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Position specific physical performance and running intensity fluctuations in elite women's football

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Abstract

The purpose of the present study was to investigate the physical performance of elite female football players during match play along with transient alterations in running performance following 1- and 5-min univariate peak periods. 54 elite female players from four top-level Norwegian teams were monitored for one season ($n = 393$ match observations), and physical performance data collected using STATSport GPS APEX. Results revealed significant differences in physical performance between the positions during full match play, particularly between wide and central players. Both full backs (FBs) and wide midfielders (WMs) covered more total distance (TD), high-speed running distance (HSRD), and sprint distance (SpD) than center backs (CBs) ($p < 0.05$–0.001), while WMs also covered more HSRD than both central midfielders (CMs) ($p < 0.01$) and forwards (FWs) ($p < 0.05$), and more acceleration -and deceleration distance (Acc_{dist} and Dec_{dist}) than both CBs and CMs ($p < 0.01$–0.001). A similar pattern was observed for the peak period analysis, with FBs and WMs covering more SpD in peak 1 min than CBs and CM ($p < 0.001$) and more SpD in peak 5-min than CBs, CMs, and FWs ($p < 0.001$). Irrespective of the variable analyzed, greater distances were covered during the peak 5-min period than in the next-5 and mean 5-min periods ($p < 0.001$). Significant ($p < 0.001$), but small to trivial (Cohen's D_z: 0.07–0.20), decreases in distance covered were also observed for each variable following each univariate peak 5-min period. In conclusion, practitioners should account for differences in physical performance when developing training programs for female football players and be aware of transient reductions in physical performance following univariate peak 1- and 5-min periods. Specifically, the very high intensity in 1-min peak periods adds support to the principal of executing speed endurance activities during training to mirror and be prepared for the physical demands of match play.

KEYWORDS

global positioning system, peak periods, physical performance, women's football

1 | INTRODUCTION

Women's football has surpassed an undeniable transformation during the last decade, and its development has been a priority for the Fédération Internationale de Football Association.[1] This increased professionalism and growing popularity have impacted the scientific community with focused research increasing the body of knowledge regarding the women's game. Nevertheless, studies about player positioning monitoring and match physical performance are still scarce, since most of the research topics in women's football are related to injury.[2]

Time-motion analysis involving the intermittent activity pattern of women's football is necessary to assess the locomotor and mechanical demands of match play, which in turn is essential for specific training prescription.[3,4] Women's football has been described as a sport with multiple brief intense actions separated by low-intensity activities, with mean values for total distance (TD) and high-speed running distance (HSRD) ranging from 9.2–11.3 km to 1.2–2.7 km, respectively.[5–7] However, it is well documented in male football that different playing positions accumulate different external match load[8–11] and that such load presents large individual variations.[4,12] Therefore, to describe and characterize physical demands of football competitions, it is recommended to present these analyses by playing positions rather than reporting only the team averages.[13]

The majority of the studies that aim to analyze the external load of match play through locomotor activity do not account the energy cost associated with accelerations (Acc) and decelerations (Dec),[14] which may underestimate match load by 6%–8%.[15,16] To the best of our knowledge, only three studies women's football[17–19] have included the metrics of Acc and Dec in their analysis, while simultaneously adopted a more detailed categorization of the playing positions (into 4–6 positions) instead of the commonly used categorization into defenders, midfielders, and attackers.[4,5,7,20–23] However, the study of Mara et al.[17] included a considerably small sample size (12 players across 7 matches) and their intention was to focus only on Acc and Dec profiles, excluding other important variables such as HSRD and sprints from the analysis.

The reporting of absolute or average demands has been advantageous to profile the players' overall physical loading. However, it must be noted that football presents a stochastic nature[24] and training programs designed to replicate these average demands of competition will likely lead to players being underprepared for the more intense periods of a football match.[25] While high-intensity phases have received particular attention in men's football in recent years,[26–32] sparse information has been provided in relation to the peak demands of different playing positions in women's football. Another interesting aspect is whether decrements in high-intensity running occur following these periods, which may be indicative of physiological fatigue or pacing strategy.[33] However, while several studies on men have found transient decrements following high-intensity phases of 1 and 5 min,[34,35] no study to date has investigated this in women.

