Training Status and Match Activity of Professional Soccer Players Throughout a Season

João R. Silva,[1,5] José Magalhães,[2,3] António Ascensão,[2,3] André F. Seabra,[3,4] and António N. Rebelo[1,5]

[1]*Department of Soccer, Faculty of Sport, University of Porto, Porto, Portugal;* [2]*Department of Sports Biology, Faculty of Sport, University of Porto, Porto, Portugal;* [3]*Research Center in Physical Activity, Health and Leisure (CIAFEL), Porto, Portugal;* [4]*Department of Kinanthropometry, Faculty of Sport, University of Porto, Porto, Portugal; and* [5]*Center of Research, Education, Innovation and Intervention in Sport (CIFI2D), Porto, Portugal*

Abstract

Silva, JR, Magalhães, J, Ascensão, A, Seabra, AF, and Rebelo, AN. Training status and match activity of professional soccer players throughout a season. *J Strength Cond Res* 27(1): 20–30, 2013—The purpose of this study was to examine match activity (MA) and fatigue development (FD) during official soccer games in different moments of a season and the influence of training status (TS) on MA and FD. Match activity of 13 professional players was examined by time-motion analysis at 4 time points of a competitive season. In addition, per time point within the 2-week period between the 2 games video-filmed, players performed the following physical tests: countermovement jump, 5- and 30-m sprints, change of direction, knee extensor and flexor isokinetic strength, and Yo-Yo intermittent endurance test-level 2. The players covered a greater high-intensity distance running (HI; $p < 0.05$) in the last quarter of the season (E4) than in the second (E2) and the third (E3) quarters. Within each assessment period, a greater distance was covered in HI during the peak 5-minute period of the match (P5-min) than in the 5-minute period after P5-min (Next5-min) and the remaining 5-minute periods (Av5-min; $p < 0.05$) of the match. Also, P5-min was higher in E4 than in the beginning of the season (E1, E2, and E3; $p < 0.05$). The physical fitness variables, composites scores of power-related and isokinetic strength tests were correlated (r ranging between 0.59 and 0.73, $p < 0.05$) with game physical parameters (GPPs) analyzed by time motion. Soccer players were found to cover more HI during the game and in the P5-min toward end of season. The players with greater muscle strength and power expressed lower performance decrements in the GPPs. In conclusion, the results highlight the relevance of players' neuromuscular function on game physical performance.

Key Words performance analysis, competitive period, strength, muscle power, fatigue

Address correspondence to João R. Silva, jm_sivl@hotmail.com.

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Introduction

Match analysis is a widely used instrument in professional soccer to study tactical and physical performance of players and referees (2). Research with some of the most up-to-date technologies such as the multicamera method (2,42,44), global position systems (44), and video-based time-motion analysis (30,44) revealed detailed information about players' movement patterns (8,26,30). Moreover, these methods seem to be able to detect performance decrements during soccer games and thereby enable the study of game-induced fatigue (44). Data revealed that several signs of fatigue can be manifested temporally during a game (6,30,31), toward the end of the game (6,30,31), and persist afterward (4,28,32,45) with a time dependency for the fitness parameter evaluated. Also, it has been observed through these methods that performance during the match is dependent on multiple factors (7,25,26,30,42).

Recent investigations observed that physical performance during the game changes throughout the season (30,42) and is related to players' training status (25,26,41). In fact, some studies showed that soccer players' performance in the Yo-Yo intermittent recovery test in both men (25) and women (26), in incremental field tests (shorter version of the University Montreal Track Test) (41), and in the repeated shuttle sprint ability test (41) are indicators of game-related physical performance.

However, data on nonlocomotive activity and on unorthodox movements (e.g., shuffling, diving), soccer-specific movements (e.g., heading, blocking), and accelerations and decelerations are generally omitted or not taken into account

(8). In fact, a massive metabolic load is imposed on players, not only during the more intense parts of the game but also every time acceleration occurs, even when the speed is low (36). The regular evaluation of soccer physical fitness using different tests is of special importance, because soccer players should be able to successfully perform over competitive seasons of around 10–11 months. Although seasonal variations in game-physical performance have been analyzed (30,42), these investigations usually involve 3 time points of the season (beginning, middle, and end-of-season). Therefore, research assessing a higher range of time points throughout the season will be more fruitful when analyzing seasonal variations in game-related physical parameters. Moreover, scrutinized research of seasonal alterations in fatigue patterns (e.g., temporary fatigue) of soccer players during games has never been reported. Thus, we aimed to analyze game-related physical performance and fatigue development (FD) during official soccer games during 4 time points of the season.

Rapid force production is considered essential for a wide range of athletes (1,20,34). In fact, soccer players' muscle strength (3,16) and performance in sport-specific muscle power efforts (16,33) were reported to be related to the players' and team's competitive levels. Moreover, improvements in coordination specificities (12) and a greater agility (19) have been positively associated with performance and the ability to delay fatigue. In accordance with recent reports, enhancement of neuromuscular function can be a determinant in improving short- and long-term endurance capacities (1). Despite these indications and high stresses being imposed on the neuromuscular system during soccer games, until now, no study addressed whether muscle strength and power can be indicators of game-related physical performance. Therefore, we also aim to investigate whether physical conditioning evaluated in field and laboratory tests is related to game-physical performance and FD. We hypothesized, that during the season, soccer players may experience performance alterations in certain game physical parameters (GPPs) analyzed by time motion. Moreover, given the high stress levels imposed on the neuromuscular system, soccer players' training status might be associated with some game-related physical parameters.

