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Physical performance and loading for six playing positions in elite female football: full-game, end-game, and peak periods

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Abstract

The present study investigated the position-specific match demands and heart rate response of female elite footballers, with special focus on the full-game, end-game, and peak-intensity periods. In total, 217 match observations were performed in 94 players from all eight teams of the best Danish Women's League, that is, goalkeepers (GK, n = 10), central defenders (CD, n = 23), full-backs (FB, n = 18), central midfielders (CM, n = 28), external midfielders (EM, n = 18), and forwards (FW, n = 11). Positional data (GPS; 10 Hz Polar Team Pro) and HR responses were collected. HR_{mean} and HR_{peak} were 87%-89% and 98%-99% of HR_{max}, for outfield players, with no positional differences. CM, EM, and FB covered 8%-14% greater ($P < .001$) match distances than CD. EM, FW, FB, and CM performed 40%-64% more ($P < .05$) high-speed running and 41%-95% more ($P < .01$) very-high-speed running (VHSR) than CD. From the first to the last 15-minute period, total distance, except for FW, number of VHSR, except FB, peak speed and sum of accelerations and sum of decelerations decreased ($P < .05$) for all outfield positions. In the most intense 5-minute period, EM, FB, and CM performed 25%-34% more ($P < .01$) HSR than CD, whereas EM, FW, and FB performed 36%-49% more ($P < .01$) VHSR than CD. In conclusion, competitive elite female matches impose high physical demands on all outfield playing positions, with high aerobic loading throughout matches and marked declines in high-speed running and intense accelerations and decelerations toward the end of games. Overall physical match demands are much lower for central defenders than for the other outfield playing positions, albeit this difference is minimized in peak-intensity periods.

KEYWORDS

accelerations, GPS, heart rate, high-speed running, peak-intensity periods, performance decrements, soccer, sprinting

1 | INTRODUCTION

The vast majority of scientific studies on football have been performed with male players, but in recent years, the interest in women's football has increased considerably.[1] Most studies of female football players have focused on injuries and injury prevention, as well as the reporting of anthropometrics and test performance, and, to a lesser extent, the demands of the game.[1-5]

Women's football has undergone a professionalization during the last decade, and a larger number of female players can now train and compete at professional level.[5] As match performance has been shown to be related to training status[6] and match demands are higher in matches at a higher level,[7,8] it would be expected that the increased professionalism in women's football has increased match demands. A recent large-scale study, on the other hand, found only minor differences in match demands between female football players at different standards,[9] and the authors suggested that this discrepancy with previous studies could be due to the lower number of participants in the older studies leading to underpowered analysis. Another explanation may be the difference in the tracking systems used, as the older studies used video-based time-motion analysis, in contrast to the study by Scott and colleagues[9] using GPS-tracking, and different tracking systems have been shown to produce different values.[10,11]

Across tracking systems, total distance covered is typically in the range 9.2-11.3 km, whereas distance covered with high-speed running is in the range 1.2-2.7 km and the sprinting range is 160-460 m.[6-9,12-14] A number of studies have investigated match demands and found differences between playing positions. But the majority of previous studies have used a less specific categorization of positions, using defenders, midfielders and attackers,[6-8,14,15] and more specific categorization of the outfield positions is warranted,[4] as has been applied in a number of the recent studies.[9,13,16] Although presenting data for each position, the main aims of the studies by Bradley and colleagues[13] and Scott and colleagues[9] were to compare genders[13] and female players at domestic or international level.[9] Thus, large-scale studies on match demands relative to position in women's elite football are warranted.

In addition to data on external load, a number of studies have analyzed internal load using heart rate (HR) monitors and blood lactate measurements. HR_{mean} was in the range 152-186 bpm and HR_{peak} in the range 175-212 bpm, corresponding to 87 and 97% of HR_{max},[6] whereas blood lactate values were in the range 1-11 mmol/L after the first and second half.[17] None of the large-scale studies, however, have evaluated internal load, for example, by measuring heart rate, in conjunction with external load during matches and related this to positional differences.

The aim of the present study was, therefore, to investigate the position-specific match demands and heart rate response of elite female football players from the entire Danish Women's League.

2 | METHODS

2.1 | Study design

In this large-scale observational study, all eight teams from the best Danish women's football league, Gjensidige Ligaen, were monitored during the first half of the 2019/20 season. Of the eligible 180 players in the league, a total of 94 players (age: 22.5± 4.2 years, height: 170 ± 6 cm, weight: 64.0 ± 6.1 kg) were included in the analysis. A minimum of two matches (one home and one away) for each team were included (range 2-4 matches). Positional data and HR response were collected using Polar Team Pro units (Polar Electro Oy, Kempele, Finland) with GPS sampling at a 10 Hz frequency, 200 Hz tri-axial accelerometer, gyroscope, magnetometer and HR monitor, and analyzed using proprietary software. 10 Hz GPS measurements with subsequent data fusion with inertial measurement units using Kalman filter has been shown to provide valid and reliable data.[18,19] Only data from players playing full matches were included. Consequently, if one player was substituted in one game, but not the other, that player would only have one data point for each variable for analysis.

Differences in variables collected by the Polar Team Pro units were assessed based on five different categorizations of outfield playing position; central defender (CD), full-back (FB), central midfielder (CM), external midfielder (EM) and forward (FW). To describe the demands of the game for each position, data for full-game and for the peak 5-minute period are presented. Moreover, changes from first to second half and from first to last 15-minute period are analyzed. In addition, full-game values are presented for goalkeepers (GK).

The number of players in each subgroup was as follows: GK (n = 10), CD (n = 23), FB (n = 18), CM (n = 28), EM (n = 18), and FW (n = 11). Some players were measured more than once, and so as to not skew the weight of the sample size for the different positions, the average scores for each variable for each player were calculated. Furthermore, 14 players played matches in two different positions. In this case, both positions played by a single player were included in the analysis. Thus, the total number of included observations was 108.

