean $\pm s_{\bar{x}}$) participated in the study, all of whom were playing for an elite European team, competing in the Italian league and in the European Champions League. Fourteen of these players were also playing for their respective national teams (representing five nations), which were among the strongest in the world (ranked 1–10 on the official FIFA list). In addition, 24 professional players (age 26.5 ± 1.0 years, body mass 75.4 ± 1.7 kg, height 1.81 ± 0.02 m) from the top Danish league took part in the study, five of whom were playing for their respective national teams, which were of moderate ability (ranked higher than 20 on the official FIFA list).

The players were observed individually by video filming in up to seven different competitive matches throughout two consecutive seasons. A season was divided into three phases – start, middle and end of the season – to assess seasonal changes in match performance. The sample included 11 central defenders, 9 full-backs, 13 midfield players and 9 attackers. To evaluate any differences between players who played an entire match and substitute players, 13 top-class substitutes (age 25.0 ± 1.0 years, body mass 75.8 ± 1.6 kg, height 1.81 ± 0.01 m) were also video-filmed (five were also represented in the group that played an entire match). The substitutes participated in a part of the second half of the match and were observed in up to four matches on different occasions over the season. Eight of these players also played for their respective national teams (ranked 1–10 on the official FIFA list).

Match analysis

Each player was video-filmed close up during the entire match. The VHS-format cameras (NV-M50, Panasonic, Germany) were positioned at the side of the pitch, at the level of the midfield line, at a height of about 15 m and at a distance of 30–40 m from the touchline. The videotapes were later replayed on a monitor for computerized coding of the activity pattern. The following locomotor categories were used: standing ($0\ km \cdot h^{-1}$), walking ($6\ km \cdot h^{-1}$), jogging ($8\ km \cdot h^{-1}$), low-speed running ($12\ km \cdot h^{-1}$), moderate-speed running ($15\ km \cdot h^{-1}$), high-speed running ($18\ km \cdot h^{-1}$), sprinting ($30\ km \cdot h^{-1}$) and backward running ($10\ km \cdot h^{-1}$). The locomotor categories were chosen in accordance with Bangsbo *et al.* (1991), whereas the mean speed for each category was determined after detailed studies of the videotapes. Thus, the time for the player to pass pre-markers in the grass, the centre circle and other known distances was used to calculate the speed for each activity of locomotion. The above activities were later divided into four locomotor categories: (1) standing; (2) walking; (3) low-intensity running, encompassing jogging, low-speed running and backward running; and (4) high-intensity running, consisting of moderate-speed running, high-speed running and sprinting. The frequency and duration of each activity were recorded and the data are presented for 5-, 15-, 45- and 90-min periods. The distance covered for each activity within each interval was determined as the product of the total time and mean speed for that activity. The total distance covered during a match was calculated as the sum of the distances covered during each type of activity. The peak distance covered in high-intensity running in a 5-min period will be presented. This

period represents that 5 min which contains the most high-intensity running in a game and is specific for each of the monitored players. In addition, the numbers of headers and tackles were registered for each half.

Reproducibility of the results obtained by the time–motion analysis has previously been determined. In a study by Krustrup and Bangsbo (2001), no systematic differences were observed in a test–retest analysis of a match and the mean intra-individual difference in total distance covered was less than 0.2 km (coefficient of variation, CV = 1%). The intra-individual variations (CV) in walking, low-intensity running, high-intensity running and backward running were 2, 5, 3 and 3%, respectively. These values are in the same range as those reported by Bangsbo *et al.* (1991).

The 129 matches analysed in the present study were all analysed by the same experienced observer, who has analysed more than 250 soccer matches. The first and the second half of each match were analysed in a random order. Before analysis of each player was initiated, the individual players' styles of locomotion were studied intensively and several validation tests were performed for each player according to the predetermined categories of locomotion.

Yo-Yo intermittent recovery test

Both the top-class and the moderate players performed the Yo-Yo intermittent recovery test (level 1) on two occasions during the competitive season. The highest Yo-Yo test score for each individual was used in the comparison of test performance between standards of competition as well as playing positions. After a 10-min warm-up, the players performed the test, which consists of repeated 2 × 20 m runs back and forth between the start and finish line at a progressively increased speed controlled by audio bleeps from a tape-recorder (Bangsbo, 1995). Between running bouts, the participants had a 10-s active rest period consisting of 2 × 5 m jogs. When the participants failed twice to reach the finish line in time, the distance covered was recorded and was used as the test result. Performance in this test has been shown to be closely correlated with the amount of high-intensity running performed by soccer players (Krustrup *et al.*, 2003) and referees (Krustrup and Bangsbo, 2001) in high-standard soccer matches.