METHODS

Experimental Approach to the Problem

Match activity (MA) and fatigue during games has been a topic of increased research in recent years (4,6–8,28,30,40). Moreover, players' physical and physiological characteristics have already been extensively described (6,16,20). However, the seasonal alterations in MA and the influence of players' training status in game physical performance had been scarcely investigated. Therefore, to analyze seasonal alterations in GPPs and in fatigue patterns (e.g., temporary fatigue), a sequence of time-motion analysis of 13 players was performed over 8 videotaped matches during 4 time points of a competitive season (Figure 1). Temperature and relative humidity during matches at different time points were as follows: E1: first and third official games, temperature ranged from 24 to 26° C and relative humidity from 40 to 44%; E2: eighth and tenth official games, temperature ranging from 19 to 21° C and relative humidity from 55 to 60%; E3: 15th and 16th official games, temperature ranging from 13 to 15° C

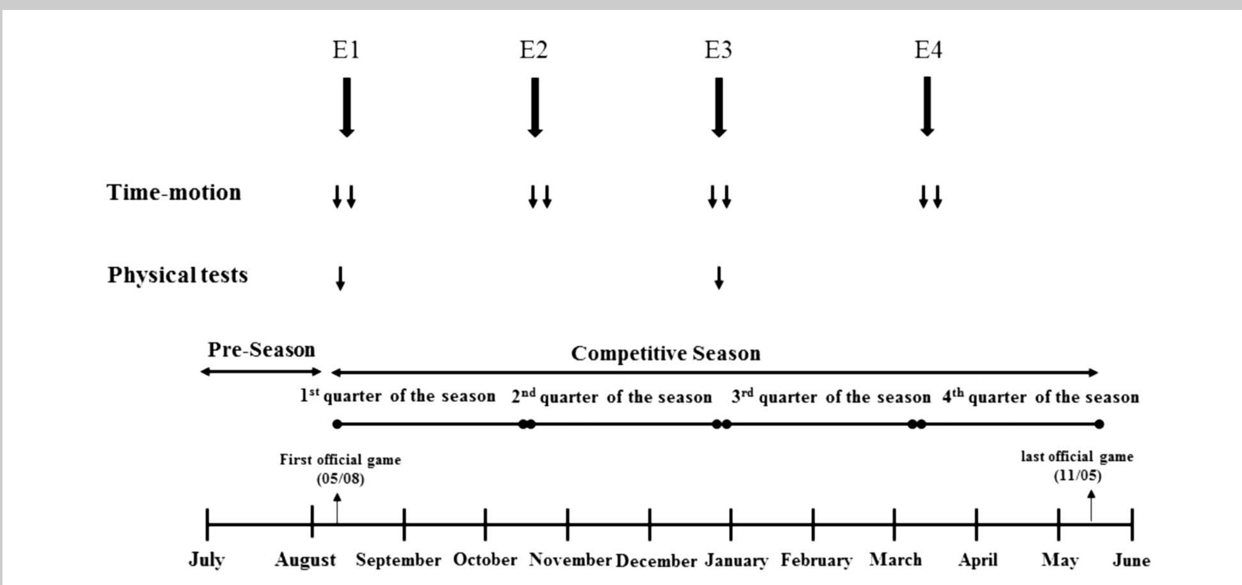

Figure 1. Season profile and measurement schedule.

TABLE 1. Rank of opposing team, frequency of activities, and distance covered in different locomotion categories throughout the different evaluation moments of the season (mean ± *SD*).*

	E1	E2	E3	E4
Rank opposite team (result)	Tenth–fourth (V–V)	Seventh–ninth (T–V)	14th–15th (V–V)	Fifth–second (V–T)
Frequencies (*n*)				
Total	1,526 ± 251	1,577 ± 200	1,583 ± 184	1,515 ± 143
FLI	635 ± 88	711 ± 90	718 ± 124	650 ± 89
FHI	130 ± 27†	130 ± 24†	130 ± 26†	189 ± 41
Distance covered (km)				
TD	9.15 ± 0.64	9.0 ± 0.41‡	9.35 ± 0.47	9.6 ± 0.31
$TD_{1st\ half}$	4.5 ± 0.33	4.5 ± 0.24†	4.7 ± 0.27	4.8 ± 0.23
$TD_{2nd\ half}$	4.65 ± 0.39	4.5 ± 0.2‡	4.6 ± 0.19	4.8 ± 0.15
LI	4.2 ± 0.53	4.4 ± 0.44	4.7 ± 0.41	4.3 ± 0.39
$LI_{1st\ half}$	2.1 ± 0.31	2.2 ± 0.24	2.4 ± 0.28§	2.2 ± 0.30
$LI_{2nd\ half}$	2.1 ± 0.27	2.2 ± 0.21	2.3 ± 0.23	2.1 ± 0.26
HI	1.35 ± 0.28	1.25 ± 0.1†	1.27 ± 0.1†	1.9 ± 0.55
$HI_{1st\ half}$	0.64 ± 0.25†	0.6 ± 0.09†	0.63 ±0.07†	1.0 ± 0.31
$HI_{2nd\ half}$	0.72 ± 0.06	0.65 ± 0.05	0.64 ± 0.06	0.9 ± 0.25

*E1 = evaluation 1; E2 = evaluation 2; E3 = evaluation 3; E4 = evaluation 4; FLI = frequency of low-intensity activities; FHI = frequency of high-intensity activities; LI = low-intensity running; HI = high-intensity running; TD = total distance; V = victory; T = tie.
†Significantly different from E4 ($p < 0.05$).
‡Significantly different from E3 and E4 ($p < 0.05$).
§Significantly different from E1.

