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ABSTRACT: This study examined the most demanding passages of match play (MDP) and the effects of playing formation, ball-in-play (BiP) time and ball possession on the 1-min peak (1-min$_{peak}$) demand in elite soccer. During 18 official matches, 305 individual samples from 223 Italian Serie A soccer players were collected. MDP and 1-min$_{peak}$ were calculated across playing position (central defenders, wide defenders, central midfielders, wide midfielders, wide forwards and forwards). Maximum relative (m·min^{-1}) total distance (TD), high-speed running (HSR), very high-speed running (VHSR), sprint (SPR), acceleration/deceleration (Acc/Dec), estimated metabolic power (P_{met}) and high-metabolic load (HML) distance were calculated across different durations (1–5, 10, 90 min) using a rolling method. Additionally, 1-min$_{peak}$ demand was compared across playing formation (3-4-1-2, 3-4-2-1, 3-5-2, 4-3-3, 4-4-2), BiP and ball/no-ball possession cycles. MDP showed *large* to *very-large* [effect-size (ES): 1.20/4.06] differences between 1-min$_{peak}$ vs all durations for each parameter. In 1-min$_{peak}$, central midfielders and wide midfielders achieved greater TD and HSR (ES:0.43/1.13) while wide midfielders and wide forwards showed greater SPR and Acc/Dec (ES:0.30/1.15) than other positions. For VHSR, SPR and Acc/Dec 1-min$_{peak}$ showed fourfold higher locomotor requirements than 90-min. 1-min$_{peak}$ for Acc/Dec was highest in 4-3-3 for forwards, central and wide midfielders. 1-min$_{Peak}$ was lower during peak BiP (BiP$_{peak}$) for HSR, VHSR and Acc/Dec (ES: -2.57/-1.42). Comparing with vs without ball possession, BiP$_{peak}$ was greater (ES: 0.06/1.48) in forwards and wide forwards and lower (ES: -2.12/-0.07) in central defenders and wide defenders. Positional differences in MDP, 1-min$_{peak}$ and BiP$_{peak}$ were observed. Soccer-specific drills should account for positional differences when conditioning players for the peak demands. This may help practitioners to bridge the training/match gap.

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INTRODUCTION

Over the recent years, the quantification of team sports physical demands has become crucial for determining the differences between training and match loads and for leading the performance development towards evidence-based practice [1, 2]. In soccer, quantification of the physical demands using different tracking technologies (e.g. global positioning system, semi-automatic video-analysis, etc.) is used currently to determine the training and/or match locomotion activities [3]. In practice, the activities recorded during the matches are used to plan the training workload and as a reference for soccer-specific drills (e.g. small-sided games or technical drills) [1, 2, 4]. The running performance analysis allows quantification of the total distance (TD), the distance covered at different running speed [5] and the distance covered while accelerating/decelerating (Acc/Dec) [6]. Moreover, the calculation of the average metabolic power (P_{met}) or the high-metabolic activities (e.g. distance covered > 20 W·Kg^{-1}) was also proposed to estimate the match energy expenditure [7]. Despite the P_{met} model having been questioned due to underestimation of the actual net energy demand during soccer-specific exercises [8, 9], some authors reported P_{met} as a useful tool for the classification of the locomotion intensity in team sports [7]. Therefore, a combination of the P_{met} approach and the traditional speed-threshold metrics can be used to provide a more comprehensive assessment of the intermittent running demands typically occurring in team sports [1, 7, 10]. Interestingly, differences in match locomotion activities have been observed across playing positions (e.g. defenders, midfielders and forwards) [5], formations (e.g. 4-4-2, 4-3-3, etc.) [11] and competitive levels (e.g. elite vs sub-elite) [12]. Contextualizing these factors could help practitioners to tailor the training activities for each player.

Although the most common time-motion analysis has been focused on fixed periods of 90-min [5], 15-min [12] and 5-min [13] match demands, the rolling method was subsequently suggested to avoid underestimation in 5-min [14] match demands. Recently attention has been focused on the most demanding passages of match play (MDP) over different lengths of time (e.g. 1 to 10 min) [15–17]. During the training process, the relative whole-match running distances fail to fully account for the worst-case scenario that occurs during official matches [14] and it may be responsible for underpreparing players for the MDP [16, 18]. Hence, recreating the MDP during the training sessions allows the players to be conditioned for the maximal demands of competition, which is not taken into account when analysing the average player's match demands only [19, 20]. Therefore, the use of a rolling average method, where distance is divided into set intervals from every time point sampled, could be a more appropriate method when quantifying the running intensity periods in team sports [14, 21]. This approach helps practitioners to plan the locomotor activities during soccer-specific drills (e.g. small- or large-sided games, positional drills) in accordance with MDP [2, 20, 22]. Recently, some studies have described the MDP in different team sports, such as rugby [18], Gaelic football [23], hurling [24] and soccer [17]. In elite soccer, the MDP during official matches were investigated in French Ligue 1 [2], English Championship [17] and reserve squad Spanish La Liga [6, 15] soccer players. However, no information about the other major European National soccer leagues (Italian Serie A, German Bundesliga, etc.) is currently available.

The intermittent nature of soccer is characterized by high-intensity interspersed with low-intensity running activities and game interruptions (i.e. when the ball is out of play,) [25, 26]. For example, an average of ~54 to ~57 min ball-in-play (BiP) time across the whole match time was observed in Italian Serie A, French Ligue 1, German Bundesliga, FIFA World Cup and UEFA Euro tournaments [25, 26]. It was suggested that a player's match-play demands which include ball out-of-play time may underestimate the highest intensity of competitions [20, 21]. Indeed, the total distance covered with ball possession [27] and tactical behaviours [28] are some of the main key factors for success in soccer performance. Therefore, BiP cycles are considered more appropriate for designing training sessions to prepare players for the MDP [20, 21]. Recently, the MDP during BiP for TD, high-speed running, accelerating/decelerating and high-metabolic load distance were suggested to gain maximal physical-performance development [20]. To date, only one study has reported the MDP during BiP in academy players [20] and investigations about the MDP during BiP and with or without ball possession in elite soccer players are still lacking. Knowledge of the MDP with or without ball possession would be of great interest to prescribe sport-specific drills improving tactical behaviour both for offensive and/or defensive phases, as well as to develop physical performance.

Therefore, the current study aimed to describe the positional MDP across different durations and to assess the effects of playing formations, BiP and ball possession on the positional 1-min peak demands in Italian Serie A soccer players.

MATERIALS AND METHODS

Participants

Two-hundred and twenty-three (*n = 223*) Italian Serie A soccer players were monitored during matches across the 2018–2019 season. Within each match, the players were classified according to playing position, resulting in the following number of data sets per position: central defenders (*n = 69*), wide defenders (*n = 27*), central midfielders (*n = 83*), wide midfielders (*n = 44*), wide forwards (*n = 34*), and forwards (*n = 48*). Particularly, a given player was analysed in the position he actually played in that game. Goalkeepers were not included in the analysis. A total of *n* = 305 individual samples were collected. The number of individual matches varied from home players [*n* = 15.5(1.9), *range:* 17-10)] to opposite players [*n* = 1.2(0.5), *range:* 3-1)] and for playing position: central defenders [*n* = 2.0(3.3), *range:* 13-1)], wide defenders [*n* = 2.0(1.0), *range:* 3-1)], central midfielders [*n* = 1.8(3.1), *range:* 15-1)], wide midfielders [*n* = 3.4(5.0), *range:* 14-1)], wide forwards [*n* = 2.4(4.0), *range:* 14-1)], and forwards [*n* = 1.5(2.2), *range:* 14-1)]. The present data arose from the daily player monitoring in which players' activities are routinely measured over the course of the season. Therefore, an Ethics Committee clearance was not required [29]. The study nevertheless conformed to the recommendations of the Declaration of Helsinki.