2.2 | Heart rate

HR_{mean} and HR_{peak} were analyzed based on continuous measurement throughout the games, excluding the half-time break, and presented as absolute values and relative

to the highest HR observed during matches or the Yo-Yo Intermittent Recovery test level 1 (Yo-Yo IR1 test) (HR_{max}). Additionally, time spent in different HR zones was categorized into four different subcategories; HRZ1 (<140 bpm), HRZ2 (140-160 bpm), HRZ3 (160-180 bpm), HRZ4 (>180 bpm). Time spent in different HR zones is presented as percentage of total playing time.

2.3 | Distance, speed, and acceleration

Positional analysis of distances covered in different speed zones, number of very-high-speed running (VHSR), peak speed, and total distances were extracted using proprietary software. Running velocity was categorized into six different speed zones: 0-5.99 km/h (SZ1), 6-11.99 km/h (SZ2), 12-14.99 km/h (SZ3), 15-17.99 km/h (SZ4), 18-24.99 km/h (SZ5), and >25 km/h (Sprinting). The distances covered in these speed zones are presented. SZ4, SZ5, and Sprinting were summarized as high-speed running (HSR; >15 km/h), while SZ5 and Sprinting were summarized as very-high-speed running (VHSR; >18 km/h).

The highest observed speed was noted as peak speed, and the number of VHSR was defined as the number of times speed exceeded 18 km/h. Accelerations and decelerations were categorized into three subgroups of low, moderate, and high: accelerations 0.50-1.49 m/s^2 (low), 1.50-2.99 m/s^2 (moderate), 3.00-4.99 m/s^2 (high); decelerations 0.50-1.49 m/s^2 (low), 1.50-2.99 m/s^2 (moderate), 3.00-4.99 m/s^2 (high).

2.4 | Statistical analysis

All data are presented as mean ± standard deviation (SD), unless otherwise stated. All data were tested for normal distribution using the Shapiro-Wilk test and heteroscedasticity using the Box's test of equality of covariances matrices. When assumptions of normality and homoscedasticity were not met, log-transformation for statistical tests was performed. Full-game and peak 5-min positional differences were evaluated using a one-way ANOVA, whereas positional differences from first half to second half and from first 15 minutes to last 15 minutes were assessed using a two-way ANOVA with repeated measures to examine whether there was a significant interaction effect (time × group interaction). When a significant interaction was detected, a one-way ANOVA was used on first to second half delta values, and post hoc comparisons were made using a Bonferroni correction to determine where the significant interaction was. Data analysis was performed using the Statistical Package for Social Science statistical software (version 25, IBM SPSS Statistics, Chicago, IL, USA). The significance level was set at 0.05.

3 | RESULTS

3.1 | Movement pattern in full-game

Total distance covered ranged from 7812 to 12 823 m for outfield players and was 14%, 13% and 8% higher in CM, EM and FB, respectively, than in CD ($P < .001$), with no other differences between outfield positions (Table 1). Limited differences were observed between outfield positions in speed zones below 18 km/h; greater distances in EM than in CD in SZ2 and SZ3, and greater distances in CM compared to CD and FW in SZ1 and SZ2, but only compared to CD in SZ3. In SZ4, FB, EM, and FW covered more distance than CD, whereas for SZ5 FB, CM, EM, and FW covered a greater distance than in CD. HSR was higher in FB, CM, EM, and FW than in CD, whereas VHSR was higher in FB, CM, EM, and FW compared to CD and in EM compared to CM, and sprinting was higher in EM compared to CD and CM (Table 1).

The number of VHSR was higher in EM and FW than in CD (54 ± 10 and 49 ± 18 vs 28 ± 12; $P < .05$), with no differences between other outfield positions. In addition, no difference was observed between positions in peak speed (range: 27.5-29.2 km/h; Table 1). Limited differences between positions were observed for number of accelerations. A higher number of moderate accelerations were observed in CM and EM than in CD (200 ± 42 and 198 ± 48 vs 162 ± 24; $P < .05$), whereas no positional differences were observed in high or low accelerations. For decelerations, no differences were observed in low decelerations, whereas a higher number of moderate decelerations was observed in CM and EM than in CD. For high decelerations, a higher number was observed in EM than in CD, FB, and CM, whereas FB, CM, and FW were higher than CD (Table 1; Figure 1).

HR_{mean} was 169-173 bpm, corresponding to 87%-89% of HR_{max}, and HR_{peak} was 190-194 bpm, corresponding to 98%-99% of HR_{max}, with no difference between positions. Percentage of total time spent in HR zones did not differ between positions in any of the HR zones (Table 1).

In GK, total distance covered was ~50% of that for outfield players, with the vast majority (66%) in SZ1. Distances were different from all outfield positions in SZ1, SZ2, SZ3, SZ4, and SZ5, but only EM was different from GK in Sprinting (Table 1). GK had fewer moderate accelerations and moderate and high decelerations than outfield players. Only CM and FW had more high accelerations than GK. HR_{mean} was 148 ± 10 bpm, corresponding to 79 ± 5% of HR max, which

TABLE 1 Full-game velocity and distances covered, heart rate responses, accelerations, and decelerations

