BMC Sports Science, Medicine and Rehabilitation

RESEARCH

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Optimizing position-specific preparation: Long-term pre-match warm-up external load analysis using micro-sensor integrated LPS in elite female volleyball players

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Abstract

Background Although it is known that determining the external loads during matches and training is essential for coaches to understand game demands, optimize and specify players' performance, or avoid overtraining or overload scenarios, it has been observed that the pre-match warm-up external load is neglected. The aims of this study were (i) assess the pre-match warm-up external load for female volleyball players and (ii) compare this load by player position.

Methods External loads (total distance, jump count, acceleration (ACC), deceleration (DEC), ACC_{max}, DEC_{max}, ACC/min, $speed_{max}$, metabolic load) of fourteen elite female volleyball players during pre-match warm-up were monitored with Local Positioning System (LPS) for a season and separated according to player positions (libero (L), outside hitter (OH), opposite (OPP), middle blocker (MB), setter (S)).

Results Elite female volleyball players performed 888.1–1078.5 m total distance, 15.9–85.3 jumps (excluding L: 7.6 jumps), 18.5–31.8 ACC and 10.4–28.2 DEC counts, 13.1–15.3 $m.sec^{-1}$ $speed_{max}$ and 214.2–406.0 m metabolic load during the pre-match warm-up. While S had significantly higher total distance, jump count, ACC and DEC count, ACC_{max}, ACC/min and $speed_{max}$ (η^2: large, $p < .001$), OH and OPP had the highest metabolic load (η^2: large, $p < .001$). L had significantly higher ACC_{max} and DEC_{max}, $speed_{max}$ data accompanied by significantly lower total distance, ACC count and metabolic load (η^2: large, $p < .001$).

Conclusion External load metrics during pre-match warm-up in female volleyball players showed clear positional differences. These findings highlight the need for coaches and strength and conditioning professionals to design role-specific warm-up strategies that reflect the physical demands of each position. By tailoring pre-match preparation in this way, practitioners may better optimize readiness, reduce the risk of fatigue or overload, and improve subsequent match performance.

Keywords Local positioning system, Pre-match warm-up load, Player position demands, Acceleration–deceleration metrics, Elite female volleyball

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Introduction

Volleyball is an interval sport discipline characterized by short-term high-intensity actions, followed by short-term rest intervals and rallies that include sprinting, jumping, shuffling and diving movements [1–4]. During volleyball game actions, repetitive high jumps, multi-directional movements and sudden acceleration and deceleration in a short time are required [5, 6]. Considering the existing literature, it appears that volleyball is a sport that requires high vertical load [1, 7, 8]. Volleyball players perform an average of 42–92 jumps per hour in training, 47–67 jumps per hour in match [9], and 70–136 jumps per match [10, 11].

In a sports discipline such as volleyball, where jumping, change of direction and sprinting are often intense, game demands lead to various external loads [8] and therefore monitoring is vital [12]. External load is a metric that includes player movement tracking, distance covered, power output, jumping and sprinting [12–15], and refers to the total amount of locomotive or mechanical stress an athlete produces during exercise [16]. External load, which includes the volume, intensity and type of physical work an athlete performs during training or competition, has profound effects on a player's performance [13]. These loads are highly variable due to the unpredictable structure and dynamic nature of the volleyball game and the specific tasks of player positions [8]. In volleyball, as in other team sports, positional differences are a critical factor in achieving success [17], and specific positions such as MB, L, S, OPP and OH have their own unique external load demands [18].

Although there is no counter movement jump and squat jump difference between player positions in female volleyball players [17], the fact that Ss have lower jump heights -submaximal- but more jumps than MB and OH (179.9, 123.3, 141.7 jumps in a training session, respectively) [19], that MBs have the highest jump load and Ss have the lowest jump load in male volleyball players during training monitoring, and that OH and OPP have similar jump loads [3], indicates that there is a difference in the intensity of external loads in these roles [6, 10]. Focusing only on jumping is not a correct approach to determining external load in volleyball. Because volleyball also includes high intensity intermittent multi-directional movements in displacements to cover short or very short distances [14]. However, the jump load of liberos is at a negligible level. This brings the need to determine positional requirements. On the other hand, in elite women's volleyball, the highest significant total distance in a training session was in OHs (3694.4 ± 1023.4 m), followed by OPPs, Ss, MBs and Ls, respectively. In a training session, female volleyball players cover an average of 3065–3694 m distance, and Ls have the highest significant ACC_{max} and DEC_{max} [1].