Design

Data were collected during 18 official home matches in the same stadium from both home and opposition players at each match. The same stadium was used to avoid possible bias due to the placement of different tracking systems in different stadia, possibly influencing the data. A semi-automatic tracking system (Stats Perform, Chicago, Illinois, USA) was used to quantify players' running performance. The validity and reliability of this system have been previously established [3]. However, the interclass correlation coefficient (ICC) for each dependent parameter was calculated.

Procedures

Following the completion of each match (~90 min), each file was trimmed so that only data recorded when the player was on the field for at least 85 min were included for further analysis. Data were loaded on a dedicated platform (K-sport, Montelabbate, PU, Italy) and then exported into a customized Microsoft Excel spreadsheet (Microsoft, Redmond, USA). A customized spreadsheet was used to allow analysis of relative distance covered ($m \cdot min^{-1}$) in the following categories: total distance (TD), high-speed running distance (HSR, 15 to 20 $km \cdot h^{-1}$), very high-speed running distance (VHSR, 20 to 24 $km \cdot h^{-1}$), sprint distance (SPR, > 24 $km \cdot h^{-1}$), and distance with variations in running speed > 3 $m \cdot s^2$ (acceleration/deceleration, Acc/Dec). The average estimated metabolic power (P_{met}) and the high metabolic load distance (HML, > 20 $W \cdot kg^{-1}$) were also calculated [6, 7]. To assist in the development of velocity-based movement indicators, rolling moving averages were calculated across six different durations (1, 2, 3, 4, 5, 10 min) for each player across each match with the maximum value collected for each specific duration recorded [15, 16, 22, 23]. To compare with the traditional metrics analysis, the distances over the whole match (~90 min) was recorded and inserted into the data analysis. The 1-min peak (1-min$_{peak}$) demands were classified according to the team playing formation both for home and opposition players, resulting in the following number of matches per formation: 3-4-1-2 (n = 17), 3-4-2-1 (n = 11), 3-5-2 (n = 13), 4-3-3 (n = 7), 4-4-2 (n = 4) [11]. Moreover, 1-min$_{peak}$ for TD, HSR, VHSR and Acc/Dec were analysed also for the net time with BiP (i.e. the time in which play is ongoing prior to the ball exiting the pitch or the referee stopping play) [20]; the time with any interruptions during the match was excluded (e.g. ball out of the playing area, goals, fouls, injuries or any other interruption over the match) [20]. Lastly, 1-min$_{peak}$ was calculated during BiP periods (BiP$_{peak}$) with vs without ball possession. The match-to-match variability for the home-team soccer players was also calculated for relative TD, HSR, VHSR, SPR and Acc/Dec both for the 1-min$_{peak}$ and the whole match (90 min).

Statistical analysis

SPSS (version 26, Chicago, IL, USA) was used to perform the statistical analysis. Intra-class coefficient (ICC) was calculated for each dependent parameter and interpreted as follow: < *0.50: small,* 0.50–0.69: *moderate, 0.70*-0.89: *large*, > 0.90: *very large*. A linear mixed models analysis was used to compare the effects of position (i.e. central defenders, wide defenders, central midfielders, wide midfielders, wide forwards, and forwards) x duration (i.e. 1, 2, 3, 4, 5, 10, 90 min) on the dependent parameters [30]. Furthermore, position x playing formation x ball possession interaction was also calculated to detect the differences in 1-min$_{peak}$ for each dependent parameter [30]. BiP cycles were also analysed across players' positions. The model used for each dependent parameter was with position, formation and ball possession as independent fixed factors and random intercepts on the individual players. A log-likelihood ratio test was used to assess the goodness of fit of the models. Bonferroni's correction was used for multiple comparison analysis. Between-matches coefficient of variation (CV) values were calculated for 1-min$_{peak}$ and the whole match (90-min) demands for TD, HSR, VHSR, SPR, Acc/Dec. Cohen's d effect size (ES) with 95% confidence intervals (CI) was used to describe the magnitude of the pairwise differences and interpreted as follows: < 0.20: *trivial*; 0.20–0.59: *small*; 0.60–1.19: *moderate*; 1.20-1.99: *large*; ≥ 2.00: *very large* [31]. Statistical significance was set at $\alpha < 0.05$. Unless otherwise stated, all values are presented as mean (SD) as reported using descriptive statistics.

RESULTS

The ICC was *very large* for TD [ICC: 0.740 (0.450/0.920)], *moderate* for HSR [ICC: 0.624 (0.450/0.920)], VHSR [ICC: 0.561 (0.250/0.720)], Acc/Dec [ICC: 0.684 (0.410/0.880)] and *small* for SPR [ICC: 0.438 (0.150/0.620)].

The most demanding passages of play between durations and positions

Position x duration interaction was found for TD ($F_{5, 140}$ = 4.069, P = 0.001), HSR ($F_{5, 140}$ = 17.011, P < 0.001), VHSR ($F_{5, 140}$ = 3.630, P = 0.003), SPR ($F_{5, 140}$ = 2.397, P = 0.038), Acc/Dec ($F_{5, 140}$ = 2.516, P = 0.028), P_{met} ($F_{5, 140}$ = 5.228, P < 0.001) and HML ($F_{5, 140}$ = 7.022, P < 0.001). Table 1 shows the maximal locomotor demands for each duration (1 to 5, 10, 90 min). For each variable and position as the time-dependent period decreases, an increase in maximal relative locomotor demand was found. Within 1-min$_{peak}$, wide midfielders covered greater (P < 0.05) maximum relative TD [198(19) m·min^{-1}], VHSR [41(14) m·min^{-1}], SPR [49(17) m·min^{-1}], Acc/Dec [35(4) m·min^{-1}], P_{met} [22(8) m·min^{-1}]