	GK	CD	FB	CM	EM	FW
Total distance [m]	5214 ± 949 (3510-6806)	9274 ± 762 (7812-10537)	10 053 ± 639† (9117-10871)	10 572 ± 880† (8317-12823)	10 519 ± 963† (8474-12484)	9745 ± 988 (8426-11784)
HSR [m]	99 ± 70 (25-273)	1088 ± 261 (631-1567)	1529 ± 369† (1114-2258)	1518 ± 499† (854-3370)	1786 ± 527† (1120-2917)	1561 ± 372† (1083-2047)
VHSR [m]	31 ± 31 (5-106)	442 ± 135 (191-695)	717 ± 242† (399-1175)	623 ± 252† (315-1381)	863 ± 299†,§ (354-1320)	737 ± 223† (399-1117)
Sprinting [m]	1 ± 3 (0-9)	19 ± 17 (0-63)	46 ± 48 (0-199)	33 ± 31 (0-108)	91 ± 81†,§ (0-245)	56 ± 45 (4-148)
Peak speed [km/h]	21.5 ± 1.2 (19.4-22.9)	27.5 ± 2.3 (23.7-30.6)	28.2 ± 3.2 (23.7-32.0)	27.8 ± 2.0 (23.7-30.8)	27.6 ± 2.1 (23.1-30.3)	29.2 ± 3.2 (25.1-31.6)
HR mean [bpm]	148 ± 10 (130-159)	169 ± 9 (154-185)	171 ± 11 (144-185)	170 ± 10 (146-187)	173 ± 8 (157-188)	170 ± 8 (159-186)
HR mean % of HR max	79 ± 5 (70-85)	87 ± 4 (78-93)	89 ± 3 (79-93)	89 ± 3 (82-93)	89 ± 4 (78-93)	87 ± 3 (80-93)
HR peak [bpm]	181 ± 11 (165-193)	192 ± 8 (172-216)	190 ± 9 (171-206)	190 ± 11 (169-208)	193 ± 13 (176-235)	194 ± 6 (181-204)
HR peak % of HR max	96 ± 4 (90-100)	98 ± 2 (92-100)	99 ± 1 (96-100)	99 ± 2 (91-100)	99 ± 1 (96-100)	98 ± 3 (91-100)
% of total time with HR 160-180 bpm	23 ± 16 (0-42)	50 ± 14 (17-71)	47 ± 20 (18-80)	45 ± 18 (13-83)	53 ± 15 (25-82)	50 ± 14 (20-65)
% of total time with HR > 180 bpm	2 ± 3 (0-8)	26 ± 25 (0-79)	32 ± 27 (0-82)	35 ± 25 (0-82)	30 ± 21 (0-71)	29 ± 23 (0-80)
High accelerations [n]	2.8 ± 1.5 (1-6)	6.7 ± 3.7 (2-17)	8.0 ± 4.9 (3-23)	10.0 ± 6.8 (0-26)	7.1 ± 5.4 (0-18)	12.1 ± 7.0 (0-25)
Sum of accelerations [n]	695 ± 164 (441-857)	864 ± 114 (701-1143)	878 ± 136 (730-1248)	945 ± 140 (705-1209)	871 ± 116 (678-1092)	884 ± 126 (709-1140)
High decelerations [n]	3.3 ± 1.3 (2-5)	12.6 ± 4.3 (4-22)	17.4 ± 4.6† (8-27)	16.4 ± 5.5† (8-30)	22.5 ± 6.7†,‡,§ (9-37)	18.7 ± 3.9† (9-23)
Sum of decelerations [n]	738 ± 139 (517-887)	887 ± 101 (698-1133)	895 ± 137 (710-1226)	946 ± 135 (735-1232)	893 ± 123 (670-1116)	921 ± 148 (712-1220)

Note: Mean ± SD and range (min-max).

Abbreviation: GK, goalkeepers; CD, central defenders; FB, full-backs; CM, central midfielders; EM, external midfielders; FW, forwards.

†Different from CD.

‡Different from FB.

§Different from CM.

was lower than for outfield players, whereas HR_{peak} was 181 ± 11 bpm, corresponding to 96 ± 4%, which was lower than in CM, EM, and FB.

3.2 | Peak 5-minute periods

During the most intense 5-minute period, total distance covered was greater in CM than in CD (683 ± 57 vs 625 ± 57 m), with no other differences between outfield positions. CM covered greater distance in SZ2 than CD and EM, and greater distance in SZ3 than CD, EM, and FW. Distance covered with HSR ranged 132-177 m for the five outfield positions and was greater in FB, CM, and EM than in CD, whereas distance covered with VHSR was in the range 74-110 m and was greater in FB, EM, and FW than in CD (Table 2).

The number of VHSR was higher in EM and FW than in CD, with no other differences between positions, whereas no positional differences were found in peak speed. No

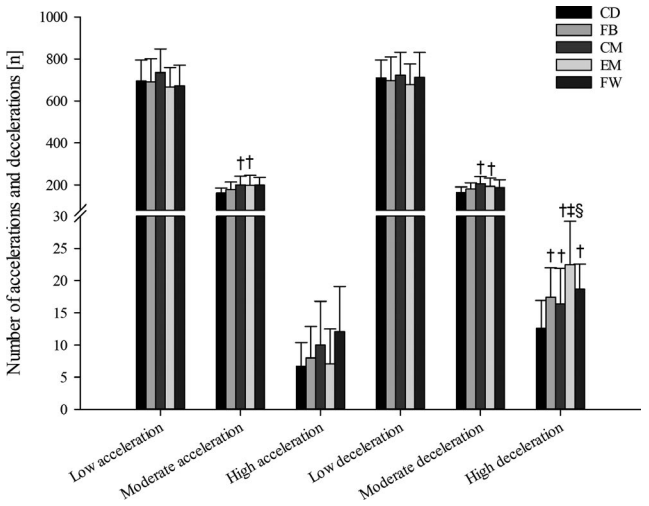

FIGURE 1 Full-game accelerations and decelerations. †Different from central defenders (CD), ‡Different from full-backs (FB), §Different from central midfielders (CM). EM, external midfielders; FW, forwards

difference was observed in accelerations and decelerations, except for a higher number of high decelerations in EM than in CD (3.7 ± 1.0 vs 2.7 ± 0.8) (Table 2).

HR_{mean} and HR_{peak} did not differ between positions, and no difference was observed between positions in percentage time spent in HR zones (Table 2).

3.3 | Comparing the first and second half

Total distance covered did not change from first to second half for CD, FB, EM, and FW, but was 1.7% lower in CM in the second compared to the first half ($P < .05$). In CM, distance covered decreased ($P < .05$) in the second half for SZ2 (5.8%), SZ3 (7.2%), SZ4 (12.0%), and SZ5 (10.3%), whereas distance covered in SZ1 increased (7.5%) and Sprinting was unchanged. In CD, distance covered in SZ1 increased by 5.1% in the second half, with no differences between halves for other speed zones. In EM, a 26.4% decrease in Sprinting was observed, whereas no differences were observed between halves for any speed zone in FB and FW (Table 3). The only time × group interaction observed was for SZ4, and post hoc tests revealed that the change in CM was significantly different ($P < .05$) from the change in FB.