and relative humidity from 60 to 65%; E4: 24th and 26th official game, temperature ranging from 14 to 16° C and relative humidity from 60 to 75%. In addition, to analyze the influence of player training status in game physical performance, the players underwent a group of laboratory and field physical tests within 2 weeks of each of the 2 time points of competitive games video-filmed (E1 and E3; Figure 1). The players performed the countermovement jump (CMJ), 5-m (T5) and 30-m (T30) sprints, change-of-direction (COD) ability (*t*-test), knee extensor (KE) and knee flexor (KF) maximal isokinetic strength, and the Yo-Yo intermittent endurance test level 2 (YYIE2). These tests provide valid and reliable data allowing an evaluation of the physical fitness parameters directly (agility, sprint, jump, and intermittent endurance) and indirectly (isokinetic strength) related to soccer physical performance. In addition, composite scores were determined to provide a more complex operational indicator of physical fitness. With this option, we aimed to investigate the association between GPPs and certain soccer players' specific physical fitness parameters to provide a more global indicator of the soccer players' training status (e.g., the sum of the scores in the soccer-specific muscle power-related tests).

Subjects

A group of 13 professional male soccer players (4 defenders, 5 midfielders, and 4 attackers (mean ± *SD*: 25.7 ± 4.6 years, body mass 76.5 ± 9.2 kg, height 178.1 ± 5.7 cm, and 9.8 ± 3.7% fat percentage) from a professional team competing in the Portuguese championship (Professional Soccer League) was involved. All the subjects had a minimum of 3 and a maximum of 10 years of senior soccer professional activity. Only injury-free players participating in full training schedules were tested. In accordance with the professional Club policy and medical requirements, all the soccer players underwent physical examinations both at the beginning and throughout the season (e.g., blood sample analysis, resting electrocardiogram, lung X-Ray). All the subjects were informed of the purpose of the study, and written informed consent was obtained according to the Declaration of

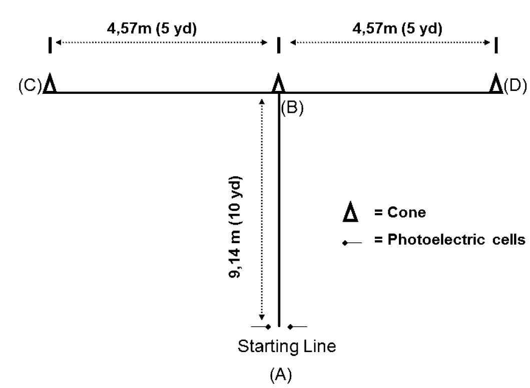

Figure 2. Layout of the *T*-test. Modified from Semenick (46).

Table 2. Distance covered in different categories of HI throughout the season (mean ± *SD*).*

HI (m)		E1	E2	E3	E4
Moderate-speed running	First half	399 ± 49	365 ± 52†	367 ± 50†	552 ± 163
	Second half	437 ± 156	397 ± 23	361 ± 67	490 ± 160
	Total	837 ± 157	763 ± 48	728 ± 99†	1,043 ± 320
High-speed running	First half	190 ± 34†	189 ± 34†	210 ± 43	338 ± 104
	Second half	229 ± 77	200 ± 30†	219 ± 22	322 ± 89
	Total	420 ± 107	380 ± 56†	430 ± 54	661 ± 193
Sprint	First half	46 ± 12†	50 ± 19†	53 ± 26†	124 ± 50
	Second half	52 ± 21	46 ± 12	59 ± 16	82 ± 30
	Total	98 ± 28†	96 ± 25†	111 ± 33†	206 ± 78

*E1 = evaluation 1; E2 = evaluation 2; E3 = evaluation 3; E4 = evaluation 4; HI = high-intensity running.
†Significantly different from E4 ($p < 0.05$).

Helsinki. The study was approved by the Scientific Committee of the Sports Faculty of the University of Porto.

Evaluation Procedures

Match Analyses. To avoid variations in pitch dimensions, all videotaped records were restricted to home-played matches (as "Host team") and were filmed by the same group of researchers. Game score and rank of the opposing team data are presented in Table 1.

Time motion was performed according to the procedures defined by Krustrup et al. (26). Each player was filmed close up during the entire match by a VHS movie camera (DCR-HC53E, Sony, Tokyo, Japan) positioned at the side of the field, 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 activity patterns. 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 the results of Bangsbo et al. (7), whereas the mean speed for each category was determined after detailed studies of the videotapes. Thus, the time for the players to pass landmarks in the grass, center circle, and other known distances was used to calculate the speed for each locomotor activity. The above activities were later divided into 4 locomotor categories: (a) standing; (b) walking; (c) low-intensity running, encompassing jogging, low-speed running, and backward running; and (d) high-intensity running (HI), consisting of moderate-speed running, high-speed running, and sprinting. The frequency and duration of each activity were recorded at 5-, 15-, 45-, and 90-minute periods throughout the game. The distance covered by each locomotor activity was determined in 5-minute intervals as the product of the total time and mean speed for that activity. The total distance (TD) covered during a match was calculated as the sum of the distances covered during each type of activity. The peak distance covered in HI in a 5-minute period is also presented. This period represents that particular 5 minutes that comprises the