The most intense periods have been studied using different methodologies, including different temporal durations (epochs) and analysis techniques. Studies initially started by examining fixed-time periods of 15[24,36] or 5 min.[33,35] However, in a systematic review of the methodologies used to quantify the peak match demands, Whitehead et al.[37] concluded that pre-defined time periods lack sensitivity to find the true peaks of physical outputs when compared with a rolling average method. Indeed, in a study with elite male football players, Varley et al.[38] reported that fixed compared with rolling 5-min epochs underestimated peak running demands by up to 25%, which is in line with more recent research that also analyzed shorter time periods (eg, 1 and 3 min).[27,35,39] Despite Trewin et al.[19] having studied the most intense periods in match play of elite female football players using a rolling average approach, the authors only analyzed 5-min epochs, resulting in limited information for training prescription.[37]

Therefore, the aims of the present study were twofold. We first aimed to characterize the physical performance in elite women's football by position. Secondly, we aimed to investigate transient alterations in running demands following rolling peak periods of 1 and 5 min.

2 | METHODS

With ethical institutional approval from the Norwegian Centre for Research Data (reference number: 296155) and written informed consent from the participants, 108 female football players (22 ± 4 years of age) from four top-level Norwegian clubs were included in the study. Locomotor data from the four clubs′ official matches in the 2020 season (60 matches) were collected using GPS APEX (STATSports), with a sampling frequency of 10 Hz. The validity and levels of accuracy (bias <5%) of this tracking system have been previously presented.[40] During matches, each player wore a tight vest with the GPS unit on the back of their upper body between scapula as described by the manufacturer. The microsensor devices were activated 15 min prior to the start of each match, in accordance with the manufacturer's recommendations and previous research,[41] with this period of time being excluded from analyses. To minimize inter-devices error,[40] each player used the same GPS unit during the entire season.

Doppler derived speed data was exported from manufacturer software (STATSport Sonra 2.1.4) into Python 3.7.6. for processing (linearly interpolating any missing raw data) and to derive metrics. Raw acceleration was then calculated over a period of 0.6 s. After deriving all the metrics, the data were transferred to R (R.4.0.5, R Core Team, 2021) for statistical analysis.

2.1 | Physical performance variables

The physical parameters analyzed included total distance (TD), high-speed running distance (HSRD) (>4.44 m.s^{-1}), sprint distance (SpD) (>5.55 m.s^{-1}), acceleration and deceleration distances (Acc_{dist}/Dec_{dist}), and peak speed ($Peak_{speed}$). Acc_{dist} and Dec_{dist} were defined as the distance covered with a positive or negative change in speed of more than ±2.26 m.s^{-2}, with a minimal effort duration of 0.3 s, finishing when the rate of acceleration/deceleration reached 0 m.s^{-2}. The speed thresholds were chosen according to the previous research.[19,20] Except for $Peak_{speed}$, all other variables were used to analyze both full match (absolute values) and peak locomotor demands (1- and 5-min peak periods rolling analysis periods). The epoch length for the peak locomotor demands was chosen according to the findings of Doncaster et al.,[39] where 1-min epochs produced the highest relative intensities when compared with 3- and 5-min epochs.