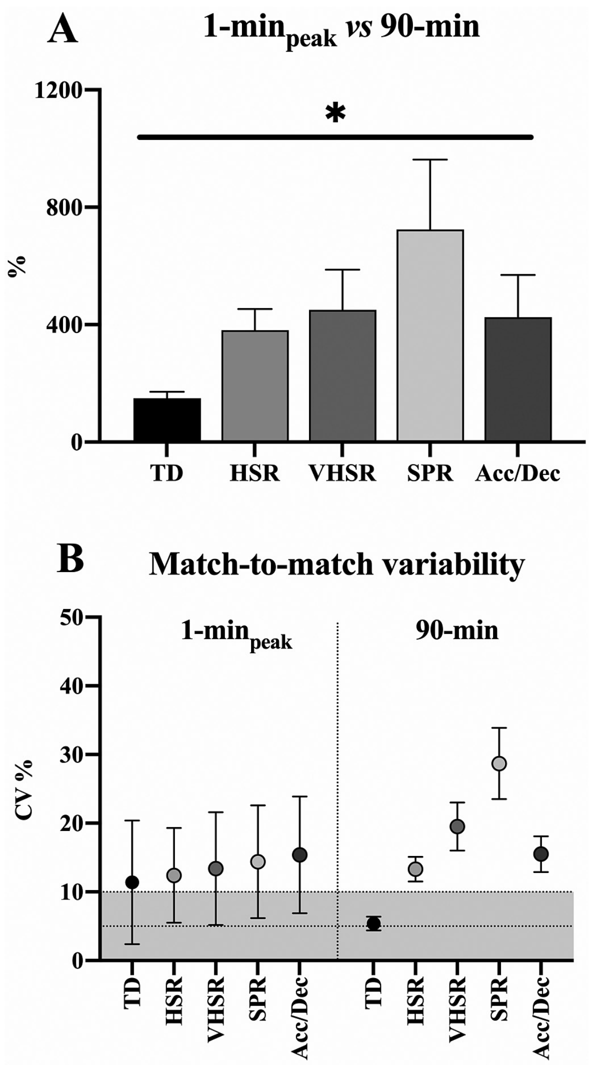

FIG. 1. The 1-min$_{peak}$ as percentage of the whole-match demands (90-min) (Panel A) and the match-to-match variability for both 1-min$_{peak}$ and 90 min (Panel B) are shown for total distance (TD), high-speed running distance (HSR), very high-speed running distance (VHSR), sprint distance (SPR) and acceleration/deceleration distance (Acc/Dec).
Note: *P < 0.05 vs other metrics.

TABLE 1. The most demanding passage of match play for each position during official matches for different time duration (1, 2, 3, 4, 5, 10, 90-min). All data are reported as average (SD). 95% confidence intervals of the effect size were shown for the differences between 1-min vs all other time durations (horizontal direction).