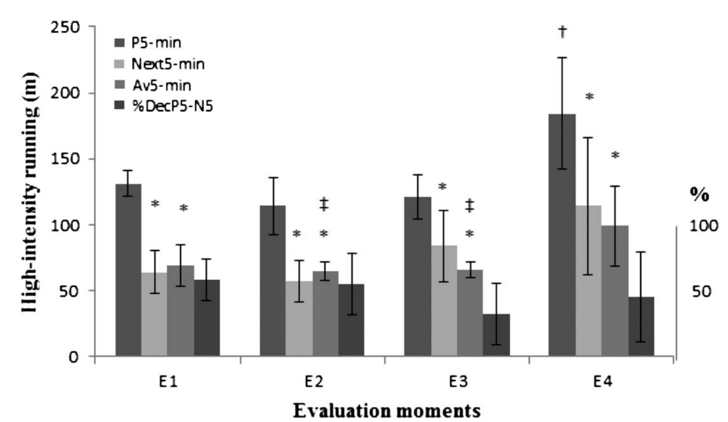

Figure 3. Results of peak distance covered in high-intensity in a 5-minute period (P5-min), in the next 5-minute period (Next5-min), in the average distance covered in the remaining 5-minute periods (Av5-min) and variation from peak period to next 5-minute period (%DecP5-N5); *significantly lower than P5-min ($p < 0.05$); †significantly higher than P5-min in E1, E2, and E3 ($p < 0.05$); ‡significantly lower than Av5-min in E4 ($p < 0.05$).

Table 3. Physiological and functional data of the professional soccer players (mean ± *SD*; *N* = 13).*

Muscle power-related tests				Isokinetic knee strength (90°·s^{-1}; N·m)				Intermittent endurance test		
T5 (s)	T30 (s)	COD (s)	CMJ (cm)	KED	KEND	KFD	KFND	YYIE2 (m)	HRmax	HRmean
1.02 ± 0.05	4.2 ± 0.13	8.57 ± 0.4	42.4 ± 4.4	233 ± 29	230 ± 32	130 ± 17	123 ± 16	1,776 ± 358	196 ± 7	181 ± 7

*YYIE2 = Yoyo intermittent endurance test level 2; T5 = 5-m sprint time; T30 = 30-m sprint time; COD = change of direction test; CMJ = countermovement jump; KED = peak torque of knee extensors dominant leg; KEND = peak torque of knee extensors nondominant leg; KFD = peak torque of knee flexors dominant leg; KFND = peak torque of knee flexors nondominant leg; HRmax = maximum heart rate; HRmean = mean heart rate.

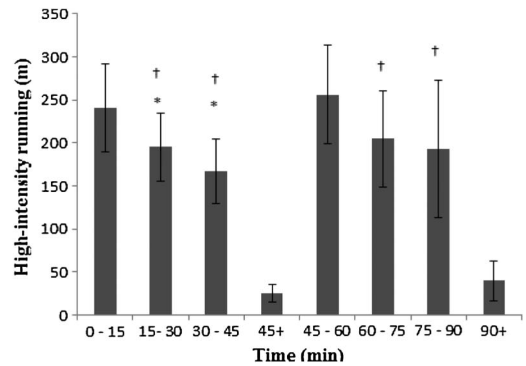

Figure 4. Distance covered in high-intensity running (HI) in 15-minute periods ($n = 13$). *Significantly different from 0- to 15-minute period ($p < 0.05$); †significantly different from 45- to 60-minute period ($p < 0.05$).

most HI in a game and is specific to each of the monitored players. All the match recordings were analyzed by an experienced observer. Krustrup and Bangsbo (24) observed that the coefficients of variation for test-retest analysis were 1, 2, 5, 3, and 3%, respectively, for the TD covered, walking, low-intensity running, HI, and backward running. In this study, the coefficient of variation (CV) for test-retest analysis in different locomotors parameters was <5%. Each player's locomotive style was previously extensively analyzed, and several validation tests were performed according to the predetermined locomotor categories (26). Both halves were analyzed in a random order.

Physical Fitness Testing

All the evaluations took place at the same time of the day, after the players had a regular overnight sleep. The players were instructed to maintain normal routines for daily food and water intake, and they followed the same dietary recommendations defined by the medical staff. In addition, during the days of physical tests, the players were instructed to refrain from drinking beverages containing caffeine and alcohol and from consuming food during the 3 hours before testing. In the 2 days preceding evaluations, the players had a day off (first day) and a training session (second day) involving low-intensity exercises aimed to improve post-match recovery.

The CMJ, sprint, and COD tests were conducted indoors to exclude the influence of ground surface variations of the soccer pitch on the results. The YYIE2 was performed on a field of natural grass where the team normally conducted their training sessions. The order of the tests was as follows: (a) CMJ, (b) sprint, (c) COD ability, (d) KE and KF isokinetic strength, and (e) YYIE2. Before the tests, all the players performed a 10- to 15-minute warm-up consisting of light jogging, specific mobility exercises and stretching routines, and three 10-m sprints. The players completed 2 rounds of

Table 4. Correlations between time-motion variables and sprint, agility, CMJ, and CSPRT.*

	T5 (s)	T30 (s)	COD (s)	CMJ	CSPRT
Next5-min	−0.578 (p = 0.039)†	−0.631 (p = 0.021)†	−0.545 (p = 0.054)	0.400 (p = 0.175)	0.677 (p = 0.011)†
%$Dec_{P5/N5}$	0.569 (p = 0.042)†	0.622 (p = 0.023)†	0.601 (p = 0.030)†	−0.516 (p = 0.071)	−0.725 (p = 0.005)‡
HI_{3rd}	−0.674 (p = 0.012)†	−0.473 (p = 0.103)	−0.561 (p = 0.046)†	0.195 (p = 0.522)	0.598 (p = 0.031)†
HI_{4th}	−0.623 (p = 0.023)†	−0.581 (p = 0.037)†	−0.473 (p = 0.103)	0.220 (p = 0.943)	0.534 (p = 0.060)
$HI_{3rd+6th}$	−0.404 (p = 0.171)	−0.348 (p = 0.244)	−0.013 (p = 0.966)	0.555 (p = 0.052)	0.413 (p = 0.161)
$SP_{1st\ half}$	−0.589 (p = 0.034)†	−0.458 (p = 0.115)	−0.147 (p = 0.632)	−0.099 (p = 0.748)	0.344 (p = 0.250)
$SP_{2nd\ half}$	−0.564 (p = 0.045)†	−0.726 (p = 0.005)‡	−0.341 (p = 0.254)	0.347 (p = 0.245)	0.622 (p = 0.023)†
SP	−0.621 (p = 0.023)†	−0.650 (p = 0.016)†	−0.298 (p = 0.324)	0.089 (p = 0.772)	0.521 (p = 0.068)
$SP_{1st+4th}$	−0.590 (p = 0.034)†	−0.482 (p = 0.096)	−0.194 (p = 0.525)	0.101 (p = 0.747)	0.430 (p = 0.143)