Peak speed did not differ between halves, but a lower number of VHSR was observed for all positions, except FB. The number of low accelerations decreased from first to second half in CM and FW, whereas a decrease in the number of moderate accelerations was observed for CD, CM, and FW. In addition, the number of high accelerations decreased in CM, EM, and FW (Table 3). The number of low decelerations decreased in FB, CM, and FW, whereas the number of moderate decelerations decreased in CD, CM, and FW and the number of high decelerations decreased in the second half in CD, CM, and EM (Table 3).

HR_{mean} as a percentage of maximal HR decreased from first to second half in CD, FB, CM and EM, whereas HR_{peak} as a percentage of maximal HR decreased in all five outfield positions (Figure 2). Time spent in the highest HR zone dropped from first to second half in all positions except FW (Table 3), and time spent in HRZ2 increased for CD, FB, CM and EM.

3.4 | Comparing the first and last 15-minute period

Total distance decreased in all outfield positions from first to last 15-minute period, by 4.9%-12.8% except in FW. Distance covered in SZ2-6 decreased concurrently with an increase in

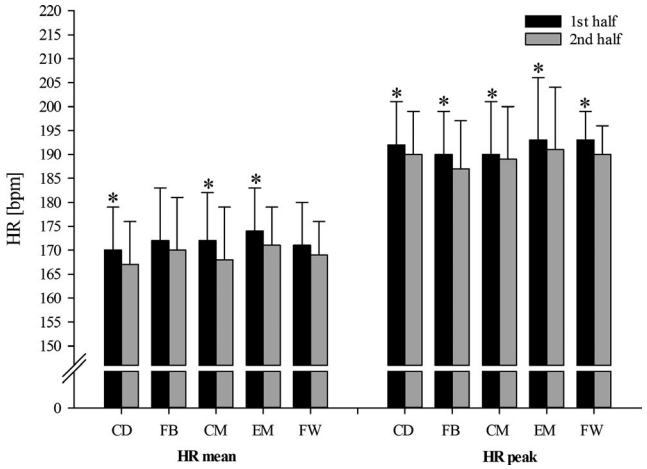

FIGURE 2 First to second half HR mean and HR peak. *Different from second half within group. CD, central defenders; FB, full-backs; CM, central midfielders; EM, external midfielders; FW, forwards

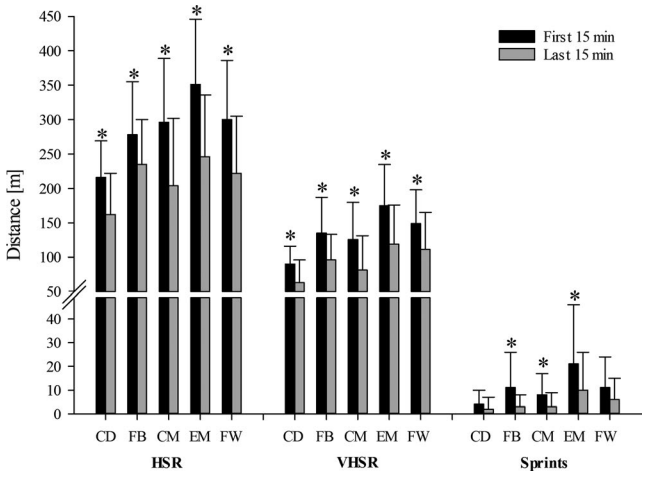

FIGURE 3 First 15-min to last 15-min distance in high-speed running (HSR), very high-speed running (VHSR), and Sprinting. *Different from last 15-min within group. CD, central defenders; FB, full-backs; CM, central midfielders; EM, external midfielders; FW, forwards

distance covered in SZ1 in CM. In EM, distance covered in SZ1 increased, whereas distance covered in SZ3-6 decreased. In FW, distance covered in SZ4 and SZ5 decreased in the last 15-minute period, with no other differences for the position. In CD, distance covered dropped in SZ2, SZ3, SZ4, and SZ5, whereas in FB decrements in the distance covered were observed for SZ2 and SZ5. The number of VHSR decreased in the last 15-minute period in all positions except FB, whereas peak speed dropped markedly (12.7-17.1) in all five outfield positions (Figure 3; Table 4).

The number of low accelerations was lower in the last compared to the first 15-minute period in all five outfield positions, and lower for all except FW in moderate accelerations and for all except FB in high accelerations. The number of low decelerations was also lowered for all except FW, whereas the number of moderate decelerations was lowered for all except EM and the number of high accelerations was lowered for CM and EM (Table 4).

HR_{mean} was 87%-90% of HR_{max} in the first 15-minute period and was not altered for any positions in the last 15-minute period. HR_{peak} reached 95%-96% of HR_{max} during the first 15-minute period, which was not different in the last 15-minute period. Percentage of time spent in the highest heart rate zone was 26%-37% in the first 15-minute period, compared to 22%-31% in the last 15-min period, with only CD being significantly lower in the first compared to the last 15-min period (Table 4).

4 | DISCUSSION

The major findings of the present study were that competitive elite female matches impose very high physical demands on all outfield playing positions, including central defenders, full-backs, central midfielders, external midfielders and forwards, resulting in high aerobic loading throughout matches and marked declines in physical performance toward the end of games. For all outfield playing positions, pronounced decrements were observed in the last 15-minute period of the game in peak speed (~15%), intense accelerations and decelerations (~20%), and intense running bouts (~30%), whereas heart rates were similarly high. Moreover, the present study revealed that the overall physical match demands are much higher for central midfielders, external midfielders, full-backs and forwards, compared to central defenders, with the largest differences observed in the full-game values for high-speed running and sprinting as well as the number of moderate and intense accelerations and decelerations. The physical demands of the most intense 5-minute period of the game were also higher for central midfielders, external midfielders, full-backs and forwards, compared to central defenders, albeit the differences were smaller.