		1-min	2-min	3-min	4-min	5-min	10-min	90-min	ES (95% CI)
TD	FW	177.2 (38.3)[a]	148.0 (33.8)[a]	139.1 (29.5)[a]	132.0 (31.3)[a]	129.4 (29.5)[a]	107.9 (42.8)[a]	105.4 (3.6)[ab]	0.80 to 2.62
	WF	190.5 (18.6)	160.2 (13.4)	149.9 (12.4)	142.9 (12.0)	138.1 (9.8)	126.0 (15.2)	119.5 (6.4)[ab]	1.84 to 5.05
	CM	197.5 (27.1)	168.0 (27.6)	155.5 (24.1)	149.9 (25.6)	145.2 (23.5)	130.0 (32.7)	133.9 (5.7)	1.07 to 3.23
	WM	197.6 (18.5)	167.4 (17.9)	156.6 (14.1)	147.5 (22.6)	143.1 (19.0)	125.6 (36.6)	135.6 (6.8)	1.64 to 4.41
	CD	180.7 (29.6)[a]	150.9 (27.7)[a]	141.3 (23.3)[a]	136.3 (25.7)[a]	132.7 (22.9)[a]	121.3 (28.4)	126.9 (7.1)	1.03 to 2.49
	WD	186.9 (26.7)	157.1 (27.0)[a]	144.4 (20.9)	140.2 (23.1)	136.2 (20.9)	121.4 (30.0)	132.9 (5.0)	1.09 to 2.77
	Avg	188.4 (25.5)	158.6 (23.9)	147.8 (20.2)	141.5 (22.5)	137.5 (42.7)	122.0 (28.6)	125.7 (7.3)	1.20 to 3.34
HSR	FW	48.1 (21.3)[abc]	23.1 (13.2)[a]	18.3 (17.4)[a]	19.5 (13.3)[a]	12.9 (6.0)[a]	12.9 (3.3)[ab]	11.8 (3.8)[ab]	1.40 to 2.35
	WF	58.0 (19.2)[d]	28.5 (9.6)	25.7 (14.2)	24.4 (10.6)	20.8 (5.3)	14.5 (3.2)a	14.9 (4.6)a	1.89 to 3.12
	CM	68.4 (19.2)	36.3 (11.8)	35.6 (16.3)	32.4 (11.5)	27.4 (5.0)	20.8 (4.0)	20.9 (4.3)	1.83 to 4.42
	WM	67.9 (19.7)	34.6 (13.4)	33.9 (17.4)	31.7 (14.2)	26.3 (6.1)	22.5 (4.6)	20.6 (4.0)	1.81 to 3.30
	CD	49.6 (21.9)[abc]	22.7 (10.7)[abc]	18.4 (14.3)[abc]	18.4 (11.8)[abc]	17.3 (6.5)[a]	11.5 (3.3)[ab]	10.9 (4.4)[ab]	1.55 to 2.44
	WD	56.0 (18.6)[ad]	26.0 (13.9)[a]	23.9 (19.3)[a]	21.3 (14.1)[a]	18.9 (5.8)	12.5 (3.4)[ab]	12.7 (3.9)[ab]	1.66 to 3.19
	Avg	58.0 (17.5)	28.5 (12.1)	26.0 (16.5)	24.6 (12.6)	20.6 (5.8)	15.8 (2.7)	15.2 (3.3)	1.94 to 3.81
VHSR	FW	34.2 (12.8)	21.5 (8.2)[a]	16.3 (5.7)	13.7 (5.2)	12.2 (4.6)	8.6 (4.0)	5.6 (0.8)[ab]	1.17 to 3.13
	WF	38.8 (7.8)	22.3 (5.5)	17.7 (3.8)	14.4 (3.6)	13.0 (3.2)	9.8 (2.5)	7.5 (0.9)	2.42 to 5.57
	CM	39.4 (11.6)	24.2 (8.1)	18.6 (5.2)	15.8 (4.8)	13.8 (4.0)	9.6 (3.4)	9.4 (1.3)	1.51 to 3.62
	WM	40.8 (13.5)	25.2 (9.2)	19.6 (5.8)	16.9 (6.0)	14.9 (4.6)	10.7 (4.3)	10.7 (1.3)	1.34 to 3.11
	CD	33.7 (11.2)[ab]	19.2 (6.6)[ab]	15.1 (4.7)[ab]	12.5 (4.1)[ab]	11.2 (3.5)	7.7 (2.7)	7.4 (1.1)	1.57 to 3.29
	WD	37.3 (12.5)	21.6 (7.9)[a]	16.9 (5.6)	13.5 (4.5)	12.4 (4.1)	8.7 (3.6)	9.3 (0.6)	1.48 to 3.12
	Avg	37.4 (11.5)	22.3 (7.3)	17.4 (5.2)	14.5 (4.6)	12.9 (5.2)	9.2 (3.3)	8.3 (1.4)	1.56 to 3.55
SPR	FW	37.7 (19.0)[b]	21.0 (11.2)	16.0 (8.1)	13.0 (7.5)	11.3 (6.1)	6.7 (4.2)	4.5 (0.8)[ab]	1.06 to 2.45
	WF	46.3 (14.4)	26.7 (9.4)	18.7 (6.7)	15.9 (6.0)	13.1 (4.7)	8.2 (3.2)	5.8 (0.8)	1.59 to 3.93
	CM	40.3 (16.5)	22.5 (9.5)	16.0 (6.9)	13.1 (5.6)	11.4 (5.0)	7.1 (3.3)	6.0 (1.2)	1.32 to 2.92
	WM	48.5 (16.7)[d]	27.3 (9.5)	20.3 (7.9)	16.4 (5.8)	14.7 (5.7)	9.2 (4.4)	7.2 (1.2)	1.55 to 3.46
	CD	35.6 (14.9)[b]	19.4 (8.5)	14.4 (6.4)	11.3 (5.0)	9.7 (4.0)	5.8 (2.6)	5.1 (1.0)	1.33 to 2.87
	WD	43.7 (14.5)[d]	23.0 (8.9)	17.9 (7.4)	13.7 (5.7)	11.3 (5.1)	7.0 (3.3)	6.4 (0.5)	1.70 to 3.58
	Avg	42.0 (15.8)	23.3 (9.3)	17.2 (6.9)	13.9 (5.8)	11.9 (5.7)	7.3 (3.3)	5.8 (1.2)	1.44 to 3.22
Acc/Dec	FW	29.3 (4.7)[ae]	17.2 (2.9)	14.2 (2.3)	11.5 (1.9)	10.8 (1.7)	7.3 (1.6)	6.5 (0.7)[b]	3.07 to 6.73
	WF	33.1 (3.8)	21.1 (2.4)	15.9 (1.7)	13.5 (1.3)	12.0 (1.1)	8.4 (0.9)	6.4 (0.7)[b]	3.73 to 9.66
	CM	30.7 (4.2)[d]	18.2 (2.4)	14.5 (1.9)	12.2 (1.5)	11.3 (1.5)	7.9 (1.2)	7.6 (0.9)	3.64 to 7.57
	WM	34.6 (4.4)	20.7 (2.7)	16.8 (2.0)	13.7 (1.9)	12.5 (1.4)	9.1 (1.6)	9.6 (1.2)	3.77 to 7.68
	CD	31.4 (4.2)[a]	18.4 (2.5)	14.5 (2.0)	11.7 (1.6)	10.7 (1.5)	7.3 (1.1)	7.6 (0.9)	3.74 to 7.79
	WD	32.5 (4.6)[d]	19.7 (2.6)	15.2 (1.9)	12.7 (1.6)	11.4 (1.6)	8.1 (1.3)	7.0 (0.5)	3.38 to 7.68
	Avg	31.9 (7.0)	19.2 (4.0)	15.2 (3.0)	12.6 (2.4)	11.5 (2.6)	8.0 (1.6)	7.5 (1.1)	2.22 to 4.86
P_{met}	FW	19.4 (3.7)[d]	15.5 (3.1)[a]	14.4 (2.7)	13.4 (2.6)[a]	10.7 (5.5)[abcd]	11.1 (3.4)[a]	10.4 (0.5)[ab]	1.13 to 3.38
	WF	20.0 (2.3)	16.2 (1.7)	14.8 (1.4)	14.1 (1.2)	12.8 (3.2)	12.1 (1.6)	10.2 (0.6)[ab]	1.86 to 5.76
	CM	21.1 (3.7)	17.3 (2.2)	15.9 (1.7)	15.1 (1.9)	13.3 (4.5)	12.9 (2.5)	11.6 (0.6)	1.24 to 3.57
	WM	21.7 (8.1)	17.4 (4.5)	16.0 (3.1)	14.8 (2.9)	13.2 (4.4)	12.7 (3.1)	11.7 (0.7)	0.65 to 1.72
	CD	19.3 (3.5)[abc]	15.5 (2.5)[a]	14.3 (2.3)[a]	13.6 (2.2)[a]	12.8 (3.1)	11.9 (2.4)	10.4 (0.6)	1.24 to 3.52
	WD	19.9 (3.3)	15.7 (3.2)[a]	14.3 (2.4)[a]	13.6 (2.7)[a]	12.3 (4.3)	11.6 (3.4)[a]	10.4 (0.7)	1.27 to 3.92
	Avg	20.2 (4.1)	16.3 (2.9)	15.0 (2.3)	14.1 (2.3)	12.5 (4.2)	12.1 (2.7)	10.8 (0.5)	1.10 to 3.21
HML	FW	85.5 (23.3)[ab]	59.5 (16.6)[ab]	51.6 (13.2)[a]	45.9 (12.8)[a]	35.8 (20.1)[abc]	34.6 (12.6)[a]	28.0 (2.9)[ab]	1.27 to 3.43
	WF	93.8 (16.5)[d]	66.0 (11.8)[d]	56.2 (9.4)	50.7 (8.5)	43.9 (12.7)	38.8 (7.6)	29.0 (3.1)[ab]	1.92 to 5.40
	CM	102.6 (17.1)	75.3 (14.1)	63.9 (10.4)	58.8 (10.9)	50.3 (18.3)	45.5 (10.6)	36.6 (3.3)	1.73 to 5.33
	WM	102.9 (20.7)	74.6 (16.2)[d]	64.2 (12.8)[d]	57.4 (12.7)	49.9 (18.0)	44.8 (12.4)	37.8 (4.1)	1.51 to 4.32
	CD	87.8 (20.2)[abc]	60.0 (13.2)[a]	51.7 (11.0)[ac]	46.3 (10.0)[a]	41.9 (11.6)[a]	36.4 (8.9)[a]	27.3 (2.9)[ab]	1.62 to 4.17
	WD	91.5 (24.0)[ad]	64.6 (17.1)[a]	54.1 (12.8)[a]	49.4 (12.6)[a]	42.8 (16.3)	37.7 (12.5)[a]	29.8 (2.7)[ab]	1.27 to 3.56
	Avg	94.0 (20.3)	66.7 (14.9)	57.0 (11.6)	51.4 (11.3)	44.1 (16.2)	39.6 (10.8)	31.4 (2.3)	1.53 to 4.33

Abbreviations: TD, maximum relative total distance; HSR, high-speed running distance; VHSR, very high-speed running distance; SPR, sprint distance; Acc/Dec, and distance with velocity changes calculated using > 3 $m \cdot s^{-2}$ accelerations and decelerations; P_{met}, average metabolic power; HML, high-metabolic load distance (> 20 $W \cdot kg^{-1}$). FW, forwards; WF, wide-forwards; CM, central-midfielders; WM, wide-midfielders; CD, central-defenders; WD, wide-defenders. [a] $P < 0.05$ *vs* CM; [b] $P < 0.05$ *vs* WM; [C] $P < 0.05$ *vs* WF; [d] $P < 0.05$ vs CD.