Statistical analysis

Results are presented as the mean ± standard error of the mean ($s_{\bar{x}}$). Differences between the first and second half were determined using Student's paired *t*-test. Differences between the two standards of competition were analysed using Student's unpaired *t*-test. Differences between the four team positions were tested by a one-way analysis of variance. Differences between 5- or 15-min periods within a match, as well as seasonal changes in match activities, were determined using one-way analyses of variance with repeated measurements. In the event of a significant difference between treatments, Tukey's *post-hoc* tests were used to identify specific differences between the means of the two standards of play. Statistical significance was set at $P < 0.05$. The coefficient of variation was used as a measure of intra-individual variation in high-intensity running and total distance covered during matches and was calculated as the standard deviation of the difference between repeated measurements divided by the mean and multiplied by 100 (Atkinson and Nevill, 1998).

Results

Match activities

The top-class players spent 19.5 ± 0.7, 41.8 ± 0.9 and 29.9 ± 1.3% of the time during a game standing, walking and in running of low intensity, respectively, which was similar to the moderate players (Fig. 1). The top-class players performed more ($P < 0.05$) high-intensity running and sprinting than the moderate players (8.7 ± 0.5 *vs* 6.6 ± 0.4% and 1.4 ± 0.1 *vs* 0.9 ± 0.1%, respectively; Fig. 1). In addition, the top-class players spent more ($P < 0.05$) time running backwards than the moderate players (3.7 ± 0.3 *vs* 2.9 ± 0.2%). The numbers of low-intensity runs, high-intensity runs and sprints were also higher ($P < 0.05$) for the top-class than the moderate players (587 ± 23 *vs* 566 ± 20, 217 ± 13 *vs* 171 ± 7 and 39 ± 2 *vs* 26 ± 1, respectively; Table 1). There was no difference in the mean duration of any of the activities between the two groups (Table 1). The top-class players ran more ($P < 0.05$) at both a low and high intensity during the first compared with the second half (31.1 ± 1.3 *vs* 28.4 ± 1.4% and 9.0 ± 0.4 *vs* 7.7 ± 0.5%, respectively; Fig. 2). In addition, the top-class players sprinted more ($P < 0.05$) in the first than in the second half (1.6 ± 0.1 *vs* 1.2 ± 0.1%; Fig. 2). Similar differences ($P < 0.05$) were observed for the moderate players when low- and high-intensity running and sprinting were compared in the two halves (first half *vs* second half: 32.5 ± 1.4 *vs* 29.6 ± 1.2, 7.0 ± 0.4 *vs* 6.3 ± 0.3 and 0.9 ± 0.1 *vs* 0.8 ± 0.1%, respectively; Fig. 2). The top-class players performed more ($P < 0.05$) bouts of low- and high-intensity running in the first than in the second half (302 ± 12 *vs* 285 ± 12 and 114 ± 6 *vs* 103 ± 7, respectively). The moderate players showed no significant difference between the two halves (first half *vs* second half: 281 ± 11 *vs* 285 ± 10 and 88 ± 4 *vs* 82 ± 4, respectively). Both the top-class and the

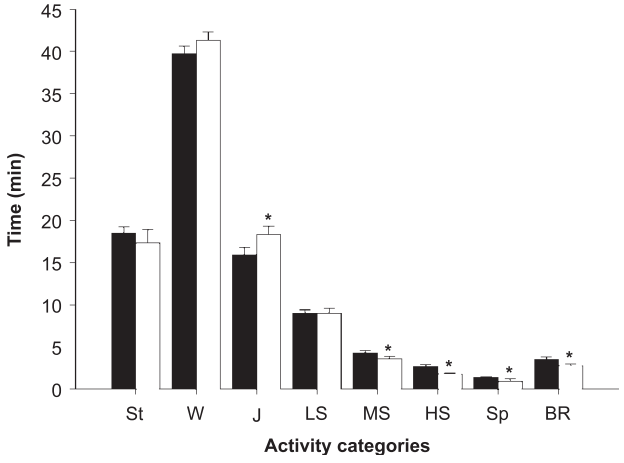

Fig. 1. Locomotor categories for top-class players (■) and moderate players (□) during a soccer game expressed as total time (mean $\pm s_{\bar{x}}$) *Significant difference ($P < 0.05$) between groups. St = standing; W = walking; J = jogging; LS, MS and HS = running at a low, moderate and high speed, respectively; Sp = sprinting; BR = backwards running.