2.2 | Statistical analysis

Both between-positional differences during full match and within-positional differences between peak, next, and mean periods, were determined using linear mixed-modelling. To deal with the nested structure of the data, we treated matches in which two of our teams met as separate matches, and, due to positional differences in locomotor demands, the same player in a new position as a new player. Furthermore, to get a representative sample, we only included players who completed, at least, two full-time (90 min) matches. Also, match performance data of <90 min were treated as missing, and goalkeepers were excluded from analysis. This resulted in an initial sample of 501 observations with 108 missing values, which were subsequently removed in the complete case analysis (CCA). The final sample included 393 match observations (M_{obs}) from 54 players (center backs, CB, $n = 10$, $M_{obs} = 113$; full backs, FB, $n = 11$, $M_{obs} = 84$; central midfielders, CM, $n = 16$, $M_{obs} = 105$; wide midfielders, WM, $n = 9$; $M_{obs} = 57$ and forwards, FW, $n = 8$, $M_{obs} = 34$). These positions were chosen according to previous research.[35] The mean number of satellites and horizontal dilution of precision was 17.5 ± 2.8 and 1.4 ± 0.6, respectively. For the full match between-positional analysis, we specified for each physical parameter a model with *Position* as the fixed effect and *Team*, *Match ID*, and *Player ID*, as the random effects. Similarly, to investigate within-positional differences between peak, next, and mean periods, we specified for each physical parameter a model with *Position*, *Period*, and an interaction term as the fixed effects, and *Team*, *Match ID*, and *Player ID*, as the random effects. Moreover, the Tukey method was applied to adjust the multiple comparisons, with an α-level set at 0.05 as the level of significance. To calculate effect sizes (ES) we used Cohen's D_z.[42] All statistical analyses were done using the lme4[43] and emmeans[44] packages. Unless otherwise stated all results are estimate marginal means ± 90% confidence intervals.

3 | RESULTS

3.1 | Full match activity profiles

There were significant differences between certain playing positions across all metrics except for peak speed (Table 1). The results obtained for TD and HSRD revealed that CB covered less distance than both FB and CM. Moreover, also WM performed higher HSRD than CM and FW. Regarding sprint distance, CB covered less distance than FB, WM, and CM, with WM also presenting higher values than FW. Significant higher values were also observed for WM than FW for total distance and high-speed distance (Table 1).

No significant differences in peak speed were observed between outfield positions. Regarding the acceleration profiles, WM performed higher Acc_{dist} than CB and CM, and higher Dec_{dist} than both CB, CM, and FW (Table 1).

3.2 | 1- and 5-min peak period profiles

No significant differences were observed between positions in 1-min peaks for TD. However, three playing positions (FB, WM, and CM) performed significantly higher peak 5-min TD compared with CB (Table 2). FB and WM performed more 1- and 5-min peak HSRD than CB during both periods, with WM also performing more HSRD than CM and FW in the 5-min peak (Table 2). The results obtained for SpD revealed a similar trend, with FB and WM presenting higher values in the 1-min peak, than CB and CM, and in the 5-min peak than CB, CM, and FW. WM was the playing position with the highest values observed

TABLE 1 Full match activity profiles by position

	CB	FB	CM	WM	FW	Contrasts
TD (m)	8934 ± 264	9590 ± 255	9982 ± 229	10131 ± 284	9376 ± 311	FB > CB (656 ± 557)*; WM > CB (1197 ± 591)*; WM > FW (755 ± 646)*; CM > CB (1048 ± 525)*
HSRD (m)	1054 ± 148	1573 ± 144	1483 ± 130	1894 ± 160	1429 ± 174	FB > CB (519 ± 308)***; WM > CB (840 ± 327)***; WM > CM (411 ± 300)**; WM > FW (465 ± 359)*; CM > CB (429 ± 290)**
SpD (m)	227 ± 54	413 ± 53	293 ± 47	530 ± 59	380 ± 65	FB > CB (187 ± 118)*; WM > CB (303 ± 126)***; WM > CM (237 ± 116)***; FW > CB (154 ± 134)*
Peak speed (km/h)	27 ± 1	28 ± 1	27 ± 1	29 ± 1	28 ± 1	No sig. differences
Acc (m)	427 ± 42	488 ± 41	433 ± 36	578 ± 46	506 ± 51	WM > CB (151 ± 97)**; WM > CM (145 ± 90)**
Dec (m)	305 ± 34	406 ± 33	361 ± 30	493 ± 38	382 ± 42	FB > CB (101 ± 75)**; WM > CB (188 ± 80)***; WM > CM (132 ± 73)***; WM > FW (111 ± 88)*

$^{*}p < 0.05$.; $^{**}p < 0.01$.; $^{***}p < 0.001$.

for Acc_{dist} and Dec_{dist}, both in 1- and 5-min peak periods, with results being significantly higher, during 1-min peak, than CM, and higher than CB, CM, and FW during 5-min peak (Table 2).