Warm-up is a protocol specifically implemented to prepare athletes for the beginning of subsequent physical tasks, which may be a training session or competition [20]. Such routines aims to increase neural activation and elevate core and skeletal muscle temperature to increase blood flow and optimize metabolic responses during exercise [21]. In team sports, these preparatory activities are considered essential for improving acute explosive performance. During both training and competition, structured routines have been suggested to play a critical role in enhancing readiness for the upcoming effort and, consequently, maximizing performance [22]. In volleyball, external load of match [4, 9, 12, 18, 23, 24], and external load of training have been frequently studied [1, 5, 6, 25, 26]. Most of the studies examining external load in volleyball are on jumping [2, 3, 7, 10, 16, 19, 27]. There are limited studies examining the pre-match warm-up load in soccer [20], and futsal [28]. These studies may be important in recognizing the effective warm-up intensity and volume to determine pre-match external load. In this sense, tailoring the pre-activity phase in volleyball can allow coaches to align demands more precisely with the strengths and weaknesses of specific playing positions.

Although it is known that monitoring the adaptive responses of athletes in training and match throughout the season is very important to achieve optimal performance [18, 26], it has been observed that pre-match warm-up load monitoring in volleyball is neglected. Considering that jump load is a predominant determinant metric in volleyball, it is known that 21–179 jumps are performed during training and 50–136 jumps are performed during match, but it may be interesting to consider whether the match external load added to the pre-match external load exceeds the external load experienced in training and whether this leads to a possible decrease in performance or fatigue. From a practice perspective, this research, which is the first on external load monitoring in pre-match warm-up in volleyball, offers a multidimensional approach; this approach highlights role-specific demands and general match warm-up demands. The element that makes this research unique is the detailed examination of the pre-match warm-up load, which has not been adequately addressed before. In this context, our study contributes to the understanding of external loads that occur during warm-up for different player positions, thus bringing an important innovation to the literature in the field of warm-up load monitoring in volleyball. In particular, there is a lack of pre-game warm-up external load data in volleyball players. Therefore, the aims of this study were (i) to determine the pre-match warm-up external load of female volleyball players, and (ii) to compare the pre-match warm-up external load by playing positions. We hypothesized that

the pre-match warm-up external load for female volleyball players would differ depending on player positions.

Methods

Participants

The participant group comprised 14 elite female volleyball players, including 4 OHs (age: 26.5 ± 4.4 y, height: 183.8 ± 4.5 cm, body mass (BM): 72.0 ± 12.2 kg, mean ± SD), 4 MBs (age: 27.5 ± 3.7 y, height: 192.3 ± 7.5 cm, BM: 79.3 ± 10.3 kg), 2 OPPs (age: 28.5 ± 7.8 y, height: 194.0 ± 0.0 cm, BM: 76.5 ± 9.2 kg), 2 Ss (age: 24.5 ± 2.1 y, height: 183.0 ± 1.4 cm, BM: 71.5 ± 9.2 kg), and 2 Ls (age: 26.5 ± 0.7 y, height: 170.5 ± 3.5 cm, BM: 64.5 ± 3.5 kg), all competing at the highest level in the 2022–2023 Turkish Women's Sultans League and European leagues, and were national team players. Athletes were excluded if they were unable to participate due to injuries, illness, or pre-existing cardiovascular or metabolic conditions. The authors were able to access information that could identify individual participants after data collection with official permission from the volleyball club. Written informed consent was obtained from all players before the study. The study was conducted in accordance with the latest version of the Declaration of Helsinki and was also approved by the Local Ethics Committee (Research Code: 2023 – 536).

Study design

This research conducted a one-season longitudinal study design to examine a single female professional team to analyze warm-up data from 18 official home matches played over 32 weeks during an 8-month competitive season in the 2022–2023 Turkish Women's Sultans League and European League season. The pre-match warm-up protocol consists of a series of activities lasting a total of 45 min. The standardized warm-up protocol performed prior to matches, including both physical and technical components. In the initial phase, players completed 20 min of stretching, mobility exercises, core and hip activation, and dynamic stretching routines. This was followed by line drills to finalize the physical preparation, after which players engaged in approximately 5 min of paired ball passing. In the subsequent phase, three players performed defensive and setting drills, while the other players simultaneously executed serving, passing, and short-court attacking drills (5 min). The final phase consisted of structured offensive and serving drills, including 4 min of attacking from position 4, 4 min of attacking from position 2, and 2 min of serving practice, which concluded the warm-up protocol. The data were monitored by an athletic performance specialist.

External match loads were measured using the KINEXON ONE system (KINEXON, GMBH, Precision Technologies, Munich, Germany), a Local Positioning System (LPS) with wearable sensors that transmit real-time data to anchors around the court (Fig. 1a). This system enables precise tracking of players' movements, capturing data on position, speed, acceleration, and other kinematic metrics. During pre-match warm-ups, players wore the LPS units in a specially designed vest between the shoulder blades (Fig. 1b), ensuring consistent sensor placement for accurate data collection.