*CSPRTs = composite scores of power-related tests; T5 = 5-m sprint time; T30 = 30-m sprint time; COD = change-of-direction test; CMJ = countermovement jump; Next5-min = peak distance in HI in a 5-minute period after peak 5-minute period (P5-min) of the game; %$Dec_{P5/N5}$ = decrement from P5-min to Next5-min; $HI_{3rd-4th}$ = distance in HI in the third and fourth 15-minute periods of the match; $HI_{3rd+6th}$ = sum of distance in HI in the third and sixth 15-minute periods of the match; $SP_{1st\ half}$ = distance in sprinting in the first half of the match; $SP_{2ndhalf}$ = distance in sprinting in the second half of the match; SP = distance in sprinting during all match; $SP_{1st+4th}$ = sum of sprinting in the first and fourth 15-minute periods of the match.
†$p < 0.05$.
‡$p < 0.01$.

each test in the same order. Each subject was allowed a minimum of a 5-minute rest between tests to ensure adequate recovery.

The CMJ was performed using an Ergojump platform (Digitime 1000, Digitest, Jyvaskyla, Finland) according to Bosco et al. (9), whereby the highest vertical jump (in centimeters) and the longest flight time (in seconds) were registered. Sprint ability measurements were carried out with telemetric photoelectric cells (Brower Timing System, IRD-T175, Draper, UT, USA) placed at the starting line (0 m), at 5 and 30 m. Change-of-direction ability, defined as the ability to decelerate, reverse, or change movement direction and accelerate again (23), was evaluated using an agility test (*t*-test; Figure 2). The *t*-test does not include a perceptual or decision-making component and can be used to measure the COD ability. An adapted version of the *T*-test by Semenick (46) was performed. The subjects began with both their feet 0.3 m behind the starting point A. At their own discretion, each subject sprinted forward 9.14 m (10 yd) to point B and touched the base of the cone with their right hand. They then sprinted to the left 4.57 m (5 yd) and touched the base of a cone (C) with their left hand. The subjects then sprinted to the right 9.14 m (10 yd) and touched the base of a cone (D) with their right hand. Next, they sprinted to the left 4.57 m back to point B and touched the base of a cone with their left hand. They turned 270° and then ran to point A, passing the finishing line. Two test trials were performed, and times were recorded to the nearest one-hundredth of a second. As described for sprint ability, the measurements were carried out with telemetric photoelectric cells (Brower Timing System). Test time was activated when the players passed the electronic sensors at point A, and the clock stopped the instant the players again crossed this point. In sprint and COD testes, the players were instructed to run as quickly as possible from a standing start 0.3 m behind the starting line.

To evaluate the players' lower limb muscle function, maximal gravity corrected concentric quadriceps and hamstrings peak torque of the dominant and nondominant legs at an angular velocity of $90°\cdot s^{-1}$ ($1.57\ rad\cdot s^{-1}$) was measured during isokinetic knee joint movement (Biodex System 2, Shirley, NY, USA) according to Magalhães et al. (27). Before muscle function measurements, the subjects performed a standardized warm-up consisting of 5-minute periods on a cycle ergometer (Monark E-824, Vansbro, Sweden) with a fixed load corresponding to 2% of the body weight. The players were then seated on the dynamometer chair at an inclination of 85° (external angle from the horizontal) with stabilization straps at the trunk, abdomen, and thigh to prevent inaccurate joint movements. The contralateral leg was not secured to avoid influencing the strength developed by the knee muscles being tested. The tested knee was positioned at 90° of flexion (0° = fully extended knee), and the axis of the dynamometer lever arm was aligned with the distal point of the lateral femoral condyle. Before the anatomical alignments and procedures, all the subjects were

Table 5. Correlations between time-motion variables, isokinetic parameters, and composite scores of isokinetic strength.*

	KED (N·m)	KEND (N·m)	KFD (N·m)	KFND (N·m)	CSKE	CSKF	CSKEF
$HI_{\%Dec1st/3rd}$	−0.312 (p = 0.323)	−0.560 (p = 0.058)	−0.346 (p = 0.270)	−0.586 (p = 0.045)†	−0.470 (p = 0.123)	−0.485 (p = 0.110)	−0.497 (p = 0.100)
$HI_{\%Dec4th/6th}$	−0.493 (p = 0.104)	−0.611 (p = 0.035)†	−0.414 (p = 0.181)	−0.449 (p = 0.143)	−0.594 (p = 0.042)†	−0.450 (p = 0.142)	−0.542 (p = 0.069)
$HI_{\%Dec1st/6th}$	−0.328 (p = 297)	−0.581 (p = 0.047)†	−0.329 (p = 0.297)	−0.429 (p = 0.164)	−0.490 (p = 0.106)	−0.395 (p = 0.204)	−0.459 (p = 0.133)
$HI_{\%AvDec1st/3rd-4th/6th}$	−0.486 (p = 0.109)	−0.733 (p = 0.007)‡	−0.470 (p = 0.123)	−0.667 (p = 0.018)†	−0.657 (p = 0.020)†	−0.592 (p = 0.042)†	−0.649 (p = 0.022)†

