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ORIGINAL RESEARCH

# Comparison of external load and specific activities of starters *vs.* non-starters by position in men's professional volleyball competition

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## Abstract

**Background**: The purpose of this study was to analyze volleyball specific activity data of men's professional players during the competition to determine differences in external loads between starters and non-starters and to quantify the loads required per set for starters. **Methods**: A total of 21 players (27.5 ± 4.5 years), including three liberos (L), four setters (S), eight opposite/outside hitters (OPP/OH) and six middle blockers (MB), participated in the study. Starters were defined as players included in the starting lineup of each of the 36 matches, while non-starters began in the warm-up zone. External load variables included match time (MT), player load (PL), total jumps (TJ), low-range jumps (LRJ), mid-range jumps (MRJ), high-range jumps (HRJ), explosive efforts (EE), planar explosive efforts (PEE) and repeated high-intensity efforts (RHIE), which were objectively measured using wearable activity monitors. An independent *t*-test compared loads between starters and non-starters, while one-way analysis of variance (ANOVA) analyzed positional differences for starters. **Results**: The results revealed that, while total MT did not differ between starters and non-starters across all positions, starters consistently recorded higher loads in PL, TJ, MRJ, HRJ, PEE and EE. Among starters, the S showed the highest values for TJ ($p < 0.001$) and MRJ ($p < 0.001$), while the MB recorded the highest values for HRJ ($p < 0.001$) and RHIE ($p < 0.001$). The OPP/OH had the highest values for EE ($p < 0.001$), and the L showed the highest values for PEE ($p < 0.001$). Our findings revealed apparent external load differences between starters and non-starters and positional variations in the relative importance of individual load components. **Conclusions**: These results emphasize the necessity of designing position-specific training programs tailored to the per-set load demands of starters, thereby optimizing player performance and managing training loads effectively.

## Keywords

Performance analysis; Wearable technology; Activity monitoring; Match demands; Jumps

## 1. Introduction

Analyzing external load in sports competitions is essential for systematically designing athletes' training intensity and volume [1–3]. Since the mid-2010s, advances in wearable activity monitors and accelerometers have rapidly expanded research on external load monitoring in team sports [4]. These studies have primarily focused on timed sports such as soccer, basketball, rugby, and football where apparent differences in external load have been identified between playing positions and between starters and non-starters [5–8]. In time-regulated team sports, starters consistently record higher activity levels than non-starters [9], and failure to account for these differences in activity levels when calculating average loads may lead to an inaccurate representation of the demands required during actual competition.

Due to its nature, volleyball requires different specific activities than other popular sports such as soccer and basketball, including frequent jumping. Moreover, quantifying the external load demands of matches in "set-based sports" such as volleyball presents several challenges [10]. For example, starters may be substituted during a match due to performance decline or injury. Additionally, because volleyball allows for relatively frequent substitutions (up to 6 per set under International Volleyball Federation rules), players who were not part of the starting lineup may sometimes have higher external loads than starters [11]. Moreover, the fifth set in volleyball differs from other sets in that it ends when one team reaches 15 points, as opposed to the 25-point limit of other sets, leading to variations in load calculation methods depending on the number of sets and scoring format [11]. Therefore, these unique aspects of the sport must be considered to quantify the external load demands of volleyball games accurately.

Previous studies on volleyball match loads have reported notable differences between positions, with setters performing the most jumps, while middle blockers and outside hitters recorded the greatest number of explosive efforts and high-band jumps [12–15]. Another study effectively described the increase in external load variables as the number of sets accumulated [10]. However, these previous studies have limitations in fully reflecting the unique characteristics of volleyball matches [10, 14–16]. In particular, calculating average external loads without distinguishing between starters and non-starters may underestimate the actual load demands during matches. It has been reported that starters have higher weekly training loads and perceive greater internal loads than non-starters [17], suggesting differences in overall training demands between the groups. Given the possibility of non-starters transitioning into starting roles, an accurate measure of starting load is essential to address the load demands of volleyball players. However, to the best of our knowledge, no studies have examined external load by distinguishing between starters and non-starters in volleyball matches.