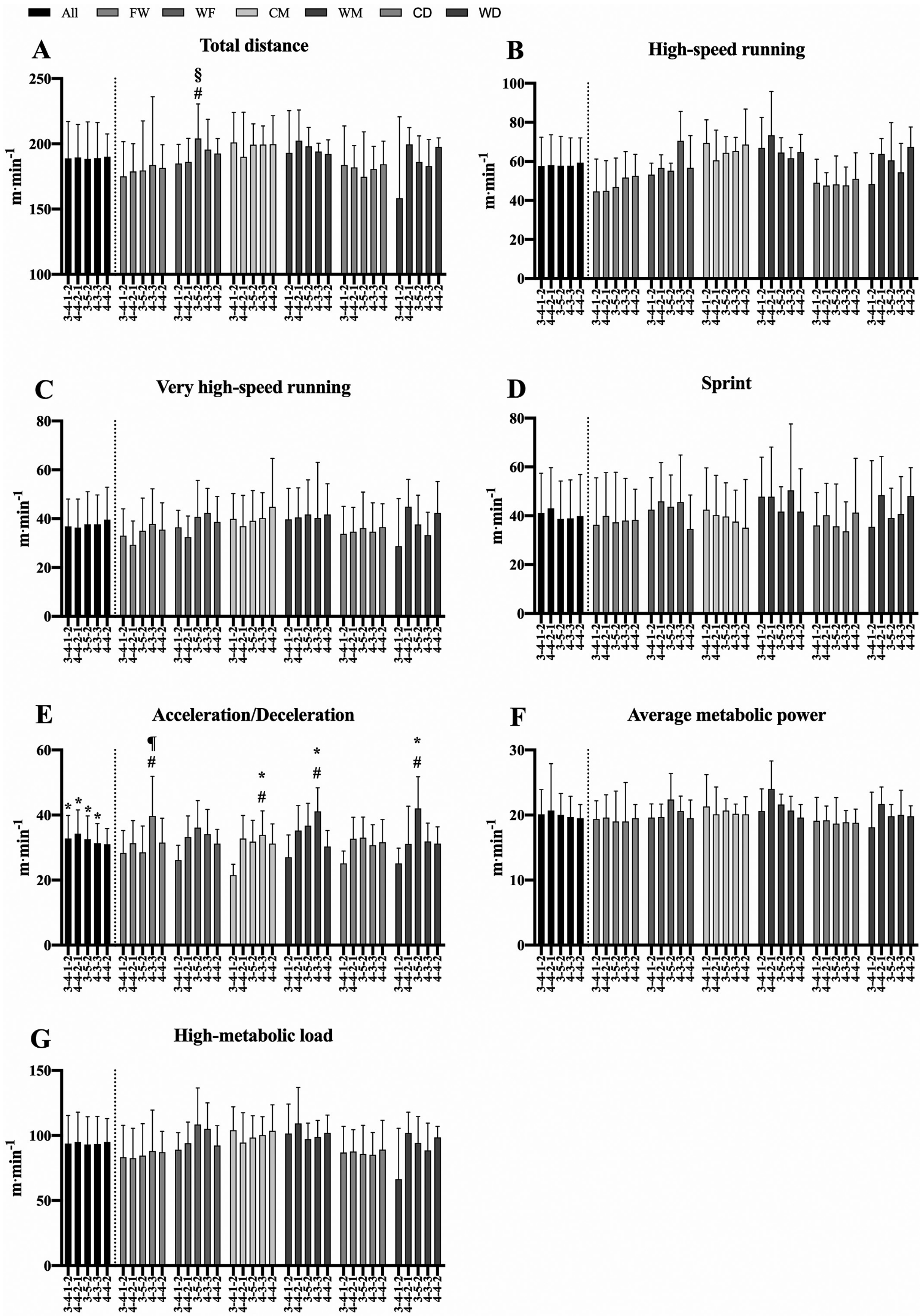

FIG. 2. Differences in 1-min$_{peak}$ for each position within different formations are shown for all players (All), forwards (FW), wide forwards (WF), central midfielders (CM), wide midfielders (WM), central defenders (CD), wide defenders (WD). Total distance (Panel A), high-speed running (B), very high-speed running (C), sprint distance (D), acceleration/deceleration distance (E), average metabolic power (F), high-metabolic load (G).

Note: *P < 0.05 vs 4-4-2; #P < 0.05 vs 3-4-1-2; §P < 0.05 vs 3-4-2-1; ¶P < 0.05 vs 3-5-2.

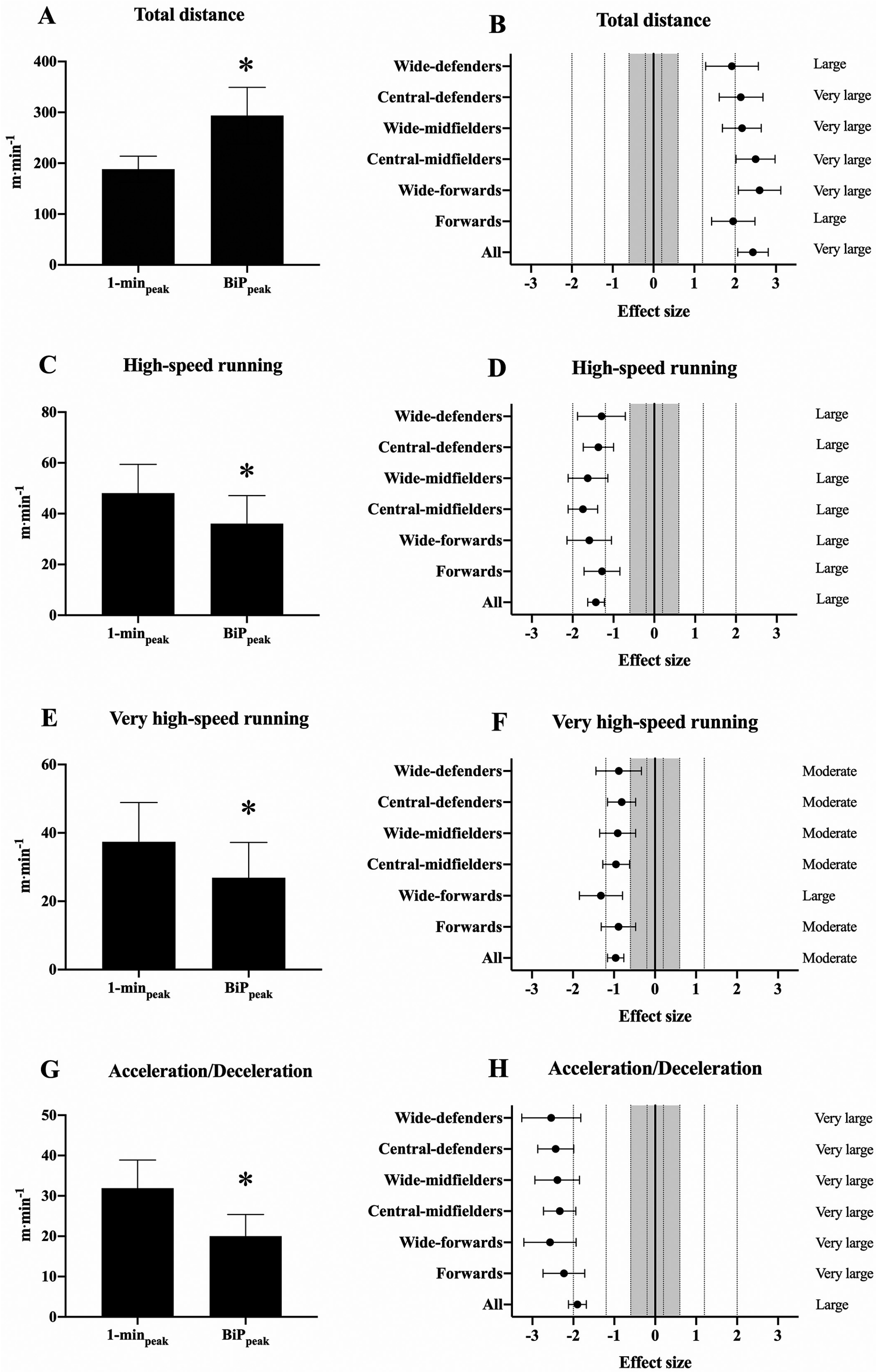

FIG. 3. Differences between the 1-min$_{peak}$ and the most demanding passage of play during effective time with ball in play (BiP$_{peak}$) are shown (Panels A, C, E, G).
Note: The effect sizes with 95% confidence intervals are shown for the differences between BiP$_{peak}$ and 1-min$_{peak}$ (Panels B, D, F, H) for each position. The shaded area, spanning -0.6 to 0.6, represents nonmeaningful effect sizes. Total distance (Panels A-B), high-speed running distance (C-D), very high-speed running distance (E-F), acceleration and deceleration distance (G-H). *$P < 0.05$ vs 1-min$_{peak}$.