moderate players sprinted more frequently ($P < 0.05$) in the first than in the second half (22 ± 2 *vs* 17 ± 1 and 14 ± 1 *vs* 12 ± 1, respectively). For the top-class players, the mean times of standing and walking intervals were longer ($P < 0.05$) in the second half than in the first half (7.5 ± 0.4 *vs* 6.5 ± 0.3 s and 6.5 ± 0.3 *vs* 6.2 ± 0.3 s, respectively). There was no difference in the mean duration of any of the other locomotor activities between the first and the second half for players of either standard.

Distances covered

The total distance covered during a match was 10.86 ± 0.18 km for the top-class players, which was 5% more ($P < 0.05$) than for the moderate players (10.33 ± 0.26 km). The amount of high-intensity running during a match was 28% greater ($P < 0.05$) for top-class than for moderate players (2.43 ± 0.14 *vs* 1.90 ± 0.12 km). The distance covered when sprinting was 0.65 ± 0.06 km for top-class players, which was 58% more ($P < 0.05$) than for moderate players (0.41 ± 0.03 km). The distance covered during the first half was longer ($P < 0.05$) than in the second half for top-class players (5.51 ± 0.10 *vs* 5.35 ± 0.09 km); no difference was observed for moderate players (5.20 ± 0.14 *vs* 5.13 ± 0.12 km). Both groups of players covered a greater ($P < 0.05$) distance in high-intensity running in the first than in the second half of the match (top-class: 1.27 ± 0.07 *vs* 1.15 ± 0.08 km; moderate: 1.01 ± 0.07 *vs* 0.90 ± 0.06 km, respectively). Furthermore, distance covered when sprinting both for top-class and moderate players was also greater ($P < 0.05$) in the first than in the second half (0.35 ± 0.04 *vs* 0.30 ± 0.03 and 0.21 ± 0.03 *vs* 0.19 ± 0.02 km, respectively).

Performance within a match

The distance covered in high-intensity running by top-class players in the last 15 min was 14–45% lower ($P < 0.05$) than in the first four 15-min periods (0.32 ± 0.03 *vs* 0.36 ± 0.02 to 0.46 ± 0.03 km; Fig. 3a). The moderate players covered 17–35% less ($P < 0.05$) distance in high-intensity running in the last four 15-min periods than in the first 15 min (0.27 ± 0.03 to 0.31 ± 0.03 *vs* 0.36 ± 0.03 km; Fig. 3a). The distance covered by the top-class players when sprinting was shorter ($P < 0.05$) in the last compared with the first four 15-min periods (0.07 ± 0.01 *vs* 0.09 ± 0.01 to 0.13 ± 0.02 km); there was no difference for the moderate players (Fig. 3b). Thus, the distance covered by top-class players when sprinting was 43% less ($P < 0.05$) in the last 15 min than in the first 15 min.

The peak distance covered in high-intensity running in a 5-min period was 219 ± 8 m for top-class players, which was 27% more ($P < 0.05$) than for the moderate players (172 ± 9 m) (Fig. 4). In the next 5-min period, the amount of high-intensity running was 106 ± 6 m for top-class players, which was 12% less ($P < 0.05$) than the average distance covered during all 5-min intervals (except that of peak intensity; 121 ± 4 m). The moderate players performed 94 ± 8 m of high-intensity running in the 5 min after the most intense period, which tended to be lower ($P = 0.08$) than the average distance covered in high-intensity running (105 ± 5 m; Fig. 4). In addition, when the data for the two groups of players were combined, the distance covered in high-intensity running during the first 5 min of the first half was greater ($P < 0.05$) than during the first 5 min of the second half (160 ± 10 *vs* 130 ± 7 m, respectively), whereas no significant difference was apparent between the second 5-min period of the first and the second half (130 ± 9 and 109 ± 7 m, respectively).