External load

The dataset includes pre-match warm-up measurements from an LPS for a professional women's volleyball team of 14 athletes, collected over 18 matches. Since the primary focus of the study was the pre-match warm-up phase, external loads were monitored for all players, independent of their subsequent participation in the match. This approach reflects the natural structure of volleyball, in which every player completes the warm-up routine regardless of being included in the starting six. No players were excluded, and no missing data occurred during the monitoring process. Metrics recorded were total distance (m), jump count, ACC, DEC, metabolic

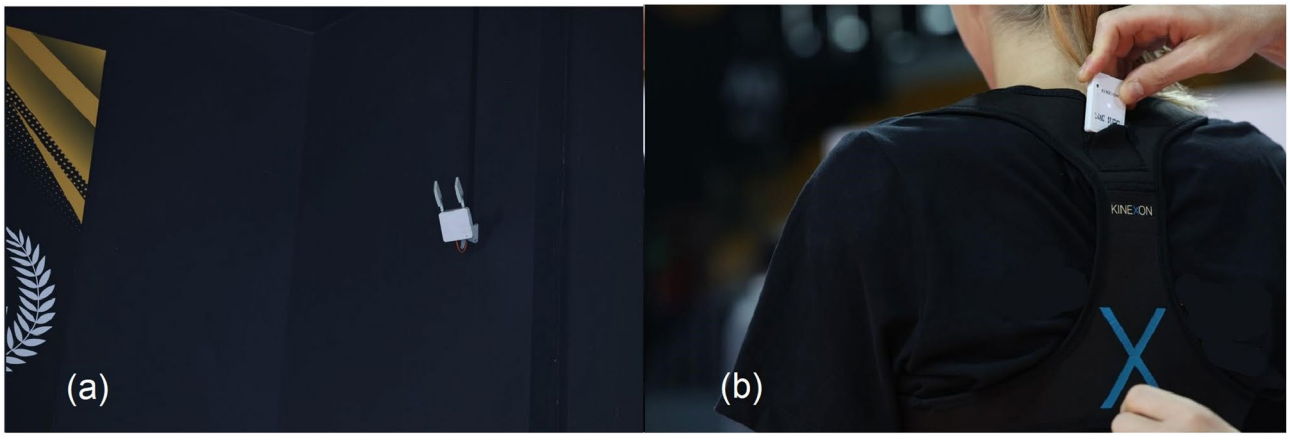


Fig. 1 KINEXON ONE System Technologies locations in the volleyball hall (**a**) and KINEXON LPS device on the player (**b**)

load, ACC_{max} ($m.sec^{-2}$), DEC_{max} ($m.sec^{-2}$), $speed_{max}$ ($m.sec^{-1}$), and ACC/min. Among the 14 players, the team included 2 Ls, 4 MBs, 4 OHs, 2 Ss, and 2 OPPs, providing a detailed dataset on position-specific physical demands and external loads.

Data analysis

Data normality was tested using the Shapiro-Wilk test. Descriptive statistics (mean ± SD) were calculated to determine the pre-match warm-up external load of female volleyball players. External load comparisons by player positions used one-way ANOVA and Holm-Sidak multiple comparisons. Partial eta squared effect sizes (η^2) were classified as small (0.01), moderate (0.06), and large (0.14) [29]. The data analysis was performed using SigmaPlot 11.0 (Systat Software, Inc., San Jose, USA), with significance set at 0.05.

Results

Total distance and jump counts of elite female volleyball players during the pre-match warm-up are presented in Fig. 2. S players have the highest significant total distance (1078.5 ± 76.8 m). This is followed by OH (1067.9 ± 81.8 m), MB (992.2 ± 66.0 m), OPP (952.7 ± 67.8 m) and L (888.1 ± 70.4 m) respectively (Fig. 2a). S players have significantly higher total distance than L ("large" F = 63.49, $\eta^2 = 0.638$), OPP ("large" F = 28.6, $\eta^2 = 0.443$) and MB ("large" F = 13.77, $\eta^2 = 0.277$), while OH has significantly higher total distance than L ("large" F = 52.76, $\eta^2 = 0.594$), OPP ("large" F = 22.32, $\eta^2 = 0.383$) and MB ("large" F = 9.85, $\eta^2 = 0.215$), and MB and OPP have significantly higher total distance than L players (MB-L: "large" F = 22.05, $\eta^2 = 0.380$, OPP-L: "large" F = 8.30, $\eta^2 = 0.187$, respectively). Regarding the jump counts, S had the highest jump counts (85.3 ± 16.5) while L had the lowest (7.6 ± 3.0) (Fig. 2b). OH 23.3 ± 2.9, OPP 15.9 ± 1.8, MB 23.3 ± 3.1 reached the average jump counts in the pre-match warm-up. S had significantly higher jump counts than other player positions (S-L: "large" F = 412.25, $\eta^2 = 0.920$, S-OH: "large" F = 264.1, $\eta^2 = 0.880$, S-OPP: "large" F = 335.47, $\eta^2 = 0.903$, S-MB: "large" F = 264.63, $\eta^2 = 0.880$).