TABLE 2. The peak with ball-in-play with or without ball-possession for each position during official matches. Data are reported as mean (SD). Effect size (ES) and 95% confidence intervals (CI) were shown for the differences between ball-possession and no ball-possession (horizontal direction).

		Ball-possession	No ball-possession	ES (95% CI)
Duration	Time (s)	51.6 (4.4)	49.2 (5.4)	ES: 0.49, CI: 0.30 to 0.67
Total distance	All players	294.6 (64.6)	293.1 (61.0)	ES: 0.02, CI: -0.28 to 0.33
	Forwards	300.8 (82.3)	262.2 (67.4)*	ES: 0.50, CI: 0.06 to 0.95
	Wide-forwards	316.3 (60.4)	281.3 (49.1)*	ES: 0.63, CI: 0.22 to 1.04
	Central-midfielders	304.0 (53.1)	308.8 (56.5)	ES: -0.09, CI: -0.45 to 0.28
	Wide-midfielders	300.5 (65.2)	305.2 (61.7)	ES: -0.07, CI: -0.45 to 0.30
	Central-defenders	263.3 (61.7)	306.4 (63.6)*	ES: 0.68, CI: -1.14 to -0.23
	Wide-defenders	283.0 (65.2)	294.4 (67.7)	ES: -0.17, CI: -0.70 to 0.37
High-speed running	All players	34.2 (11.2)	38.1 (10.3)	ES: -0.37, CI: -0.56 to -0.18
	Forwards	32.9 (9.4)	28.9 (7.2)*	ES: 0.47, CI: 0.07 to 0.88
	Wide-forwards	42.2 (7.8)	32.3 (11.8)*	ES: 0.98, CI: 0.48 to 1.48
	Central-midfielders	41.3 (7.9)	41.0 (8.1)	ES: 0.04, CI: -0.27 to 0.34
	Wide-midfielders	42.0 (9.5)	42.2 (10.0)	ES: -0.02, CI: -0.44 to 0.40
	Central-defenders	23.0 (8.3)	37.7 (8.6)*	ES: -1.73, CI: -2.12 to -1.34
	Wide-defenders	28.7 (10.4)	39.2 (10.4)*	ES: -0.99, CI: -1.56 to -0.43
Very high-speed running	All players	25.6 (10.2)	28.2 (10.4)	ES: -0.25, CI: -0.07 to -0.44
	Forwards	24.3 (10.0)	23.0 (11.1)	ES: 0.12, CI: -0.28 to 0.52
	Wide-forwards	30.5 (9.3)	24.0 (9.5)*	ES: 0.68, CI: 0.19 to 1.17
	Central-midfielders	25.9 (11.1)	31.7 (10.3)	ES: -0.54, CI: -0.85 to -0.23
	Wide-midfielders	29.6 (10.6)	29.7 (10.5)	ES: -0.01, CI: -0.43 to 0.41
	Central-defenders	20.5 (9.8)	29.5 (10.2)*	ES: -0.89, CI: -1.24 to -0.54
	Wide-defenders	22.6 (10.3)	31.3 (10.8)*	ES: -0.81, CI: -1.37 to -0.26
Acceleration/deceleration	All players	20.0 (5.7)	19.9 (5.1)	ES: 0.02, CI: -0.17 to 0.20
	Forwards	18.8 (4.7)	16.9 (6.0)	ES: 0.35, CI: -0.05 to 0.75
	Wide-forwards	22.9 (6.4)	18.6 (4.6)*	ES: 0.76, CI: 0.27 to 1.26
	Central-midfielders	19.5 (5.2)	20.4 (4.6)	ES: -0.18, CI: -0.49 to 0.12
	Wide-midfielders	23.7 (6.4)	20.8 (5.1)*	ES: 0.50, CI: 0.07 to 0.92
	Central-defenders	17.8 (5.2)	21.6 (5.4)*	ES: -0.71, CI: -1.06 to -0.37
	Wide-defenders	17.2 (6.0)	21.3 (5.2)*	ES: -0.72, CI: -1.27 to -0.17

Note: * $P < 0.05$ vs Ball-possession

and HML [103(21) $m \cdot min^{-1}$] than any other position, while central midfielders covered the greatest ($P < 0.05$) overall HSR [68(19) $m \cdot min^{-1}$]. Descriptive results with differences across all positions for relative TD, HSR, VHSR, SPR, Acc/Dec, P_{met} and HML are presented in Table 1. As shown in Figure 1 (Panel A) the magnitudes of the percentage differences between 1-min_{peak} vs 90-min were SPR > VHSR > Acc/Dec > HSR > TD. The 1-min_{peak} performance showed ~13% match-to-match variability, with lower SPR variability than 90-min (~29%). No further difference in match-to-match variability between 1-min_{peak} and 90-min was found (Figure 1, Panel B).

Overall results for the 1-min_{peak} demands across formations, BiP and ball possession

The linear mixed model revealed no position x formation x ball possession interaction in 1-min_{peak} for TD ($F_{40, 986} = 0.889$, $P = 0.669$), HSR ($F_{40, 986} = 0.463$, $P = 0.998$), VHSR ($F_{40, 986} = 0.554$, $P = 0.989$) and Acc/Dec ($F_{40, 986} = 0.941$, $P = 0.577$).

The 1-min_{peak} demands between formations

Figure 2 shows the 1-min_{peak} for each position across different playing formations. No position x formation interaction was observed for the 1-min$_{peak}$ demands in TD ($F_{20, 197}$ = 0.846, *P* = 0.658), HSR ($F_{20, 197}$ = 1.255, *P* = 0.201), VHSR ($F_{20, 197}$ = 1.063, *P* = 0.384), SPR ($F_{20, 197}$ = 0.712, *P* = 0.813), Acc/Dec ($F_{20, 197}$ = 1.375, *P* = 0.125), P_{met} ($F_{20, 197}$ = 0.962, *P* = 0.509) and HML ($F_{20, 197}$ = 1.06, *P* = 0.396). All differences across formations by playing position are reported in Figure 2. Comparing 1-min$_{peak}$ across different playing formations within position, wide forwards showed higher (*P* < 0.05) 1-min$_{peak}$ for TD in 3-5-2 than 3-4-1-2 and 3-4-2-1 (ES: 0.37 to 1.31). Irrespective of positions, 1-min$_{peak}$ for Acc/Dec was lower in 4-4-2 than any other formation (ES: -0.42 to -0.13). In contrast, forwards showed higher (*P* < 0.05) 1-min$_{peak}$ in 4-3-3 than 3-4-1-2 and 3-5-2 (ES: 0.70 to 1.57), central midfielders showed higher (*P* < 0.001) 1-min$_{peak}$ in 4-3-3 than 3-4-1-2 and 4-4-2 (ES: 1.76 to 2.52), wide midfielders showed higher (*P* = 0.005) 1-min$_{peak}$ in 4-3-3 than 3-4-1-2 and 4-4-2 (ES: 1.23 to 2.21), wide defenders showed higher (*P* < 0.001) 1-min$_{peak}$ in 3-5-2 than 3-4-1-2 and 4-4-2 (ES: 1.50 to 2.84). No further between-position difference across formations was found for VHSR, SPR, P_{met} and HML.