3.3 | Running intensity fluctuations (peak, next and mean periods)

Both CB, FB, CM, and FW presented significantly higher values during the 1-min peak than in the following 5-min periods, for HSRD, SpD, $Acc_{dist,}$ and Dec_{dist} (Figure 1). A similar trend was seen for WM, who also presented significantly higher peak 1-min versus next 5-min values, except for HSRD. Furthermore, small but significant decreases in distance covered. Furthermore, both CB, FB, and WM covered less distance, during the 5-min period following the peak 1-min compared to the mean 5-min period. For CM, there were no differences between these two epochs in Acc_{dist}, while for FW the same was observed in TD, HSRD, and SpD. With exception of TD, CB presented significantly higher values during the peak 1-min period compared to the mean 5-min period. Similarly, FB and CM presented higher SpD and Acc_{dist} during the 1-min peak. For WM and FW, significantly differences between those moments were observed only in SpD.

With respect to the analysis of peak, next, and mean 5-min, the same trend, without exception, was observed for every playing position (Figure 2). Irrespectively of the variable analyzed, the results revealed higher intensities during the peak 5-min than in both next and mean 5-min periods. Next 5-min periods also presented lower values compared to the mean 5-min of each variable (ES range: 0.07–0.20).

4 | DISCUSSION

For the first time, running intensity fluctuations using 1- and 5-min peak periods have been studied in detail in elite women's football. The major findings are that that HSRD, Acc_{dist} and Dec_{dist} in the 1-min peak correspond to ~50% of the distances covered in the 5-min peak and that the peak 1-min sprint period is significantly higher, in every playing position, than the mean 5-min period for the same variable. In addition, these differences between 1- and 5-min peaks are even smaller in SpD, with the most demanding minute of the match corresponding to ≥60% of the SpD performed in the 5-min peak.

These findings are in line with previous research in professional male footballers[29] and may be important for practitioners during training prescription. As an example, it may allow coaches to make evidence-based decisions regarding durations for exercises that aim to replicate, or to prepare, the players to cope with these peak periods of the match. Preparing players to cope with the 5-min peak periods of the match do not necessarily mean that these players will be ready for the most demanding 1-min peaks,

TABLE 2 Peak period (1 and 5 min) profiles by position

	CB	FB	CM	WM	FW	Contrasts
Peak 1-min period						
TD (m)	174 ± 15	192 ± 16	189 ± 14	191 ± 19	178 ± 23	No sig. differences
HSRD (m)	71 ± 9	93 ± 9	85 ± 9	93 ± 11	77 ± 12	FB > CB (22 ± 15)**; WM > CB (21 ± 16)*
SpD (m)	37 ± 4	53 ± 4	40 ± 4	54 ± 5	44 ± 6	FB > CB (16 ± 7)***; FB > CM (13 ± 7)***; WM > CB (18 ± 8)***; WM > CM (14 ± 8)***
Acc (m)	28 ± 2	32 ± 3	28 ± 2	34 ± 3	31 ± 3	WM > CM (6 ± 5)*
Dec (m)	20 ± 2	24 ± 2	21 ± 2	27 ± 2	23 ± 3	WM > CB (7 ± 4)*; WM > CM (6 ± 4)**
Peak 5-min period						
TD (m)	634 ± 21	688 ± 22	706 ± 20	712 ± 26	658 ± 31	FB > CB (54 ± 37)**; WM > CB (78 ± 41)***; CM > CB (72 ± 35)***
HSRD (m)	139 ± 13	190 ± 13	179 ± 12	210 ± 14	164 ± 16	FB > CB (52 ± 21)***; WM > CB (71 ± 23)***; WM > CM (30 ± 21)**; WM > FW (45 ± 26)***; CM > CB (41 ± 20)***
SpD (m)	54 ± 6	82 ± 6	63 ± 6	92 ± 7	67 ± 8	FB > CB (28 ± 11)***; FB > CM (19 ± 10)***; FB > FW (15 ± 12)*; WM > CB (38 ± 11)***; WM > CM (29 ± 11)***; WM > FW (25 ± 13)***
Acc (m)	56 ± 4	66 ± 4	56 ± 3	74 ± 4	62 ± 5	FB > CB (10 ± 7)**; FB > CM (10 ± 6)**; WM > CB (18 ± 7)***; WM > CM (17 ± 7)***; WM > FW (12 ± 8)**
Dec (m)	41 ± 3	50 ± 3	45 ± 3	59 ± 3	46 ± 4	FB > CB (10 ± 5)***; FB > CM (6 ± 5)*; WM > FB (9 ± 5)***; WM > CB (19 ± 5)***; WM > CM (14 ± 5)***; WM > FW (13 ± 6)***