S have significantly higher ACC and DEC counts during the pre-match warm-up period (ACC: 31.8 ± 3.5, S-MB: "large" F = 173.63, $\eta^2 = 0.828$, S-L: "large" F = 104.35, $\eta^2 = 0.743$, S-OPP: "large" F = 60.13, $\eta^2 = 0.625$, DEC: 28.2 ± 4.2, S-OH: "large" F = 252.26, $\eta^2 = 0.875$, S-MB: "large" F = 226.82, $\eta^2 = 0.863$, S-OPP: "large" F = 183.64, $\eta^2 = 0.836$, S-L: "large" F = 122.07, $\eta^2 = 0.772$). It was also found that OH had significantly higher ACC counts than MB ("large" F = 52.20, $\eta^2 = 0.592$) and L ("large" F = 28.54, $\eta^2 = 0.442$), and OPP had significantly higher ACC counts than MB ("large" F = 28.43, $\eta^2 = 0.441$, Fig. 3a), while L had significantly higher DEC counts than OH ("large" F=11.16, $\eta^2 = 0.237$) and MB ("large" F = 6.27, $\eta^2 = 0.148$), and OPP had significantly higher DEC counts than OH ("large" F = 7.64, $\eta^2 = 0.175$, Fig. 3b).

S and L reached significantly higher ACC_{max} (Fig. 3c) and DEC_{max} (Fig. 3d) (S and L, respectively; ACC_{max}: 2.97 ± 0.29 and 2.78 ± 0.25 $m.sec^{-2}$, DEC_{max}: -2.60 ± 0.32 and − 2.77 ± 0.40 $m.sec^{-2}$, mean ± SD) during the pre-match warm-up, the lowest ACC_{max} belonged to MB (2.30 ± 0.22 $m.sec^{-2}$), and the lowest DEC_{max} belonged to OH (-2.08 ± 0.23 $m.sec^{-2}$). S and L have significantly higher ACC/min (S and L, respectively: 0.92 ± 0.05 and 0.85 ± 0.05 total/min, mean ± SD, Fig. 3e) and $speed_{max}$ (S and L, respectively: 15.3 ± 1.2 vs. 15.2 ± 1.4 $m.sec^{-1}$, mean ± SD, Fig. 3f).

OH players had a significantly higher metabolic load (OH: 406.0 ± 46.7 m, OH -L: "large" F = 159.44, $\eta^2 = 0.816$,

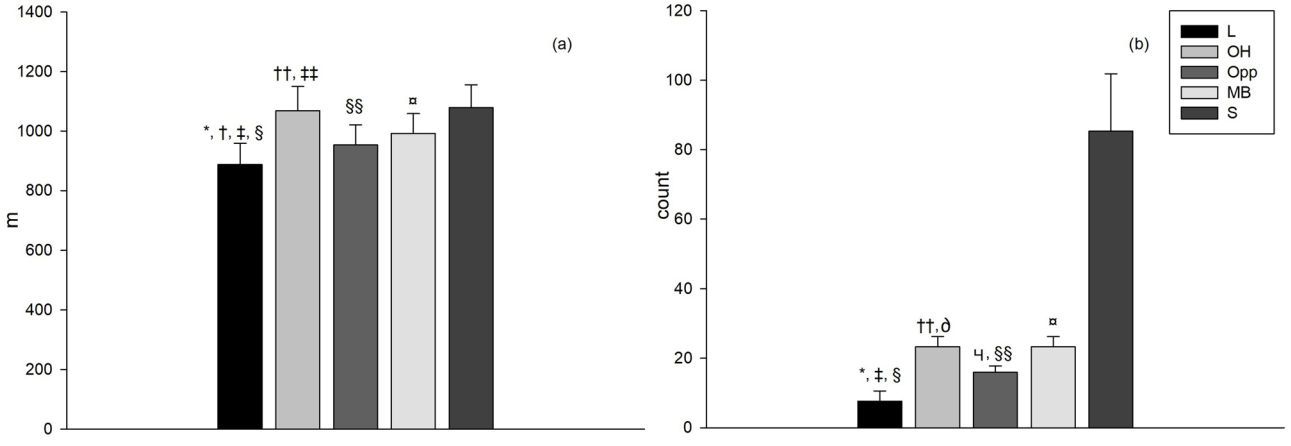


Fig. 2 Total distance (**a**) and jumps (**b**) during pre-match warm-up in female volleyball players (L: Libero, OH: Outside hitter, Opp: Opposite, MB: Middle Blocker, S: Setter). *: Significant difference between L-OH, †: Significant difference between L-Opp, ‡: Significant difference between L-MB, §: Significant difference between L-S, ††: Significant difference between OH-Opp, ‡‡: Significant difference between OH- MB, ð: Significant difference between OH-S, Ч: Significant difference between Opp-MB, §§: Significant difference between Opp- S, ¤: Significant difference between MB-S, $p < .05$