The total number of headers and tackles performed during a game was 15 ± 2 and 20 ± 2, respectively. No difference was observed in the number of headers between the first and second half (8 ± 1 *vs* 7 ± 1), whereas the players performed more ($P < 0.05$) tackles during the first than the second half (12 ± 1 *vs* 8 ± 1).

When comparing the performance of players who played the entire match with the performance of the substitutes, the amount of high-intensity running in the last 15 min of the game was 25% higher ($P < 0.05$) for the substitutes (0.40 ± 0.03 *vs* 0.32 ± 0.03 km). The amount of sprinting in the last 15 min of the game was

Table 1. Frequency, mean duration and percent of time spent on the locomotor categories for top-class and moderate players (mean ± $s_{\bar{x}}$)

	Standing	Walking	Jogging	Low-speed running	Backwards running	Moderate-speed running	High-speed running	Sprinting	Total
Frequency (*n*)									
Top-class	163 ± 6	379 ± 10*	316 ± 15	198 ± 8	73 ± 4*	109 ± 7*	69 ± 5*	39 ± 2*	1346 ± 34*
Moderate	163 ± 10	398 ± 12	321 ± 13	185 ± 8	60 ± 4	96 ± 5	49 ± 3	26 ± 1	1297 ± 27
Mean duration (s)									
Top-class	7.0 ± 0.4	6.4 ± 0.3	3.0 ± 0.1	2.6 ± 0.0	2.7 ± 0.1	2.2 ± 0.0	2.1 ± 0.0	2.0 ± 0.0	3.5 ± 0.1
Moderate	7.1 ± 0.4	6.4 ± 0.3	3.1 ± 0.1	2.7 ± 0.1	2.7 ± 0.1	2.4 ± 0.0	2.2 ± 0.0	1.9 ± 0.0	3.6 ± 0.1
% of total time									
Top-class	19.5 ± 0.7	41.8 ± 0.9	16.7 ± 0.9*	9.5 ± 0.4	3.7 ± 0.3*	4.5 ± 0.3*	2.8 ± 0.2*	1.4 ± 0.1*	100.0
Moderate	18.4 ± 1.5	43.6 ± 0.8	19.1 ± 0.9	9.4 ± 0.4	2.9 ± 0.2	3.8 ± 0.3	1.9 ± 0.1	0.9 ± 0.1	100.0

*Significant difference ($P < 0.05$) between top-class and moderate players.

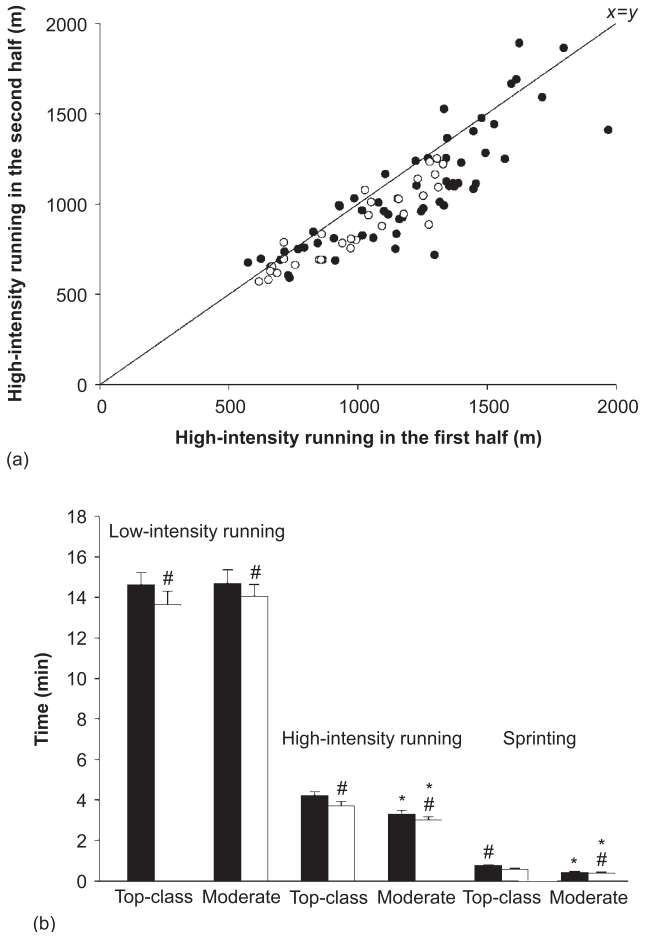

Fig. 2. (a) High-intensity running in the first (x-axis) and second (y-axis) half of the game for top-class (●) and moderate (○) players. (b) Time spent in low-intensity running (jogging, low-speed running and backwards running), high-intensity running (moderate- and high-speed running) and sprinting during the first (■) and second half (□) for top-class and moderate players (mean ± $s_{\bar{x}}$). #Significant difference ($P < 0.05$) between first and second half. *Significant difference ($P < 0.05$) between top-class and moderate professional players.