*KED = peak torque of knee extensors dominant leg; KEND = peak torque of knee extensors nondominant leg; KFD = peak torque of knee flexors dominant leg; KFND = peak torque of knee flexors nondominant leg; CSKE = composite scores of knee extensors; CSKF = composite scores of knee flexors; CSKEF = composite scores of knee extensors and flexors; $HI_{\%Dec1st/3rd}$ = decrement (percent) in HI from the highest (first) to the lowest (third) intense 15-minute periods of first half; $HI_{\%Dec4th/6th}$ = decrement (percent) in HI from the highest (fourth) to the lowest (sixth) intense 15-minute periods of second half; $HI_{\%Dec1st/6th}$ = decrement (percent) in HI from the first to the last 15-minute periods; $HI_{\%AvDec1st/3rd-4th/6th}$ = average decrement (percent) from the highest to the lowest intense 15-minute periods (first to third and fourth to sixth) of both halves ($HI_{\%AvDec1st/3rd-4th/6th}$).

† $p < 0.05$.

‡ $p < 0.01$.

instructed to kick and bend the tested leg as hard and as fast as they could through a complete range of motion (from 90° to 0°). The subjects were also instructed to hold their arms comfortably across their chest to further isolate knee joint flexion and extension movements. All the subjects also performed a specific submaximal warm-up protocol on the Biodex device to familiarize with the isokinetic device and test procedure that entailed 3 maximal repetitions at an angular velocity of $90°\cdot s^{-1}$ ($1.57\ rad\cdot s^{-1}$).

The YYIE2 was performed after a 10-minute warm-up consisting of repeated 2 × 20-m runs back and forth between the start and finish lines at a progressively increased speed controlled by audio bleeps from a CD-ROM, according to Bangsbo (5). The initial speed is $11.5\ km\cdot h^{-1}$ (12.5 seconds for 2 × 20 m) and between running bouts the participants have a 5-second rest period. The TD covered during the YYIE2 was considered as the testing score. Heart rate was measured during the YYIE2 and recorded every 5 seconds using a heart rate (HR) monitor (Polar Team System, Polar Electro, Kempele, Finland).

Intraclass correlation coefficients of all the physical fitness tests were estimated using a test-retest procedure, with a random subsample of 8 subjects in each evaluation moment. The intraclass correlation coefficients (R) for all variables were as follows. Height, weight, and fat mass: $0.93 \le R \le 0.99$; CMJ: $0.83 \le R \le 0.88$; sprint time: $0.76 \le R \le 0.87$; agility: $0.75 \le R \le 0.85$; Yo-Yo intermittent: $0.80 \le R \le 0.97$; and isokinetic strength: $0.81 \le R \le 0.98$.

Statistical Analyses

All data were reported as mean and *SD* for each variable. The assumptions of normality were assumed using the Shapiro-Wilks test and Mauchly test, respectively. After these assumptions, analysis of variance for repeated measures was used to determine if there were differences between the different 15- and 5-minute periods within the game, and between the match activity parameters in the different season time points. The Bonferroni test for multiple comparisons was used to identify specific differences between the means in locomotor activities in the different time points. Intraclass correlation coefficient and CV were calculated to estimate the reliability of the physical fitness tests and locomotor parameters, respectively. The *Z* scores were calculated for each test; scores were reversed for the 3 timed items (T5, T30, and Agility) because lower times reflect better performance. The composite scores were determined to provide a more complex operational indicator of physical fitness. Composite scores of performance in muscle power-related (composite scores of power-related test [CSPRT]; T5, T30, Agility, and CMJ) and isokinetic strength tests were calculated and their association with match analysis data was determined. Correlation coefficients (r) were used to determine the association between physical tests, physical tests composite scores, and time-motion data. The SPSS statistical package (version 14.0; Inc., Chicago, IL, USA) was used. Statistical significance was set at $p \leq 0.05$.

Results

Seasonal Variations

Results regarding seasonal variations in the frequency of activity changes, the number of runs in low intensity and in high intensity (FHI), in the TD covered during the game, and in each type of movement during the 2 halves are presented in Tables 1 and 2. The TD in the first 15-minute period was 10, 7, and 17% lower ($p < 0.05$) in E2 than in E1, E3, and E4, respectively, and 11% higher ($p < 0.05$) in E4 than in E3. In the last 15 minutes of the game, the TD was 14 and 8% higher in E4 than in E2 and E3, respectively ($p < 0.01$). The distance covered in HI in the last 15 minutes of the first half of the match in E4 was 49, 37, and 33% higher ($p < 0.05$) than in E1, E2, and E3, respectively. Also, the HI in the last 15-minute period of the game in E4 was 43% higher than in E3 ($p < 0.05$). The sum of the distance covered in the HI in the 2 last 15-minute periods of each half was 36 and 38% higher in E4 than E2 and E3, respectively ($p < 0.05$). The peak 15-minute period of HI was 30, 47, and 43% higher in E4 than in E1, E2, and E3, respectively ($p < 0.05$), whereas the lower 15-minute period of HI during the game was 58, 46, and 41% higher in E4 than E1, E2, and E3, respectively ($p < 0.05$).