The 1-min$_{peak}$ demands with ball in play

Despite the 95(2) min of playing time during official matches, the ball-in-play time was 54(11) min. Comparing the relative distance covered during the overall whole-match time and the ball-in-play time, TD was 115.5(6.0) m·min^{-1} vs 140(28) m·min^{-1}, HSR was 24.4(4.0) m·min^{-1} vs 40(11) m·min^{-1}, VHSR was 5.5(1.1) m·min^{-1} vs 9.8(2.8) m·min^{-1}, SPR was 3.9(1.1) m·min^{-1} vs 5.9(2.8) m·min^{-1} and Acc/Dec was 5.4(0.9) m·min^{-1} vs 7.0(2.1) m·min^{-1}.

No BiP x position interaction was found in 1-min$_{peak}$ for TD ($F_{5, 328}$ = 2.025, *P* = 0.073), HSR ($F_{5, 328}$ = 0.934, *P* = 0.458), VHSR ($F_{5, 328}$ = 1.254, *P* = 0.283) and Acc/Dec ($F_{5, 328}$ = 0.479, *P* = 0.792). However, as shown in Figure 3, there was an effect of BiP on TD ($F_{1, 657}$ = 722.08, *P* < 0.001), HSR ($F_{1, 657}$ = 386.22, *P* < 0.001), VHSR ($F_{1, 657}$ = 124.96, *P* < 0.001) and Acc/Dec ($F_{1, 657}$ = 12.07, *P* < 0.001). Interestingly, despite the *very large* differences with greater TD covered in BiP$_{peak}$ than 1-min$_{peak}$, HSR, VHSR and Acc/Dec showed *moderate* to *large* differences with greater distance covered during 1-min$_{peak}$ than BiP$_{peak}$. The magnitude of the differences is shown for each position in Figure 3.

The BiP$_{peak}$ demands with or without ball possession

Position x ball possession interaction was found in BiP$_{peak}$ for TD ($F_{5, 328}$ = 3.727, *P* = 0.002), HSR ($F_{5, 328}$ = 3.28, *P* = 0.006), VHSR ($F_{5, 328}$ = 6.41, *P* < 0.001) and Acc/Dec ($F_{5, 328}$ = 0.87, *P* = 0.048). All differences across with vs without ball possession cycles by playing positions are reported in Table 2. Forwards and wide forwards showed *small* and *moderate* differences with greater TD with ball possession, respectively. In contrast, central defenders showed *moderately* greater TD without ball possession. For HSR, forwards and wide forwards showed *small* and *moderate* differences with greater distances covered with ball possession, while central defender and wide defenders covered *moderately* to *largely* greater distances without ball possession. For VHSR, wide forwards showed *moderate* differences with greater distance covered with ball possession, while central defender and wide defenders cover *moderately* greater distance without ball possession. For Acc/Dec, wide midfielders and wide forwards showed *small* and *moderate* differences with greater distances covered with ball possession, while central defender and wide defenders covered *moderately* greater distances without ball possession.

DISCUSSION

The current study aimed to describe the most demanding passages of match play over different lengths of time (i.e. 1-5, 10, 90 min) in elite soccer players with respect to position using a rolling average method. Additionally, 1-min$_{peak}$ was described across formation, ball in play, ball possession and no ball possession. The main results showed an increase in maximal relative TD, HSR, VHSR, SPR, Acc/Dec, P_{met} and HML as the time-dependent period decreases within each playing position. For VHSR, SPR and Acc/Dec, 1-min$_{peak}$ showed fourfold higher locomotor requirements than whole match (90 min). Interestingly, although no between-formation difference in HSR, VHSR, SPR, P_{met} and HML was observed, the 1-min$_{peak}$ for Acc/Dec appears the lowest in 4-4-2 on average but the highest in 4-3-3 for forwards, central and wide midfielders. Overall, BiP$_{peak}$ was lower than 1-min$_{peak}$ for HSR, VHSR and Acc/Dec.

Some methodological considerations are needed to properly interpret the results. To check for variability in the dependent parameters due to different technical and tactical requirements across the matches [32, 33], we calculated the CV for TD, HSR, VHSR, SPR and Acc/Dec. For the first time in the literature, we showed that the 1-min$_{peak}$ had ~11% to ~15% match-to-match variability in the dependent parameters. Similar between-match variability was observed for TD, HSR, VHSR and Acc/Dec for the 90-min match demands. Interestingly, higher SPR variability was found in 90-min compared to 1-min$_{peak}$, in line with ~30% match-to-match variations for distance covered > 25.2 km·h^{-1} previously found over the whole match in Major European soccer [32, 33]. Thus, the results presented during the 1-min$_{peak}$ are moderately affected by the match-to-match variability and could be interpreted confidently.

The 1-min$_{peak}$ match-play TD performance of Italian Serie A soccer players (~188 m·min^{-1}) was similar to the data reported from Spanish La Liga reserve squad (~184 m·min^{-1}) [15] and professional English Championship players (~190 m·min^{-1}) [16], while slightly higher than a French Ligue 1 soccer team (~167 m·min^{-1}) [2]. Such a small difference may be due to the pre-season friendly matches included in the data analysis that may have lowered the peak demands. Concerning the other dependent parameters, further comparisons are challenging because of the different metrics and/or threshold used. For example, in French Ligue 1 soccer players, a 1-min$_{peak}$ of ~77 m·min^{-1} for distance > 14.4 km·h^{-1} during full-size matches was reported [2]. In English Championship soccer players, a 1-min_{peak} of ~60 m·min^{-1} for distance > 19.8 km·h^{-1} during competitive matches was reported [17]. In reserve squad Spanish La Liga soccer players, a 1-min_{peak} of ~69 m·min^{-1} and ~17 W·kg^{-1} for distance covered at high-metabolic load (> 25.5 W·kg^{-1}) and P_{met} was found [6, 15]. P_{met} was slightly higher in Italian Serie A (~20 W·kg^{-1}). However, no further information among elite soccer leagues is currently available for comparisons. Similar to previous studies in soccer [2, 22] or other team sports [23, 24], the present results showed an increase in maximal relative TD, HSR, VHSR, SPR, Acc/Dec, P_{met} and HML as the time-dependent period decreases within each playing position [15, 18]. The gap between the 1-min_{peak} and 90-min demand observed here was +49%, +281%, +350%, +624% and +325% for TD, HSR, VHSR, SPR and Acc/Dec, respectively. These outcomes highlight the importance of adequately preparing players for the peak demands of competition especially for the high-intensity running activities. However, the maximal running performances theoretically occur only once or few times during the game [14]. Remarkably, a recent study in Australian football and rugby league showed that the greatest volume of activity was at ~60% of the 1-min_{peak} demands [34]. Consequently, conditioning for the worst-case scenario should be only a part of the overall periodized training programme.