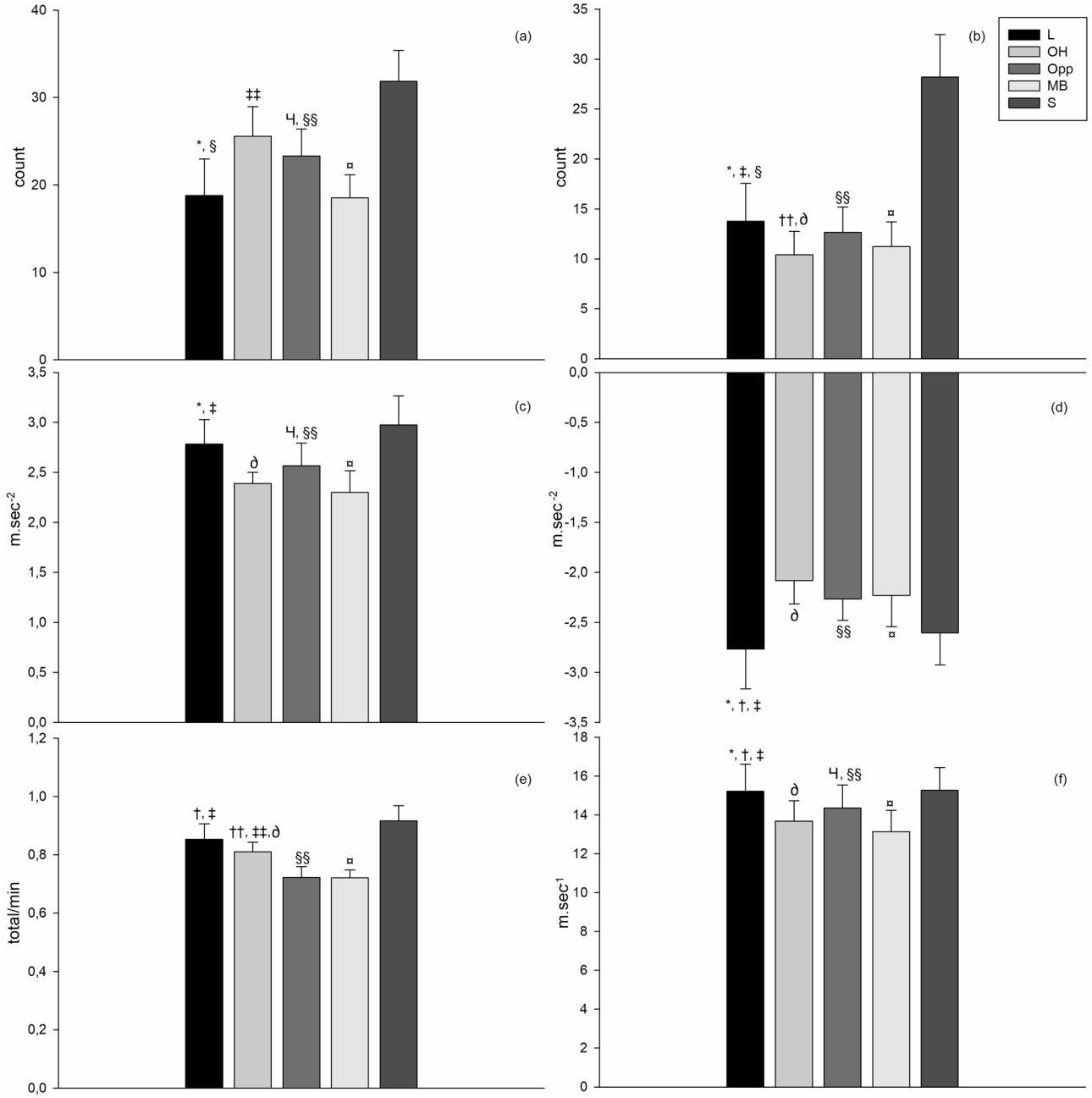


Fig. 3 ACC (**a**), DEC (**b**), ACC_{max} (**c**), DEC_{max} (**d**), ACC/min (**e**) and $speed_{max}$ (**f**) during pre-match warm-up in female volleyball players (L: Libero, OH: Outside hitter, Opp: Opposite, MB: Middle Blocker, S: Setter). *: Significant difference between L-OH, †: Significant difference between L-Opp, ‡: Significant difference between L-MB, §: Significant difference between L-S, ††: Significant difference between OH-Opp, ‡‡: Significant difference between OH- MB, ð: Significant difference between OH-S, Ч: Significant difference between Opp-MB, §§: Significant difference between Opp- S, ¤: Significant difference between MB-S, $p < .05$

OH-MB: "large" $F = 49.95$, $\eta^2 = 0.581$), while L had a significantly lower metabolic load than all other player positions (L: 214.2 ± 46.9 m, OPP-L: "large" $F = 144.55$, $\eta^2 = 0.797$, S-L: "large" $F = 46.89$, $\eta^2 = 0.566$, MB-L: "large" $F = 60.28$, $\eta^2 = 0.626$, Fig. 4).