Results from the peak distance covered in HI in a 5-minute period (P5-min), in the next 5-minute period (Next5-min), in the remaining 5-minute periods (Av5-min), and the variation of distance covered from P5-min to Next5-min ($\%Dec_{P5-N5}$) are presented in Figure 3. The players covered a higher distance in HI in the P5-min ($p < 0.05$) from E4 than in the remaining P5-min periods of the other time points. Furthermore, in all assessments points of the season, the distance covered in HI was higher in P5-min ($p < 0.05$) than in Next5-min and Av5-min within each assessment period. Moreover, higher ($p < 0.05$) Av5-min values were observed in E4 than in E2 and E3. No significant differences were observed between the distance covered in HI in the Next5-min and Av5-min within the different assessment periods.

Physical Fitness Results

Results of the different physical tests performed within the 2-week period between video-filmed matches are presented in Table 3.

Training Status in Relation to Match Analysis

Time-motion variables showed that the TD and the distance covered in HI for the first and second halves were not significantly different (4,585 ± 265 vs. 4,570 ± 301 m and 632 ± 75 vs. 680 ± 150 m, respectively). The distance covered in HI during the first 15-minute period of each half (first and fourth 15-minute periods of the game) was higher ($p < 0.05$) than in the last 15-minute period of each half (third and sixth periods of the game, respectively; Figure 4). Tables 4 and 5 show the relationship between time-motion variables and the different muscle power-related tests, isokinetic parameters, and tests composite scores, respectively. Performance in sprint tests (T5 and T30) and in the CSPRTs was the physical-related parameters that showed the highest correlations with time-motion variables. The T30 and CSPRT showed significant correlations ($r = 0.622–0.726$) with the distance covered in HI in the 5-minute period of the game after P5-min (Next5-min), with the decrement (%) in HI from P5-min to Next5-min ($\%Dec_{P5/N5}$) and with the distance in sprinting in the second half of the game (SP_{2nd} half; Table 4).

Knee extension peak torque of the nondominant leg showed significant correlations (r ranging from 0.56 to 0.73) with the following time-motion parameters: decrement (percent) in the HI between the highest (fourth) and the lowest (sixth) intense 15-minute periods of the second half ($HI_{\%Dec4th/6th}$), average decrement (percent) in the HI from the highest to the lowest intense 15-minute periods (first to third and fourth to sixth) of both halves ($HI_{\%AvDec1st/3rd-4th/6th}$) and decrement (percent) in HI from the first to the last 15-minute periods ($HI_{\%Dec1st/6th}$) of the game (Table 5). The decrement (%) in HI from the highest to the lowest intense 15-minute periods (first to third and fourth to sixth) of both halves ($HI_{\%AvDec1st/3rd-4th/6th}$) was also correlated ($r = 0.59–0.73$) with knee flexion peak torque of the nondominant leg, and with the composite scores of knee extension (CSKE), knee flexion (CSKF), and knee extension and flexion (CSKEF). The distance covered in the YYIE2 was not correlated with any of the time-motion parameters analyzed.

Discussion

The main findings of this study were that alterations in GPPs of professional soccer players occur during the season and that their training status is related to a greater ability to maintain HI-related performance variables during the match.

Time-motion analysis of the matches performed at different time points of the season showed that the players covered greater total and HI distances in the last quarter of the season (E4; Table 1). Also, it was observed that players were more frequently engaged in HI activities (FHI) during the last quarter of the season (E4; Table 1) than in the remaining season periods (E1, E2, and E3). Although differences in HI match running were only significant from E2 and E3 to E4, the analysis of each match half showed that the players performed more HI in the first half in E4 than in the first halves of the remaining periods (E1, E2, and E3 Table 2). A greater distance in HI was covered in the peak and in the lowest 15-minute periods of the match in E4 than in the corresponding 15-minute periods of the other time points of the season. Moreover, the amount of HI performed in the last 15-minute period of each half, which is indicative of the ability to maintain performance during the game (26), was again higher in E4. In agreement with our findings, others observed that players covered a greater distance in HI at the end than in the middle of the competitive season

(30,42). Although not controlled in this study, an improved physical capacity in the last part of the season could explain, at least in part, our results. In fact, increases in match-related physical performance could be attributed to an improved physical capacity (42). Several studies observed an increase in different physical parameters toward the end of the season (13,21,25,35). Studies involving longitudinal analysis of soccer players' physical capacity throughout the season observed increases in soccer-specific endurance fitness (25,35), repeated-sprint ability (21), speed (13), agility (13), and jump performance (35) toward the end of season. Nevertheless, it is important to note that these findings have not been corroborated by others (14,29).

The performance in a group of physical fitness measures and in a CSPRT (T5, T30, COD, CMJ, and CSPRT) was related to certain time-motion GPPs (Table 3). In fact, players with better T5, T30, COD abilities, and CSPRT showed an increased performance in Next5-min, a lower decrement from P5-min to the Next5-min ($\%Dec_{P5\text{-}N5}$) and achieved higher sprint distances during the second half of the games. These findings suggest that soccer players with improved capacity to perform sport-specific maximal dynamic activities have an increased ability to maintain performance during short periods of high-intensity intermittent exercise and a greater fatigue resistance in the second half of the game. Also, some isokinetic strength parameters (Table 4) and CSKE, CSKF, and CSKEF were correlated with game-related physical performance (Table 5). Relationships were observed between KE and KF muscle strength of the nondominant leg, CSKE, CSKF, and CSKEF and the following fatigue parameters, namely, decrement in HI from the first and to the final 15-minute periods of the game and decrement in HI from the highest to lowest intense 15-minute periods of both halves. These results suggest that greater levels of lower-limb strength are related to a higher ability to maintain performance during games (Table 5). This seems to suggest that players with greater ability to rapidly produce force, allowing fast accelerations and decelerations and to quickly and efficiently perform complex and coordinated movements, are able to perform at high level in certain game-related physical parameters.