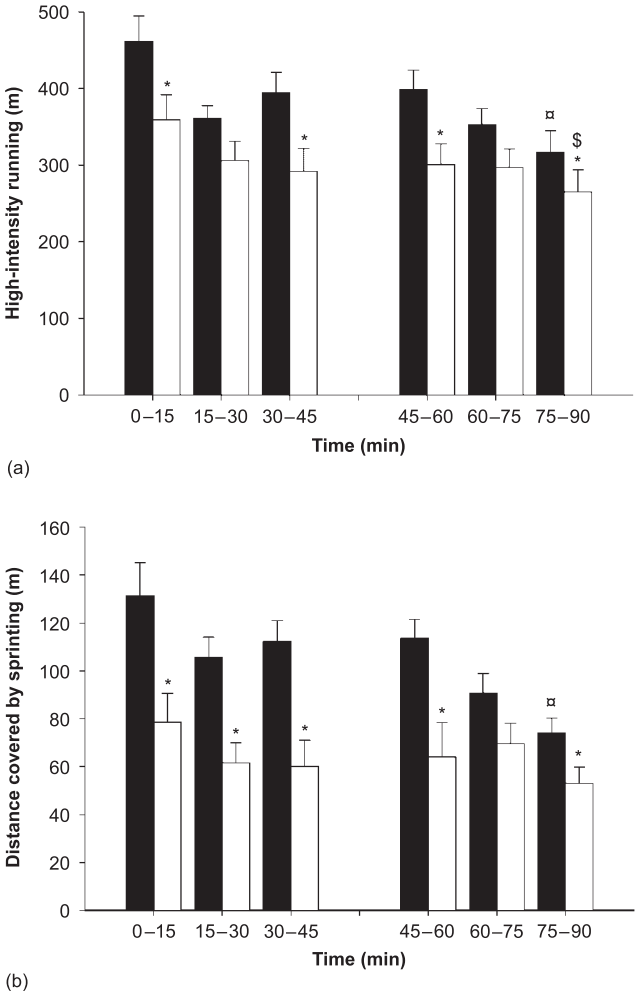

Fig. 3. High-intensity running (a) and sprinting (b) in 15-min intervals for top-class players (■) and moderate players (□) (mean ± $s_{\bar{x}}$). *Significant difference ($P < 0.05$) between top-class and moderate players. ¤Significantly different ($P < 0.05$) from the first four 15-min periods of the game. $Significantly different ($P < 0.05$) from the first 15-min period of the game.

63% higher ($P < 0.05$) for the substitutes than for the other players (0.13 ± 0.01 *vs* 0.07 ± 0.00 km; Fig. 5).

Playing position

The midfield players ($n = 13$), full-backs ($n = 9$) and attackers ($n = 9$) covered a greater ($P < 0.05$) total distance than the defenders ($n = 11$) (11.00 ± 0.21, 10.98 ± 0.23, 10.48 ± 0.30 *vs* 9.74 ± 0.22 km, respectively). The midfielders, full-backs and attackers also covered a greater ($P < 0.05$) distance in high-intensity running than the defenders (2.23 ± 0.15, 2.46 ± 0.13, 2.28 ± 0.14 *vs* 1.69 ± 0.10 km, respectively). There was no difference in the total distance covered or the distance covered in high-intensity running between the other three positions. On the other hand, the attackers and the full-backs covered a greater ($P < 0.05$) distance when sprinting than the midfield players and defenders (0.69 ± 0.08 and 0.64 ± 0.06 *vs* 0.44 ± 0.04 and 0.44 ± 0.03 km, respectively). There was no difference between the full-backs and the attackers or between the midfield players and the defenders.