Discussion

Understanding the specific external load demands of female volleyball players during training and matches by player position aids in designing strength and conditioning programs and managing load to prevent injury. However, external load during the pre-match warm-up is often overlooked. This observational, longitudinal study aimed to (i) assess the pre-match warm-up external load

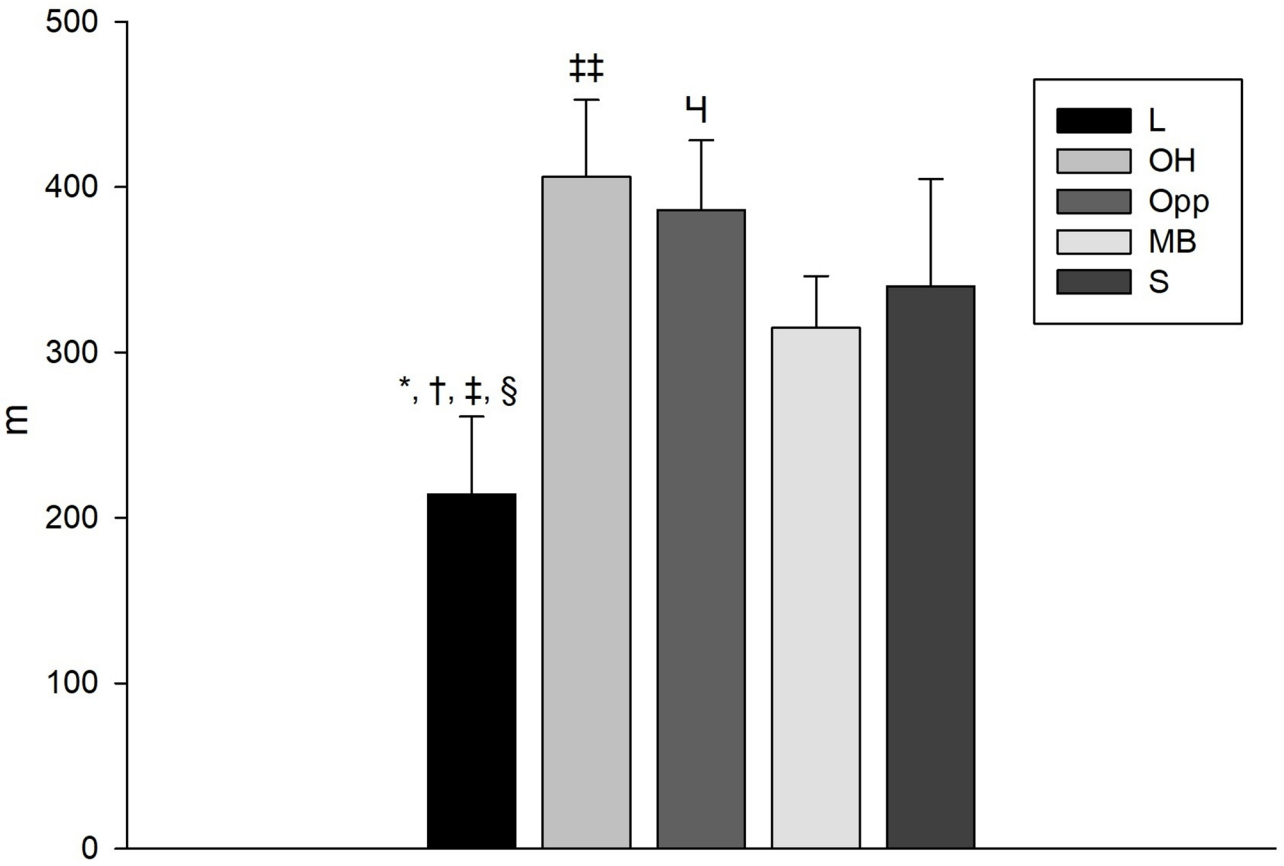


Fig. 4 Metabolic load (distance in high load zone) during pre-match warm-up in female volleyball players (L: Libero, OH: Outside hitter, Opp: Opposite, MB: Middle Blocker, S: Setter). *: Significant difference between L-OH, †: Significant difference between L-Opp, ‡: Significant difference between L-MB, §: Significant difference between L-S, ‡‡: Significant difference between OH- MB, Ч: Significant difference between Opp-MB, $p < .05$

for female volleyball players and (ii) compare this load by player position. We hypothesized that external load would vary by position. Our first main finding shows elite volleyball players covered 888.1–1078.5 m, performed 15.9–85.3 jumps (excluding L), with 18.5–31.8 ACC counts, 10.4–28.2 DEC counts, and $speed_{max}$ between 13.1 and 15.3 $m.sec^{-1}$ during warm-ups. All external load data significantly differed by position. Our second main finding indicates that S players had the highest external loads for total distance, jump count, ACC, DEC, ACC_{max}, DEC_{max}, ACC/min, and $speed_{max}$, while L had the lowest total distance and jump count, MB had the lowest ACC counts, ACC_{max}, ACC/min, and $speed_{max}$, and OH had the lowest DEC counts and DEC_{max}. Interestingly, OH and OPP exhibited significantly higher "distance in high load zone" or metabolic load, than other positions.