Accordingly, some studies showed that strength (16) and sport-specific muscle power evaluated by sprint ability (16) and agility (33) are influenced by the competitive level of the players. Also, high performance levels in jump ability, leg extension strength (3), and in intermittent exercise protocols (43) were observed in players from more successful teams compared with their less successful counterparts.

Rampinini et al. (41) did not observe any relationships between both the best time during a repeated shuttle sprint ability test (RSSA) test ($RSSA_{best}$) and jump ability (squat jump), with different match time-motion variables (TD, HI, very high-intensity running, and sprinting). However, despite the fact that low- to medium-intensity running is the predominant activity during the match, power-based efforts such as sprints, COD and change-of-speed, jumps, duels, and kicking, which are mainly dependent on maximal strength and anaerobic power, are widely accepted as essential factors for success in soccer performance (16). In fact, a massive metabolic load is imposed on players not only during the maximal intensities phases of the game but also every time acceleration occurs, even when speeds are low (36). These speed and direction of movement changes performed during games impose high levels of stress to the involved musculature, thereby affecting energy usage and resulting in a higher physiologic impact than habitual forward movements (18). Indeed, higher $\dot{V}O_2$ (11), blood lactate (11,18), HR (18), and rate of perceived exertion (18) values were observed during high-intensity intermittent exercise during shuttle mode than during in-line format. Some possible reasons could be the involvement of additional muscles, such as upper body muscles (22) and different neuromuscular activation patterns during COD activities (11). At high-speed displacements and during intermittent shuttle running, turning technique becomes more important, and anaerobic power is essential because players might accelerate after turning to reach the desired speed (18). The physiological demands and functional characteristics that are typical of soccer-specific activity patterns may explain the observed correlations found in this study between power-related tests and game-physical parameters.

Fatigue is a complex phenomenon that cannot be simply explained by a single factor (19). The ability to resist fatigue has been related to different functional and physiological features (6,12,19,31). Improvements in coordination specificities (12) and a greater ability to effect COD (19) are positively associated with performance and with an attenuated fatigue response. Indeed, an optimized performance during the game and particularly during the most intense periods would be expected in players with neuromuscular features tuned for the movements performed during the game (15).

Soccer players with greater CSPRT values may have a higher ability to accelerate, decelerate, and effect a COD than the players with lower values, leading to an improved physical capacity. This greater physical capacity may likely offset some of the mechanical and neuromuscular effects of repeated stretch-shortening cycle fatigue (15). For instance, improved training status seems to be related to the higher ability to regulate joint stiffness more efficiently during exposure to maximal intensity repeated sprints (15).

As games progress, some examples of game-induced fatigue are the reductions in concentric (4,28,40) and eccentric muscle strength (40), and in electromyography activity (39) of the major lower-limb muscles. Game-induced performance decrements are also evident in players' decreased ability to perform certain strength-dependent actions such as sprint (4,28,32) and jump (4,28). In accordance, players' fatigue reflected in reduced electrical activity of muscles and in compromised strength toward the final periods of the match may cause a lower work-rate toward the end of a soccer match (39,40). Moreover, because each specific game action requires breaking and propulsive forces, the importance of the strength and endurance capacities of leg muscles likely increases as the game progresses (10,11). Thus, strength decrements during the game could affect the performance of explosive actions such as jumping, sprinting and CODs, which require high quadriceps strength at the initiation of movement when the joint extension velocity is low (40). It is plausible to assume that soccer players with higher levels of strength have greater ability to maintain strength toward the final stages of each half of the game than players with less strength and thus show a lower decrement in work rates.

Data suggest that the athletes' ability to exercise during longer periods of time is usually related to their endurance capability (e.g., anaerobic threshold, $\dot{V}O_2$max). Nevertheless, improved endurance is also influenced by factors related to muscle recruitment and force production (37,38). It was recently observed that distance running performance and running economy of well-trained distance runners are related to the neuromuscular capacity to produce force (34). Also, improvements in soccer players' maximal strength resulting from training and neural adaptations lead to improved running economy by 4.7%, at both the lactate threshold and a fixed velocity in a treadmill test (20). Rapid force production is considered essential for a wide range of athletes (20,34), with recent reports highlighting that an enhancement in neuromuscular function can be a determinant in improving short- and long-term endurance capacities (1). In fact, there is a consensus that training-related improvements in motor unit recruitment and synchronization result in force potentiation, improving efficiency and coordination, which may delay the onset of fatigue (17,37,38).

In summary, this study gives empirical support to the neuromuscular parameters measured by sprint, COD, jump ability, strength parameters, and their composite scores as indicators of physical performance of soccer players during games. However, it is important to refer that moderate correlations do not affirm a direct cause and effect (41). Indeed, it should be considered that although data from laboratory and field tests are useful in providing information on the players' general physical profile and soccer-specific fitness, test results should not be used to predict the overall performance during match play because of the complex nature of the demands of the game (47).

Practical Applications

Our results highlight the importance of strength and power for soccer players. In fact, this study reports an association between muscle strength and power and performance decrements in game-related physical parameters. Thus, the soccer players' training should incorporate specific exercise programs to improve the athletes' strength and power during the performance of soccer-specific activities. Also, the regular evaluation of the capacity of the players' neuromuscular system to produce force and to perform powerful specific sport activities (e.g., sprint, COD) is advised. In fact, athletes need to successfully perform over competitive seasons of around 10–11 months and, according to our results, these functional qualities of players' physical fitness seem to be associated with their physical performance during games. Interventional studies designed to analyze the relationship between improvement in these physical parameters (e.g., strength, power, COD), and enhanced game-related physical parameters are warranted.

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