Total distance covered for the various outfield positions was 9274-10 572 m, which is slightly higher,[15] in the same range[6-9,16] or slightly lower[13] than previously reported in elite women's football. The greater total distance covered in FB, CM, and EM than in CD found in the present study is similar to previous findings,[8,15,16] whereas no difference was observed between FW and CM, as observed by Datson and colleagues.[16] The relevance of total distance covered for evaluating physical match performance has been questioned in several studies, as similar total distance covered has been found across playing levels,[7,8] whereas HSR distance varies more between performance level and has been shown to be closely related to fitness and training status.[6]

High-speed running was similar between FB, CM, EM, and FW, all of which were greater than CD (1518 ± 499 to 1786 ± 527 m vs 1088 ± 261 m). For VHSR (>18 km/h), the greatest distance was observed for EM (863 ± 299 m), which was higher than for CD and CM. In addition, FB, CM, and FW covered a greater distance with VHSR than CD. These observations are comparable to previous findings showing the greatest distances covered in the highest speed zones for EM or FW.[9,13,16] Due to differences in speed thresholds, it is difficult to compare values between all studies. However, Bradley and colleagues [13] used similar thresholds and presented slightly higher values for VHSR for all positions, possibly as a result of the higher standard of the matches.

Sprint distance (>25 km/h) did not differ between positions, except for a greater sprint distance in EM than in CD and CM. In the study by Datson and colleagues,[16] shorter sprint distance was found in CD than in all other positions, with no other differences. The lowest sprint distances covered were also observed in CD in the present study, whereas EM and FW displayed the greatest sprint distances, as in the study by Datson and colleagues,[16] though in both studies, the values did not reach statistical significance. Nevertheless, this indicates similar trends in the positional demands of the game. Sprint values were lower in the present study for all positions than those presented in the studies by Bradley and colleagues [13] and Datson and colleagues,[16] which used similar sprint thresholds. This may be due to the difference in the level of the players, as the present study included players from the entire league, whereas these two studies investigated players in international matches and higher match demands have been observed in international compared to domestic matches, especially for highest running speeds.[7] Large variation was observed within each position, and various factors, such as training status, the standard of players, fatigue development, tactical decisions, individual playing style, may influence the demands of the game.[6-8,17]

Preparation for the most intense periods is critical for a high performance level,[20] as these periods are linked to crucial moments such as goalscoring.[21] Data on these intense periods during women's football matches are scarce in the

TABLE 2 Peak 5-min velocity and distances covered, heart rate response, accelerations, and decelerations

	CD	FB	CM	EM	FW
Total distance [m]	625 ± 57 (514-746)	664 ± 47 (554-738)	683 ± 57† (573-861)	658 ± 52 (520-760)	639 ± 74 (505-747)
HSR [m]	132 ± 36 (50-193)	169 ± 37† (84-235)	165 ± 42† (90-314)	177 ± 37† (89-256)	167 ± 32 (71-211)
VHSR [m]	74 ± 20 (16-116)	101 ± 28† (41-164)	91 ± 27 (41-164)	110 ± 24† (27-150)	104 ± 28† (32-161)
Sprinting [m]	12 ± 9 (0-28)	21 ± 14 (0-51)	19 ± 14 (0-53)	29 ± 20† (0-70)	24 ± 18 (0-60)
Peak speed [km/h]	27.5 ± 2.3 (23.7-31.8)	28.2 ± 2.3 (23.9-32.0)	27.8 ± 2.0 (23.7-32.7)	27.6 ± 2.1 (22.9-31.3)	29.2 ± 3.2 (25.1-36.1)
HR mean [bpm]	181 ± 8 (165-198)	182 ± 10 (161-198)	181 ± 11 (158-198)	183 ± 9 (166-203)	182 ± 7 (170-191)
HR mean % of HR max	93 ± 3 (88-98)	95 ± 2 (89-97)	94 ± 3 (86-97)	94 ± 3 (86-98)	93 ± 3 (85-96)
HR peak [bpm]	192 ± 9 (172-216)	190 ± 9 (171-206)	190 ± 11 (169-208)	193 ± 13 (176-235)	194 ± 6 (185-204)
HR peak % of HR max	99 ± 2 (93-100)	100 ± 1 (97-100)	99 ± 2 (94-100)	99 ± 1 (96-100)	99 ± 1 (96-100)
% of total time with HR 160-180 bpm	84 ± 14 (54-100)	86 ± 12 (61-100)	84 ± 18 (38-100)	85 ± 15 (51-100)	85 ± 14 (61-100)
% of total time with HR >180 bpm	58 ± 31 (0-100)	73 ± 38 (0-100)	74 ± 33 (0-100)	64 ± 35 (0-99)	65 ± 31 (1-100)
High accelerations [n]	2.4 ± 1.2 (1-6)	2.3 ± 1.0 (1-5)	2.3 ± 1.1 (0-4)	1.9 ± 1.6 (0-6)	2.6 ± 1.4 (0-4)
Sum of accelerations [n]	71 ± 12 (54-87)	65 ± 11 (56-91)	71 ± 10 (57-94)	69 ± 12 (55-83)	70 ± 6 (56-98)
High decelerations [n]	2.7 ± 0.8 (1-4)	3.2 ± 0.9 (2-5)	3.3 ± 1.0 (2-5)	3.7 ± 1.0† (2-6)	3.6 ± 1.0 (2-5)
Sum of decelerations [n]	73 ± 11 (54-87)	67 ± 10 (56-91)	71 ± 11 (57-94)	71 ± 10 (55-83)	69 ± 8 (56-98)

Note: Mean ± SD and range (min-max).

Abbreviations: CD, central defenders; FB, full-backs; CM, central midfielders; EM, external midfielders; FW, forwards.