*$p < 0.05$.; **$p < 0.01$.; ***$p < 0.001$.

since the demands of 5-min peaks are not evenly distributed across every minute.

Interestingly, the performance in the 5-min period following the peak 5-min in SpD is similar to the performance observed after the peak 1-min, suggesting that the 1-min peak period is so physically demanding that it requires a long recovery period with lower intensity. Furthermore, the high intensity in the SpD 1-min peak period adds support to the prescription of speed endurance activities during training to mirror and be prepared for the physical demands of match play.[45,46]

Corroborating previous studies regarding the presence and development of temporary fatigue[47] after peak periods,[29,48] our results revealed a significant decrease of high-intensity actions in the 5-min period following the peak 1-min, across several playing positions. The next 5-min period was also less demanding, in every variable (except for Acc_{dist}), than the 5-min rolling average, for CB, FB, CM, and WM. However, while this decrease was significant, it is important to note that the differences in distance covered were quite small and that post 5-min periods are quite variable.[19]

It is important to have reference values by playing position for the demands of match play in elite women's football, since comparisons to men's football are not commensurable. To date, only two other studies[18,19] have simultaneously described the distribution of both running and acceleration patterns in elite women's football. In our study, apart from TD, a pattern emerged in the full match analysis in which external positions covered more distance in all speed zones, compared with central positions. This was especially apparent for SpD where both FB and WM covered significantly more distances than CB and CM, which partly supports the conclusions of Panduro et al.[18] where CB was considered the playing position with the lowest overall physical match demands. A similar trend was observed in the analysis of the 5-min peak periods, where FB and WM presented the highest values in high-speed variables, while CB was the playing position with the lowest work-rate in every variable analyzed. These results are somewhat similar with previous research in elite male[8] and female[13] footballers; however, in the study of Panduro et al.,[18] the authors reported CM as one of the most demanding playing positions regarding high-speed activities,