All players in both groups showed a reduction ($P < 0.05$) in high-intensity running in the second compared with the first half (Fig. 6). The attackers showed a greater ($P < 0.05$) decline in sprinting distance from the first to the second half than the

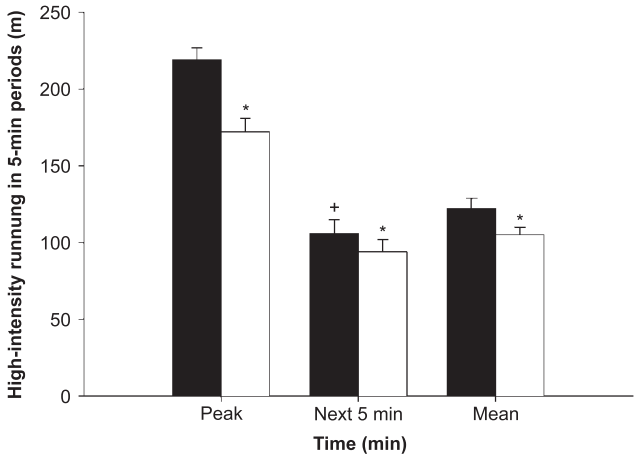

Fig. 4. Peak high-intensity running in a 5-min period, the following 5 min and average values of the remaining 5-min periods for top-class (■) and moderate players (□) (mean ± $s_{\bar{x}}$). *Significant difference ($P < 0.05$) between top-class and moderate players. $^{+}$Significantly different ($P < 0.05$) from average 5-min value.

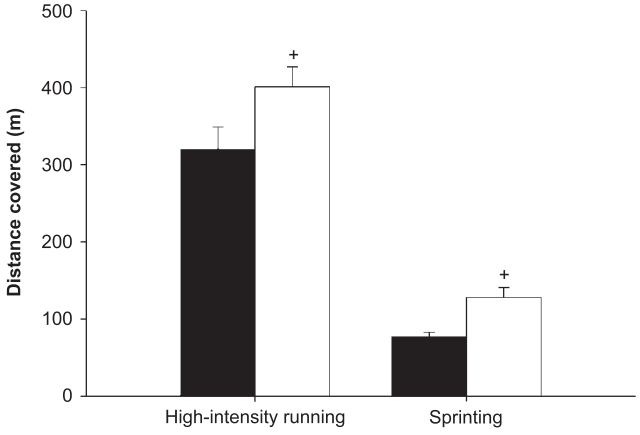

Fig. 5. High-intensity running and sprinting in the last 15 min of the game for elite players playing the entire match (■) and elite substitutes (□) (mean ± $s_{\bar{x}}$). $^{+}$Significant difference ($P < 0.05$) between substitutes and players playing the entire match.

defenders and the midfield players (19 ± 5 *vs* 11 ± 6 and 8 ± 4%, respectively).

The number of headers performed by the defenders, midfielders and attackers was higher ($P < 0.05$) than the number of headers performed by the full-backs (14 ± 2, 11 ± 2, 14 ± 5 *vs* 4 ± 0, respectively). Also, the number of tackles was higher for the defenders, midfielders and attackers than the full-backs (17 ± 2, 17 ± 2, 18 ± 3 *vs* 8 ± 1, respectively). No differences were observed in headers and tackles between the other positions.

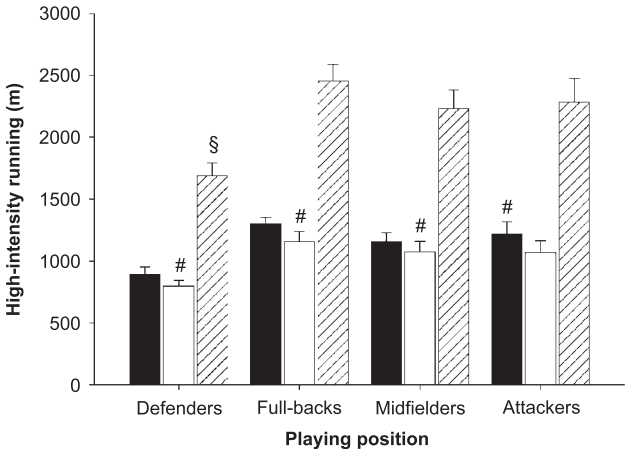

Fig. 6. High-intensity running in the first (■) and second half (□) as well as during the entire game (▨) for defenders ($n = 11$), full-backs ($n = 9$), midfielders ($n = 13$) and attackers ($n = 9$) (mean ± $s_{\bar{x}}$). $^{\#}$Significant difference ($P < 0.05$) between first and second half. §Significantly different ($P < 0.05$) from full-backs, midfielders and attackers.