†Different from CD.

scientific literature. 13%-17% of total distance covered with VHSR and 32%-63% of total distance covered with sprinting were observed during the most intense 5-minute period of the game, though a 5-minute period equates to approximately 5.6% of total playing time. This highlights the importance of preparing for the most intense periods and not using averages of whole-match values. When analyzing differences between positions, only CD stands out in intense running speed, with lower distance in sprinting than EM, lower VHSR than FB, EM, and FW, and lower HSR distance than FB, CM, and EM. Thus, only minor differences between positions were observed during the most intense periods. Values for peak 5-minute periods may, however, have been underestimated by up to 25%, since data were analyzed in predefined 5-minute periods and not rolling averages.[22,23] Overall, the present values for HSR are similar to those for players participating in the Champions League.[13]

HR_{mean} was 87%-89% of HR_{max} and HR_{peak} was 98%-99% of HR_{max}, which for both variables is similar to or slightly higher than previously reported in female players.[6,12,17] In the present study, individual HR_{max} was obtained as the highest HR during matches or Yo-Yo IR1 testing. Only 62 of the 95 players included completed the Yo-Yo IR1 test, and of these 62 players a total of 57 had their highest heart rate measured during the Yo-Yo IR1 test. Thus, higher HR_{max} may have been obtained if more players had completed the Yo-Yo testing, leading to a slightly lower relative heart rate. Time spent with high heart rate was high, with 26%-35% of the total time

TABLE 3 First to second half velocity and distances covered, heart rate response, accelerations, and decelerations

		CD	FB	CM	EM	FW
Total distance [m]	1st	4663 ± 400	5031 ± 405	5283 ± 481*	5283 ± 481	4906 ± 560
		(3968-5291)	(4438-5685)	(4747-6396)	(4108-6035)	(4180-5932)
	2nd	4611 ± 394	5022 ± 286	5193 ± 544	5236 ± 524	4839 ± 483
		(3834-5257)	(4606-5400)	(3232-6427)	(4250-6449)	(4246-5852)
HSR [m]	1st	560 ± 133	768 ± 201	804 ± 252*	923 ± 242*	813 ± 173
		(327-818)	(574-1208)	(402-1715)	(567-1433)	(583-1029)
	2nd	528 ± 144	761 ± 195	714 ± 261	863 ± 304	748 ± 221
		(246-832)	(513-1051)	(393-1655)	(476-1484)	(436-1034)
VHSR [m]	1st	232 ± 56	367 ± 131	328 ± 129*	459 ± 158*	383 ± 95
		(124-345)	(221-671)	(110-714)	(241-745)	(240-539)
	2nd	210 ± 87	350 ± 121	295 ± 134	404 ± 169	354 ± 136
		(49-406)	(178-538)	(141-667)	(111-731)	(132-577)
Sprinting [m]	1st	10 ± 11	26 ± 25	17 ± 14	53 ± 52*	28 ± 23
		(0-37)	(0-96)	(0-51)	(0-167)	(0-68)
	2nd	9 ± 9	19 ± 26	16 ± 20	39 ± 39	28 ± 24
		(0-27)	(0-103)	(0-80)	(0-98)	(0-81)
Peak speed [km/h]	1st	25.9 ± 2.0	27.0 ± 2.1	26.3 ± 1.7	27.1 ± 2.0	27.5 ± 2.3
		(21.8-30.6)	(23.7-32.0)	(22.2-28.7)	(22.9-30.3)	(24.6-31.2)
	2nd	25.5 ± 1.7	26.4 ± 1.5	25.8 ± 1.9	26.4 ± 1.9	27.4 ± 2.0
		(22.7-28.5)	(23.2-28.9)	(21.7-30.4)	(22.8-28.8)	(23.8-30.1)
HR mean [bpm]	1st	170 ± 9*	172 ± 11	172 ± 10*	174 ± 9*	171 ± 9
		(157-189)	(141-186)	(147-188)	(156-189)	(161-187)
	2nd	167 ± 9	170 ± 11	168 ± 11	171 ± 8	169 ± 7
		(151-184)	(147-186)	(145-186)	(156-186)	(157-184)
HR mean % of HR max	1st	88 ± 4*	90 ± 4*	90 ± 3*	89 ± 4*	87 ± 3
		(79-95)	(77-94)	(83-93)	(78-94)	(81-94)
	2nd	86 ± 4	89 ± 3	88 ± 3	88 ± 4	86 ± 4
		(77-93)	(81-93)	(77-93)	(77-92)	(79-92)
HR peak [bpm]	1st	192 ± 9*	190 ± 9*	190 ± 11*	193 ± 13*	193 ± 6*
		(172-216)	(171-204)	(169-208)	(176-235)	(184-204)
	2nd	190 ± 9	187 ± 10	189 ± 11	191 ± 13	190 ± 6
		(170-207)	(166-206)	(165-207)	(174-234)	(175-197)
HR peak % of HR max	1st	98 ± 2*	99 ± 1*	98 ± 2*	99 ± 1*	98 ± 3*
		(92-100)	(96-100)	(91-100)	(95-100)	(91-100)
	2nd	97 ± 3	98 ± 1	98 ± 2	98 ± 2	97 ± 4
		(89-100)	(95-100)	(91-100)	(95-100)	(87-100)
% of total time with HR 160-180 bpm	1st	50 ± 17	45 ± 21	43 ± 20*	50 ± 16	48 ± 20
		(8-79)	(12-75)	(9-86)	(22-86)	(11-71)
	2nd	50 ± 14	50 ± 21	48 ± 19	55 ± 18	51 ± 11
		(26-74)	(13-86)	(15-80)	(27-85)	(29-67)
% of total time with HR >180 bpm	1st	29 ± 26*	37 ± 29*	41 ± 27*	34 ± 24*	32 ± 28
		(0-88)	(0-86)	(0-84)	(0-78)	(0-89)
	2nd	22 ± 25	28 ± 26	30 ± 23	25 ± 21	25 ± 20
		(0-70)	(0-78)	(0-80)	(0-69)	(0-71)

(Continues)

TABLE 3 (Continued)