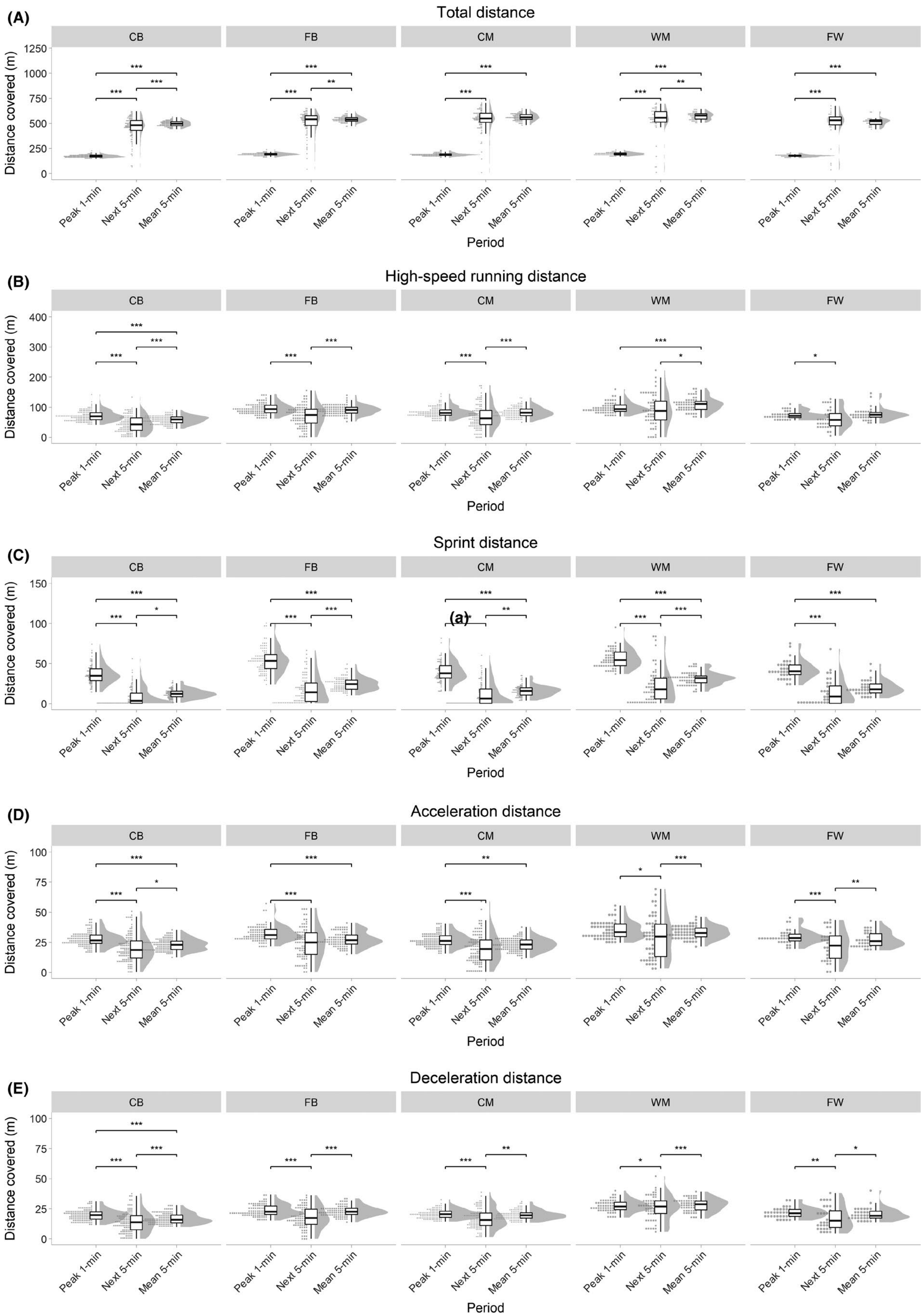

FIGURE 1 Distance covered during the peak 1-min, the next 5-min, and the mean 5-min period, for total distance (A), high-speed distance (B), sprint distance (C), acceleration distance (D), and deceleration distance (E)