The neuromuscular system faces considerable demands from the repetitive, multidirectional movements (e.g., sprints, dives, jumps) performed during a match. Due to the unique roles and tasks associated with each position in volleyball, external loads are likely to vary between player position [30], but it has been observed that the external load differences between player positions are neglected in the pre-match warm-up in volleyball. Total distance is the most monitored metric for volleyball players during training and match [25]. Although it is known that the training external load decreases towards the day before the match [1, 6], it is also a question mark whether the match external load added to the pre-match external load data exceeds the training external loads. Perhaps it may be necessary to examine whether the neglected pre-match warm-up external load is an indicator of achieving optimal performance other than preparing the athletes for the match or whether it has a mechanism that may cause fatigue. In elite women's volleyball, the highest significant total distance in a training session was in OH (3694.4 ± 1023.4 m), followed by OPP, S, MB and L, respectively, and in one training session, female volleyball players achieve a total distance of 3065–3694 m [1]. In another study, it was noted that elite female volleyball players reached a total distance of 3109–4030 m in season-long training, with OH having the highest total distance and MB having the lowest total distance [25]. Our research confirms significant positional differences in total distance during pre-match warm-up, with S and OH players covering the most distance, while L and OPP

players cover the least. Reviewing metabolic load data reveals that OH and OPP players experience significantly higher metabolic loads, while L has the lowest. Supporting our findings, a previous study reported that female volleyball players reach 713–1261 m high metabolic load distance in training, with OH showing the highest and S the lowest metabolic load, highlighting that OH and OPP face the greatest external loads [25].

Each player position performs maximal and sub-maximal jumps according to the in-game scenario [2, 31]. Volleyball game requires high levels of repetitive jumping. Jumping capacity is suggested as one of the most important physical characteristics of volleyball players [32] and point-winning movements (spike, block and serve) are mostly through jumping, and the number of jumps varies depending on the players' roles due to different technical-tactical and match demands [3, 30]. However, another important point to remember is that in volleyball, players with different roles perform different types of jumps with different frequencies and different intensities [6, 10]. In our research, the highest jump count in the pre-match warm-up belonged to the S (approximately 3–5 times more jumps than OH, OPP and MB). This finding may be related to the fact that S often jump and pass the ball during setting in the pre-match warm-up. However, it can be said that the reason why L have the lowest jump count is because their positions do not require this activity. Previous research confirms that jump load varies according to player positions during training or match. In elite women's volleyball, the highest and significant jump counts in a training session was in S (126.6 jumps), followed by MB, OPP, OH and L, respectively. In a training session, female volleyball players -excluding the libero- perform an average of 83–126 jumps [1]. Confirming this finding, the highest jumping frequency was found in S and MB players [9]. In NCAA Division-I women volleyball competitions, S have the highest jump count compared to other player positions, accompanied by the highest submaximal jump count, while MB have the highest maximal jump count [24]. In another study, although the highest jump count belonged to S and jumped at 41% of their maximum performance, while OPP jumped at 69% [9]. In Division I collegiate volleyball, OH performed 53% of jumps as attacks, MB performed 55% as blocks, and S performed 54% as jump sets, with S jumps noted to be of lower intensity and submaximal [17]. In a study conducted on the NCAA Division-I women's volleyball team, attackers, defenders, and S recorded an average of 74.5 ± 39.2, 27.1 ± 11.1 and 136.7 ± 36.8 jumps per match and 71.6 ± 21.4, 35.4 ± 6.1 and 113.6 ± 26.0 jumps in training, respectively, during a season, and S were found to have the highest jump count [10]. In addition to previous research findings confirming our research, examining the jump heights accompanying the jump count in further studies may provide important findings.

ACCs occur in almost every action in volleyball, such as movement within a block, defensive play, jump serve, and even preparation before an attack or serve [5]. Players perform actions that include diagonal displacements, ACC, DEC, and jumps, and these position-specific tasks provide a multifaceted understanding of determining external load in volleyball [8]. The findings of our research revealed that S have significantly higher ACC and DEC count, ACC_{max} and DEC_{max}, ACC/min data during the pre-match warm-up in volleyball. It is seen that this finding is also accompanied by L players -except for the ACC count-. Volleyball players performed 18.5–31.8 ACC count, 10.4–28.2 DEC count, 2.30–2.97 $m.sec^{-2}$ ACC_{max}, -2.08 vs. -2.77 $m.sec^{-2}$ DEC_{max}, 0.72-0.92 ACC/min in pre-match warm-up.