		CD	FB	CM	EM	FW
High accelerations [n]	1st	3.8 ± 2.1 (0-9)	4.4 ± 3.0 (1-11)	5.9 ± 4.4* (0-19)	4.8 ± 4.0* (0-16)	7.6 ± 5.1* (0-19)
	2nd	2.9 ± 2.2 (0-8)	3.6 ± 2.4 (2-12)	4.1 ± 2.9 (0-1)	2.3 ± 1.9 (0-7)	4.6 ± 2.7 (0-8)
Sum of accelerations [n]	1st	441 ± 61* (338-565)	445 ± 70 (369-634)	487 ± 71* (389-643)	442 ± 71 (327-601)	462 ± 95* (355-666)
	2nd	423 ± 57 (344-578)	432 ± 70 (350-614)	458 ± 73 (303-619)	428 ± 48 (351-531)	422 ± 40 (346-474)
High decelerations [n]	1st	7.0 ± 2.6* (2-12)	9.0 ± 3.5 (2-15)	9.4 ± 3.7* (5-18)	12.5 ± 3.7* (7-22)	10.0 ± 2.6 (5-13)
	2nd	5.5 ± 2.7 (0-12)	8.4 ± 2.5 (5-14)	7.0 ± 2.8 (1-12)	10.0 ± 3.5 (1-16)	8.9 ± 2.2 (4-12)
Sum of decelerations [n]	1st	452 ± 55 (353-578)	454 ± 75 (352-635)	486 ± 73* (383-631)	456 ± 66* (332-564)	480 ± 104* (370-708)
	2nd	435 ± 50 (345-555)	440 ± 68 (339-591)	460 ± 68 (342-602)	437 ± 61 (338-565)	441 ± 56 (342-545)

Note: Mean ± SD and range (min-max).

Abbreviations: CD, central defenders; FB, full-backs; CM, central midfielders; EM, external midfielders; FW, forwards.

*Different from second half within group.

spent with HR above 180 bpm. This demonstrated that the external load highly taxes the players' aerobic system. No differences were found between positions in HR_{mean}, HR_{peak} or percentage of time in HR zones, as also described by Krustrup and colleagues,[6] indicating that the players' training status matches their match demands, as minor differences were found between positions in external load.

To evaluate fatigue development and changes during the game, we compared the first and second halves as well as the first and last 15-minute periods. A decrease in total distance was only observed in CM, whereas 6%-11% and 10%-12% drops were observed in HSR and VHSR for both midfield positions, underpinning that these positions have the overall highest match demands (figure 3). Fluctuations in external load throughout the match were evident for all positions, with all having lower HSR and VHSR in the last 15-minute period compared to the first, whereas all except FW experienced a decrease in total distance. This is in agreement with previous studies showing lower distance covered at the end compared to the beginning of the match.[7,8,13,15,16] A drop in the number of low, moderate, and high accelerations and decelerations was also observed for some of the positions. A drop in acceleration and deceleration performance toward the end of a match has also been observed in men.[24] These observations support the observation that football players' capacity to perform is decreased likely as a result of fatigue toward the end of a match.

Despite covering less distance in total and in HSR and VHSR, performing fewer intense runs and lower peak speed, all indicating lower intensity, heart rate response did not differ between the first and last 15-minute periods. This may be due to a deteriorated fluid balance and lowering of plasma volume leading to a higher HR to maintain cardiac output.[25] HR_{mean} and HR_{peak} were, though, slightly lower in the second than in the first half, and less time was spent in the higher HR zones for more positions.

Even though this study is the first large-scale study to present data on external and internal load in women's football for an entire league, the study has a few limitations that should be acknowledged. Only two thirds of the participants completed the Yo-Yo test, and since 92% of those completing the Yo-Yo test obtained their highest HR during the test, this may have influenced the relative HR measurements. Heart rate should be related to individual HR_{max}, and individualized HR zones would have been preferable to absolute values. Due to limitations in the software, this was unfortunately not possible. Individualized thresholds for external load have also been debated by a number of researchers,[26-28] but were not applied in the current study. Moreover, analyses were performed using predefined 5-minute periods and not rolling averages, which may have limited the values in peak 5-minute periods.[22,23] Positional data were collected using Polar Team Pro system, which has only undergone few independent scientific validity and reliability tests.[18,19] In an internal validity test of Polar Team Pro system against other more thoroughly validated systems (Tracab and ZXY, Chyron Hego), Polar Team Pro was considered valid and

TABLE 4 First 15 min to last 15 min velocity and distances covered, heart rate response, accelerations and decelerations