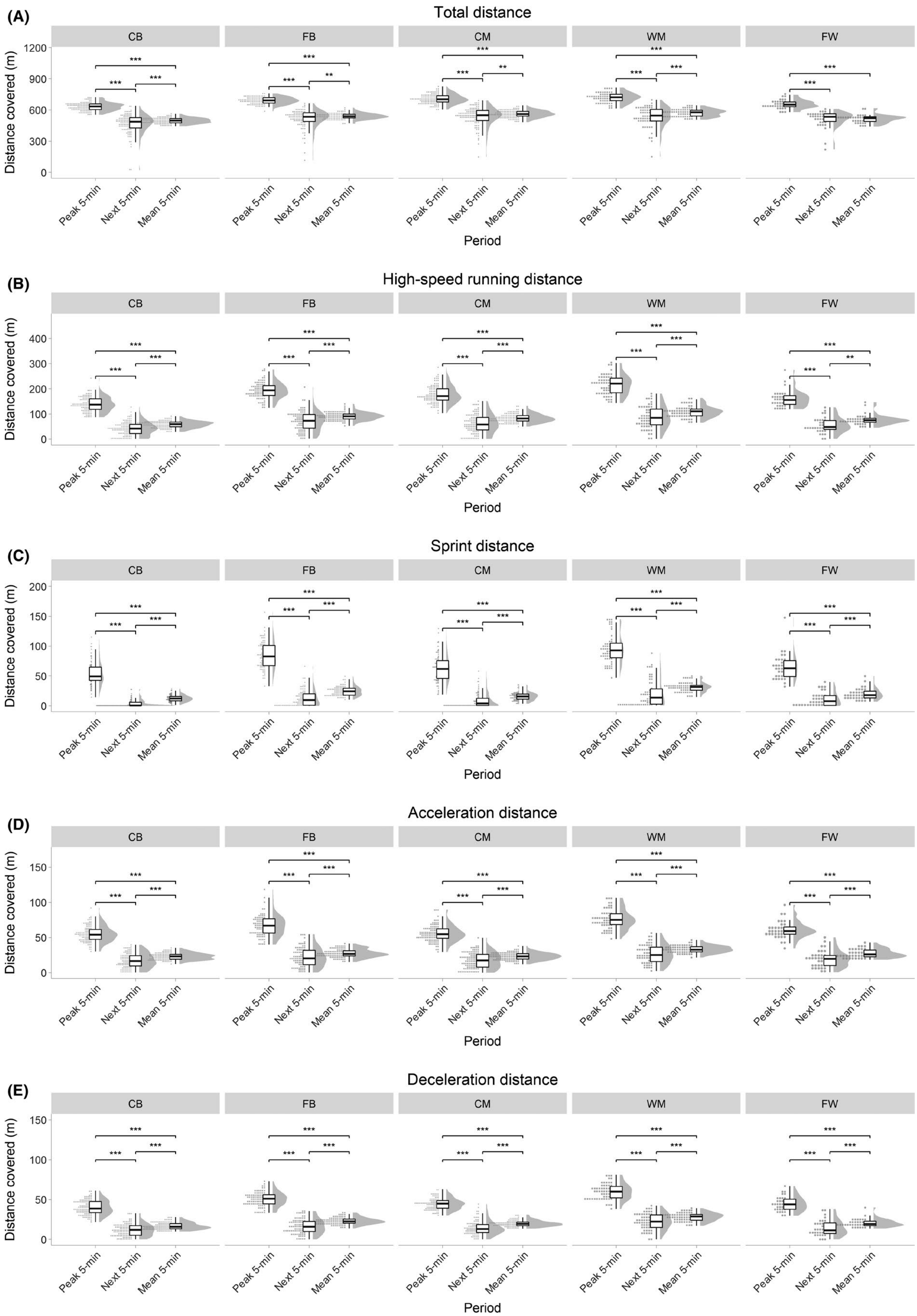

FIGURE 2 Distance covered during the peak 5-min, the next 5-min, and the mean 5-min period, for total distance (A), high-speed distance (B), sprint distance (C), acceleration distance (D), and deceleration distance (E)

which is not in line with the findings of this research. In fact, 5-min peaks present larger differences between positions than 1-min peaks, which may be explained by the accumulation of differences within 5 min. The three studies used different tracking systems, and direct comparisons between studies should be done with care.

This study gathered performance data from top quality players (three teams ranked Top-4 in the National League), resulting in a large dataset, which is both rare and novel in studies on elite athletes. However, the dataset was not evenly distributed across playing positions, with FW presenting a considerably smaller sample size than the other positions. In fact, the inclusion criteria chosen for the present study (players had to play the full match—90 min) together with the fact that FW were the players more often substituted in match, resulted in a smaller sample size for this group and hence lower statistical power for the running intensity fluctuation analysis.

5 | PERSPECTIVES

The results of this study emphasize that peak 1-min SpD in all positions and Acc- and Dec distance in some positions are significantly higher than the mean 5-min period in these variables, which should have implications in the planning of training content with specific emphasis on individualized physical preparation relative to position and peak demands.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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