Match-to-match and seasonal variations

Eighteen players were analysed in two consecutive games played within a 3-week period. The match-to-match variation in total distance covered was 0.01 ± 0.08 (−0.69 to 0.82) km with a coefficient of variation of 3.1%. The match-to-match variation in high-intensity running was −0.04 ± 0.20 (−0.38 to 0.40) km, with a coefficient of variation of 9.2%. Ten of the top-class players were then examined during three different stages over the two seasons (1–3 observations within each period). Total distance covered at the end of the season was greater ($P < 0.05$) than at the start and in the middle of the season (10.72 ± 0.13 *vs* 10.34 ± 0.21 and 10.13 ± 0.35 km, respectively). The distance covered in high-intensity running was also greater ($P < 0.05$) at the end than at the start or in the middle of the season (2.51 ± 0.19 *vs* 2.11 ± 0.23 and 1.94 ± 0.19 km, respectively). There was no difference ($P > 0.05$) in distance covered when sprinting between the three stages of the season. The match-to-match variation in the total distance covered in high-intensity running for matches played at different stages of the season (separated by at least 4 months) was −0.19 ± 0.22 (−1.44 to 1.51) km, with a coefficient of variation of 6.4%. The seasonal variation in high-intensity running was −0.43 ± 0.71 (−1.64 to 1.21) km, with a coefficient of variation of 24.8%.

Yo-Yo intermittent recovery test results

The top-class players covered a 10.7% greater ($P < 0.05$) distance in the Yo-Yo intermittent recovery

test than the moderate players (2.26 ± 0.08 *vs* 2.04 ± 0.06 km). The midfield players and full-backs covered a greater ($P < 0.05$) distance than the attackers and the defenders (2.23 ± 0.10 and 2.21 ± 0.04 *vs* 1.99 ± 0.11 and 1.91 ± 0.12 km, respectively).

Discussion

The results of this study show that top-class players performed more high-intensity running during a game and were better at the Yo-Yo intermittent recovery test than professional players at a less elite standard. In addition, the players' physical performance was reduced after a period with a large amount of high-intensity exercise during match-play and towards the end of the match, suggesting that fatigue occurs both temporarily during and at the end of a game. These effects were observed independent of position played in the team. It was also clear that the physical performance and activities of elite players are closely related to the positional role in the team; for example, the defenders covered the least distance in the Yo-Yo test and in running at high-intensity during a game, and the full-backs performed few headers and tackles.

The present study focused on the performance of 18 top-class players in domestic and European games, with each player being assessed in 2–7 matches. The performances of these players were compared with those of 24 Danish professional players of a less elite standard to test the hypothesis that top-class soccer is the most demanding. The total distance covered by the moderate players in the present study was similar to that of players of a comparable standard in the late 1980s and early 1990s (Bangsbo *et al.*, 1991). However, the players in the present study performed 37% more sprinting during a game than the Danish players in the earlier study, indicating the developing physiological demands in Danish soccer over the last decade. One reason for the increase in high-intensity running may be the rule, introduced in 1992, that the goalkeeper cannot pick up a back pass (Bangsbo, 1994; Reilly, 1994).

The top-class players performed more high-intensity running (0.53 km or 28%) and sprinted more (0.24 km or 58%) than the moderate players. The greater total distance covered by the top-class players ($\sim$0.5 km) was due to the greater amount of high-intensity running they performed. Because of the intermittent nature of soccer (Reilly and Thomas, 1976; Reilly, 1990; Bangsbo *et al.*, 1991), these findings indicate that soccer at the highest standard is characterized by the players' ability to perform high-intensity work repeatedly. This notion is supported by the fact that the top-class players performed better on the Yo-Yo test than the moderate players. Thus, the training of top-class players should focus on improving their ability to perform intense exercise and to recover rapidly from periods of high-intensity exercise.