		CD	FB	CM	EM	FW
Total distance [m]	First 15 min	1572 ± 134*	1673 ± 125*	1796 ± 201*	1743 ± 175*	1571 ± 210
		(1302-1904)	(1493-2012)	(1486-2535)	(1230-2077)	(1243-1930)
	Last 15 min	1396 ± 124	1544 ± 132	1556 ± 270	1583 ± 137	1494 ± 157
		(1123-1591)	(1310-1805)	(385-1906)	(1371-1810)	(1306-1809)
HSR [m]	First 15 min	216 ± 53*	278 ± 77*	296 ± 93*	351 ± 95*	300 ± 86*
		(107-324)	(160-408)	(100-551)	(240-553)	(179-418)
	Last 15 min	162 ± 60	235 ± 65	204 ± 98	246 ± 90	222 ± 83
		(71-257)	(125-352)	(25-485)	(95-395)	(88-327)
VHSR [m]	First 15 min	90 ± 26*	135 ± 52*	126 ± 54*	175 ± 60*	149 ± 49*
		(39-148)	(61-266)	(18-243)	(81-283)	(75-222)
	Last 15 min	63 ± 33	96 ± 37	81 ± 50	119 ± 57	111 ± 54
		(14-122)	(38-171)	(3-203)	(18-227)	(23-183)
Sprinting [m]	First 15 min	4 ± 6	11 ± 15*	8 ± 9*	21 ± 25*	11 ± 13
		(0-25)	(0-53)	(0-37)	(0-85)	(0-42)
	Last 15 min	2 ± 5	3 ± 5	3 ± 6	10 ± 16	6 ± 9
		(0-16)	(0-20)	(0-22)	(0-48)	(0-22)
Peak speed [km/h]	First 15 min	24.7 ± 1.9*	25.4 ± 2.1*	25.2 ± 1.8*	25.9 ± 1.7*	26.2 ± 2.5*
		(20.9-28.3)	(20.3-29.1)	(20.3-28.0)	(22.9-28.7)	(21.9-31.2)
	Last 15 min	20.8 ± 1.5	22.0 ± 1.5	20.9 ± 2.8	22.6 ± 1.8	22.1 ± 1.9
		(18.3-24.6)	(19.6-24.6)	(8.9-24.6)	(18.7-25.1)	(17.8-24.6)
HR mean [bpm]	First 15 min	169 ± 10	171 ± 11	170 ± 11	172 ± 11	168 ± 9
		(153-189)	(142-188)	(147-191)	(150-187)	(157-186)
	Last 15 min	167 ± 10	170 ± 11	169 ± 13	172 ± 7	171 ± 8
		(142-184)	(149-187)	(130-187)	(160-187)	(158-185)
HR mean % of HR max	First 15 min	87 ± 4	90 ± 4	89 ± 3	89 ± 4	86 ± 4
		(80-94)	(78-95)	(83-94)	(79-95)	(79-94)
	Last 15 min	86 ± 5	89 ± 3	88 ± 5	89 ± 4	87 ± 4
		(72-95)	(82-94)	(66-93)	(76-95)	(79-93)
HR peak [bpm]	First 15 min	184 ± 9	184 ± 10	183 ± 11	187 ± 12	185 ± 8
		(169-203)	(162-200)	(162-203)	(168-219)	(171-197)
	Last 15 min	183 ± 8	183 ± 10	182 ± 12	185 ± 9	185 ± 7
		(167-202)	(165-201)	(152-199)	(172-214)	(170-195)
HR peak % of HR max	First 15 min	95 ± 3	96 ± 2	95 ± 2	96 ± 2	95 ± 3
		(87-99)	(89-99)	(90-99)	(92-100)	(86-98)
	Last 15 min	94 ± 3	96 ± 2	95 ± 4	95 ± 2	95 ± 4
		(86-99)	(91-98)	(78-98)	(91-98)	(85-99)
% of total time with HR 160-180 bpm	First 15 min	48 ± 17	45 ± 24	43 ± 23	47 ± 16	45 ± 18
		(10-74)	(10-77)	(5-82)	(12-73)	(11-66)
	Last 15 min	50 ± 17	50 ± 25	46 ± 22	57 ± 18†	49 ± 17
		(19-77)	(4-95)	(7-81)	(28-82)	(24-79)
% of total time with HR >180 bpm	First 15 min	28 ± 28*	35 ± 29	37 ± 28	33 ± 27	26 ± 28
		(0-86)	(0-90)	(0-90)	(0-80)	(0-88)
	Last 15 min	22 ± 27	30 ± 30	31 ± 25	25 ± 24	28 ± 24
		(0-79)	(0-96)	(0-82)	(0-72)	(0-71)

(Continues)

TABLE 4 (Continued)

		CD	FB	CM	EM	FW
High accelerations [n]	First 15 min	1.7 ± 1.5* (0-6)	1.3 ± 1.3 (0-4)	1.8 ± 1.3* (0-5)	1.8 ± 2.1* (0-9)	2.9 ± 2.2* (0-6)
	Last 15 min	0.9 ± 0.9 (0-3)	0.9 ± 0.8 (0-3)	1.1 ± 1.0 (0-4)	0.6 ± 0.6 (0-2)	1.3 ± 0.9 (0-3)
Sum of accelerations [n]	First 15 min	146 ± 18* (109-190)	149 ± 22* (123-220)	160 ± 22* (123-204)	144 ± 23* (98-182)	143 ± 24* (118-188)
	Last 15 min	127 ± 17 (99-170)	128 ± 19 (88-162)	136 ± 27 (48-186)	128 ± 15 (105-160)	128 ± 15 (106-156)
High decelerations [n]	First 15 min	2.3 ± 1.3 (0-6)	3.3 ± 1.7 (0-6)	3.1 ± 1.4* (1-6)	4.8 ± 2.4* (2-10)	3.5 ± 2.0 (0-6)
	Last 15 min	1.6 ± 1.3 (0-5)	2.6 ± 1.2 (1-6)	2.0 ± 1.2 (0-4)	3.1 ± 2.1 (0-8)	2.8 ± 1.4 (1-5)
Sum of decelerations [n]	First 15 min	150 ± 18* (114-200)	151 ± 23* (118-214)	160 ± 23* (121-215)	149 ± 18* (109-172)	149 ± 23* (126-196)
	Last 15 min	133 ± 15 (92-169)	130 ± 20 (98-165)	136 ± 27 (55-178)	131 ± 22 (94-175)	135 ± 19 (99-177)

Note: Mean ± SD and range (min-max).

Abbreviations: CD, central defenders; FB, full-backs; CM, central midfielders; EM, external midfielders; FW, forwards.

*Different from last 15-min within group.

†Different from CD delta values.

reliable for measuring distances covered during longer periods, whereas decreasing validity and reliability was observed for high speeds and short periods as observed for other tracking systems (data not shown—Elstrup, personal communication). A major strength in the present study is that all 8 teams from the Danish Women's League were included; hence, a large sample size could be used for analysis. However, due to methodological decisions on inclusion and exclusion criteria, some positional subgroups had more than a two-fold sample size compared to other subgroups. This may potentially have influenced statistical analysis, where the lack of a significant finding may have been due to low statistical power.

5 | CONCLUSION

Taken together, the present study revealed that competitive elite female matches are highly physically demanding for all outfield playing positions, with high aerobic loading throughout matches, multi-sprint peak-intensity periods and marked declines in high-speed running, peak speeds and intense accelerations and decelerations toward the end of games. The overall physical match demands are much lower for central defenders than for the four other outfield playing positions, though this difference is minimized in peak-intensity periods.

6 | PERSPECTIVES

The results of the present study clearly emphasize the relevance of monitoring physical match demands for the entire game, but also with a specific focus on the peak-intensity periods and the final periods of the game. The high and multifaceted physical demands placed on all outfield positions during competitive elite female games highlight the importance of proper physical preparation and recovery strategies to be able to cope with the demands. Coaches should pay certain attention to individualized position-specific physical demands in relation to the team's tactical plan and secure a proper training stimulus related to the individual players movement pattern. Moreover, special emphasis on preparation for peak periods (worst-case scenarios) is important.

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CONFLICTS OF INTEREST

Peter Krustrup is employed by the Danish Football Association as Fitness Coach for the Danish Women's national team.

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