In elite women's volleyball, the highest significant ACC_{max} in a training session is in L (3.09 $m.sec^{-2}$), followed by S, OH, OPP and MB, respectively, and the average ACC_{max} of female volleyball players was between 2.74 and 3.09 $m.sec^{-2}$ [1]. In the same study, the highest significant DEC_{max} was in L (-3.14 $m.sec^{-2}$), followed by S, OH, OPP and MB, respectively, and the average DEC_{max} of female volleyball players ranged between – 2.63 and 3.14 $m.sec^{-2}$ [1]. Another study found that elite female volleyball players displayed an average of 80–132 DEC and 82–142 ACC during season-long training, with OPP having the highest DEC and ACC, L having the lowest ACC, and S having the lowest DEC [25]. Therefore, it is seen that the players are below their training averages in the pre-match warm-up in volleyball.

In the pre-match warm-up, women volleyball players reached a $speed_{max}$ of 13.1–15.3 $m.sec^{-1}$. The significant high $speed_{max}$ belongs to S and L. In a training session, female volleyball players reached an average of 15.9–17.1 $m.sec^{-1}$ $speed_{max}$, and the highest significant $speed_{max}$ was in L (17.1 $m.sec^{-1}$), followed by OH, S, OPP and MB, respectively [1]. This finding also confirms our research.

Limitations

This current study is not without limitations. Primarily, we did not collect internal load data during the pre-match warm-up, which would have helped clarify how external load translates into internal load by player position. Additionally, some external load data, such as jumps, focused solely on count, without considering load intensity zones, which could indicate submaximal or maximal effort. However, we included metabolic load (distance in high-load zones) to provide insight into these aspects. Other limitations include the sample size and limited prior research. Nonetheless, to our knowledge, this is the first study to assess pre-match warm-up load in volleyball, with findings from elite national-level

players offering valuable reference data for coaches and practitioners. This research was also limited to female players; future studies could expand to include male athletes or different age groups. Finally, a further limitation is that the data were collected from a single elite female volleyball team, and therefore the findings may not be directly generalized to other teams or competitive levels. Future research should include larger samples across different teams, competition levels, and genders to provide broader insights into pre-match warm-up external loads.

Conclusions

As a result, female volleyball players demonstrated notable positional differences in pre-match external load demands. S players showed the highest total distance, jump count, ACC and DEC counts, ACC_{max}, ACC/min, and $speed_{max}$, while OH and OPP had the highest metabolic load. L players had significantly higher ACC_{max}, DEC_{max}, and $speed_{max}$ but lower total distance, ACC count, and metabolic load. MB players exhibited the lowest ACC data. From a practical perspective, these findings indicate that pre-match warm-up routines should be structured according to the specific demands of each playing position rather than applied uniformly across the team. Coaches and strength and conditioning professionals may use this information to design more targeted warm-up content, such as emphasizing jumping and change-of-direction activities for S players, metabolic-demanding actions for OH and OPP, and agility-based preparation for L players. Position-specific tailoring of pre-match routines can help ensure that each role begins the match with optimal readiness aligned with its unique technical and physical requirements. Future studies should also classify activities into maximal and submaximal zones and examine how varying pre-match loads, together with internal load monitoring, influence subsequent game performance.

Abbreviations

ACC	Acceleration
ACC_{max}	Maximum acceleration
BM	Body mass
cm	Centimeter
DEC	Deceleration
DEC_{max}	Maximum deceleration
ES	Effect size
kg	Kilogram
L	Libero
LPS	Local Positioning System
m	Meter
MB	Middle blocker
OH	Outside hitter
OPP	Opposite
S	Setter
SD	Standard deviation
sec	Second
$speed_{max}$	Maximum speed

Acknowledgements

The authors would like to thank the players who participated in the study and the coaches who supported the research.

Author contributions

EA, EC, CA and GM: study concept and design; EA, EC, CA and GM: data acquisition; EA, EC and GM: data analysis, interpretation; EA, EC and CA: article preparation. EA, EC, CA and GM: critical revision of the article. All authors read and approved the final article.

Funding

This study was conducted without any funding from companies, manufacturers or outside organizations. Open access funding provided by Gazi University, Turkey.

Data availability

The data generated and analysed during the present study are not publicly available due to ethical restrictions but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Gazi University Ethics Committee and provided with the following reference number: 2023 – 536. Participants provided informed consent after the risks and benefits of the study were explained.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Received: 8 March 2025 / Accepted: 16 September 2025
Published online: 22 October 2025

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