The defenders covered less total distance and performed less high-intensity running than players in the other positions, which probably is closely related to the tactical roles of the defenders and their lower physical capacity (Bangsbo, 1994), as also was evident from the results of the Yo-Yo test. The full-backs covered a considerable distance at a high intensity and when sprinting, whereas they performed fewer headers and tackles than players in the other positions. The attackers covered a distance at a high intensity equal to the full-backs and midfield players, but performed more sprints than the midfield players and defenders. The attackers also showed a more marked decline in sprinting distance towards the end of a game than the defenders and midfield players. In addition, the attackers did not perform as well as the full-backs and midfield players on the Yo-Yo test. Thus, it appears that the modern elite attacker needs to have a high capacity to perform high-intensity actions repeatedly.

The midfield players performed as many tackles and headers as the defenders and attackers. Midfield players covered a total distance and distance at a high-intensity similar to the full-backs and attackers. However, they sprinted less than full-backs and attackers. Previous studies have shown that midfield players cover a greater distance during a game than full-backs and attackers (Reilly and Thomas, 1976; Withers *et al.*, 1982; Ekblom, 1986; Bangsbo *et al.*, 1991; Bangsbo, 1994). These differences may be explained by the development of the physical demands of full-backs and attackers, since, in contrast to earlier studies (Bangsbo, 1994), we observed that players in all team positions showed a significant decline in high-intensity running towards the end of the match. This indicates that almost all players in elite soccer tax their physical capacity during a game. Within each playing position, there was a significant variation in the physical demands depending on the tactical role and the physical capacity of the players. For example, there was a variation in the distance covered at high intensity of 1.9 km among the midfield players in the same game.

After a 5-min period in which the most high-intensity exercise was performed, the top-class players then performed significantly less high-intensity running. There was a tendency for this to occur among the moderate players as well. Thus, it appears that the players experience temporary fatigue during the game. This is supported by the findings of a study of non-professional players (P. Krustrup, M. Mohr and J.

Bangsbo, unpublished data), in which it was observed that the players had a decreased sprinting performance after an intense period of exercise during the first half, but had recovered their performance by the end of the first half. Fatigue also appears to occur towards the end of a game, since the players in the present study performed less high-intensity work during the last 15 min of a game. It could be argued that the reduced amount of high-intensity work at the end of the game was related to the fact that the outcome of the match had been decided. However, only in six of the 27 matches observed was there a difference in score of more than one goal. Furthermore, there were no systematic differences in the activity pattern between these six matches and the other matches. That the substitutes performed more high-intensity running than the other players supports the suggestion that fatigue occurs towards the end of the game for the players who play 90 min. In line with this notion is the observation that the sprinting ability of the players was reduced in the second half (Rebelo *et al.*, 1998). This is supported further by previous studies reporting a greater distance covered in the first than the second half both for players (Reilly and Thomas, 1976; Van Gool *et al.*, 1988; Bangsbo *et al.*, 1991; Bangsbo, 1994) and assistant referees (Krustrup *et al.*, 2002). Consequently, it appears that professional soccer players experience temporary fatigue during a game and especially towards the end of a game.

When comparing the same top-class players at different stages of the season, they were seen to cover the greatest distance in high-intensity running towards the end of the season. This finding suggests that the players improved their performance during the season. One explanation could be that the players at the start and middle of the season, in contrast to the end of the season, played frequently in the Champions League and national cup competition, which often meant playing two matches a week. This allowed limited time to perform fitness training. In contrast, at the end of the season, rarely more than one match was played a week and a significant amount of fitness training was performed. Thus, it appears that fitness training is important between games to maintain and improve physical performance during a game.

In summary, the present results show that soccer players competing at the highest standard perform more high-intensity running during a match than players of a less elite standard. Defenders performed less high-intensity running during a match than the midfield players, full-backs and attackers. Fatigue appeared to occur towards the end of the match as well as temporarily during it. In addition, the match performance of the top-class players varied throughout the season and peaked at the end of the season.

Acknowledgements

We would like to thank the players who participated in the study. The technical assistance of the camera crew (David Hudson, Leonardo Reis Silveira, Per Hansen, Jandl-Malm Hansen, Christoffer Krustrup, Mikkel Linnet and Anders Markussen) is greatly appreciated. Furthermore, the cooperation of Lyngby Football Club, Jógvan Martin Olsen and the Faroese Football Association is acknowledged. The study was supported by Team Denmark and The Sports Research Council (Idrættens Forskningsråd).

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