Central/wide midfielders and forwards/central defenders showed the highest and lowest 1-min_{peak} match demands, respectively. The present results are in line with whole match positional differences observed in Spanish La Liga [5, 6], UEFA champions league [5] and English Premier league [35]. The current results highlighted that central/wide midfielders vs forwards/central defenders should be conditioned differently both for the 1-min_{peak} and whole match demands. Moreover, no between-formation difference in the 1-min_{peak} for HSR, VHSR, SPR, P_{met} and HML was found. Concerning Acc/Dec, on average 4-4-2 required the lowest distance covered while across positions forwards, central and wide midfielders covered the greatest distance in 4-3-3 and wide defenders covered the greatest distance in 3-5-2. Lastly, wide forwards showed greater TD in 3-5-2 than 3-4-1-2 and 4-4-2-1. Hence, 1-min_{peak} is quite similar across different tactical behaviours (e.g. 4-3-3, 3-5-2, etc.). However, the magnitude of these differences ranges from *moderate* to *very large,* with wide defenders and central midfielders showing the largest between-formation differences. Therefore, practitioners should mainly consider the positional between-formation differences in Acc/Dec when conditioning different positions near to the peak demands, with a special focus on wide defenders and central midfielders when suitable.

It was observed that Italian Serie A, French Ligue 1, German Bundesliga, FIFA World Cup and UEFA Euro tournaments are characterized by a total of ~54 to ~57 min BiP time [25, 26]. Similarly, the present results come with ~54 min BiP time. During the total BiP across 90 min, the present results show higher TD (~140 m·min^{-1}) than professional Rugby (~116 m·min^{-1}) [36] and youth elite soccer (~119 m·min^{-1}) [20]. When examining BiP_{peak}, the present results show higher TD (~293 m·min^{-1}) than youth elite soccer players (~200 m·min^{-1}) [20]. Moreover, youth soccer players showed a BiP_{peak} of ~68 m·min^{-1}, ~10 m·min^{-1} and ~88 m·min^{-1} for distance > 18 km·h^{-1}, Acc/Dec and high-metabolic load distances [20]. However, due to different thresholds (e.g. distance > 18 km·h^{-1} or > 20 km·h^{-1}) no direct comparisons can be performed. Remarkably, a lower training intensity in young than adult professional soccer players was previously observed [37]. The authors hence suggested that the training intensity used with youth could be increased to allow a safe transition to professional soccer to avoid an insufficient training status and possibly higher injury risk [37]. Similarly, the present results suggest the need to adequately prepare youth players for greater peak demands across elite soccer matches.

Interestingly, the present outcomes showed greater TD and lower HSR, VHSR and Acc/Dec in BiP_{peak} than 1-min_{peak}. It can be argued that rapid transitions from defensive to offensive phases (e.g. counterattacks) required rapid tactical adjustments during both BiP and ball out of play. Similarly, when a foul is committed, players have to rapidly move in their tactical position, increasing their locomotor demands during the ball out-of-play time. As such, BiP requires higher demands than the whole match, but the 1-min_{peak} showed greater peak in HSR, VHSR and Acc/Dec than BiP_{peak}, due to the locomotion requirements during both BiP and ball out of play. However, it must be remembered that this may happen only once in the game.

Across BiP_{peak}, comparing with vs without ball possession cycles, a greater distance covered with ball possession was found in forwards (i.e. for TD and HSR) and wide forwards (i.e. for TD, HSR, VHSR and Acc/Dec), while locomotor demands increased without ball possession in central defenders (i.e. for TD, HSR, VHSR and Acc/Dec), wide defenders (i.e. for HSR, VHSR and Acc/Dec) and wide midfielders (i.e. for Acc/Dec). Due to different tactical adjustments (e.g. attacking or defensive phases), these positions face different physical demands across the match duration. Therefore, practitioners need to keep in mind these differences when performing exercises aiming to elicit the BiP_{peak} demands using drills for developing attack or defence tactical behaviours.

Some limitations and future perspectives accompany the current study, with implications for future investigations. Firstly, differences in the teams' style of play and the within-players physical characteristics may have influenced the results. Secondly, the match outcomes [19] and the period of the season were not accounted for. Thirdly, additional information about how many times and when during the match the MDP, 1-min_{peak} and BiP_{peak} occur is required. Lastly, as previously proposed,[2] future research should investigate how to simulate the MDP, 1-min_{peak} and BiP_{peak} using small-sided games or individual drills.

The present findings could be used in practice to inform training intensity of drills designed to reflect the MDP, 1-min_{peak} and BiP_{peak} across different tactical requirements (e.g. BiP, offensive/defensive phases). For example, the values recorded during BiP, both with and without ball possession, could be used as a reference for soccer-specific drills as small-sided games. In this case, manipulating the pitch size, goalkeeper presence and number of players can overload or underload the locomotor demands [4]. Similarly, some positions (forwards, central defenders, etc.) should be conditioned differently (e.g. using offensive or defensive tactical behaviours) to overload their most demanding activities during BiP_{peak} (i.e. forwards' maximal peak demands differ between ball- or no ball-possession cycles). Additionally, the maximal individual capacity in different metrics (e.g. VHSR, SPR, Acc/Dec, etc.) can exceed the maximal positional match requirements. For example, MDP, 1-min_{peak} or BiP_{peak} for a given player could be lower than his VHSR, SPR or Acc/Dec maximal capacity. For training prescription purposes, considering the peak demands only may lead to lower training stimuli that could not effectively condition the players. Therefore, both the maximal individual capacity and the MDP over different lengths of time should be considered to maximize the performance development in elite soccer players across exercises lasting different durations.

CONCLUSIONS

The present study examined for the first time the MDP over different lengths of time in Italian Serie A soccer players with respect to position and the 1-min_{peak} with respect to formation, BiP and ball possession. Central and wide midfielders showed greater 1-min_{peak} demands, while lower values were observed in forwards and central defenders. Positional differences in Acc/Dec were also observed depending on the formation, with forwards, central and wide midfielders showing greater peak demands in 4-3-3 while wide defenders showed the greater peak demand in 3-5-2. Interestingly, the 1-min_{peak} was greater than BiP_{peak}, possibly due to rapid tactical repositioning when the ball is out of play. Lastly, forwards and wide forwards mainly showed greater BiP_{peak} demand with ball possession, while central defenders and wide defenders have greater BiP_{peak} demand without ball possession.

Thus, although soccer performance is affected by several factors, MDP, 1-min_{peak} and BiP_{peak} should be considered to properly condition the players for the peak demands, often underestimated when considering only 90-min activities. Moreover, individual positional 1-min_{peak} demands could be recreated by means of cycles with or without ball possession using small-sided games or technical drills.

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Conflict of interests

The authors have no conflicts of interest to disclosure.

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