Interestingly, most current studies using wearable monitoring devices have primarily focused on women's volleyball players [15, 18]; however, future studies must consider gender differences in training methods and load design. This focus may be due to the greater popularity of women's volleyball and the research interest in female athletes. As such, systematic analyses of load demands in men's volleyball players remain relatively scarce [19]. Analyzing specific activities such as frequent jumping, explosive movements (*e.g.*, accelerations, decelerations and rapid changes of direction), and repetitive high-intensity actions, which are common in volleyball, is crucial for designing training programs that reflect the sport's unique demands [20, 21].

Therefore, the present study aims to analyze in-game activity data during the regular season of men's professional volleyball players to identify differences in external loads as volleyball specific activities between starters and non-starters and to detail load demands per set for starters. The results are expected to provide an essential basis for trainers and coaches to design and optimize training programs tailored to starters' roles and positional demands, ultimately contributing to enhanced match performance. We hypothesized that starters would have higher external loads than non-starters and that specific load components would vary across positions, based on previous studies conducted on soccer players [6, 22].

## 2. Materials and methods

### 2.1 Study design

This study is a prospective observational study conducted to analyze the external loads of male professional volleyball players during the 2023–2024 Korean Volleyball League (KOVO) regular season. The KOVO regular season featured seven men's professional teams, with each team playing 36 official matches from mid-October 2023 to early March 2024. The data for this study were collected from 21 players from a single team that ranked second in the league for two consecutive years.

Each match roster varied between 14 and 16 players, with an average composition of two liberos (L), three setters (S), six opposite/outside hitters (OPP/OH) and four middle blockers (MB), resulting in approximately 15 players per match. A total of 540 events were recorded throughout the season. After excluding 15 data points due to device errors and missing data, as well as 4 data points from starters who were substituted during matches due to injuries (2 matches for MB and 2 matches for OPP/OH), 521 valid data points were included in the analysis. Of these, 248 events were attributed to starters and 273 to non-starters.

Starters were defined as players who began as part of the starting lineup in at least one of the 36 matches, while non-starters were players who started in the warm-up zone [23]. The starting lineup typically consisted of one setter (S), three opposite/outside hitters (OPP/OH), two middle blockers (MB) and one libero (L) in this study. The participants were categorized by position as follows: three liberos (L), four setters (S), eight opposite/outside hitters (OPP/OH) and six middle blockers (MB). All participants were fully informed of the research objectives and procedures prior to the study, and written informed consent was obtained from each player. The study was in accordance with the tenets of the Declaration of Helsinki.

### 2.2 Data collection and measurement variables

External load measures were obtained using Catapult's Vector S7 (Catapult Innovations, Melbourne, VIC, Australia) activity monitoring device. This device integrated a tri-axial accelerometer, global positioning system and gyroscope and was securely attached to a performance vest in a padded pouch worn between the players' shoulder blades [10]. All movements were sampled at 100 Hz and athletes wore the same device consistently over the course of the season [10]. The device was activated at the start of the match and deactivated at the end of the match. In line with previous studies, real-time radio frequency tracking was employed to accurately record the start and end times of the game, as well as breaks. The recorded data were analyzed using Catapult Sports' proprietary software (OpenField, Catapult Innovations, Melbourne, VIC, Australia, version 1.22.2). The reliability of the monitoring equipment was previously validated and documented [24].

External load variables, encompassing specific movements in volleyball, included match time (MT), player load (PL), total jumps, low-range (LR) jumps, MR jumps, HR jumps explosive efforts (EE), planar explosive efforts (PEE) and repeated high-intensity efforts (RHIE) [16, 25]. The MT refers to the total duration from start to end of matches, including the time players spend actively engaged on the court or in the warm-up zone, measured in minutes. The PL is defined by Catapult as the sum of the accelerations across all axes of the internal triaxial accelerometer during motion [15]. Jumps were defined as instances when a player remained airborne for more than 320 milliseconds and were categorized based on jump height into LR jumps (10–30 cm), MR jumps (30–50 cm) and HR jumps (50 cm or more) [15]. The EE was defined as the number of accelerations exceeding 3.5 m/s$^2$ on any axis (x, y or z) [10]. The PEE was calculated as the number of accelerations surpassing 3.5 m/s$^2$ on the x and y axes only, excluding vertical movements (HR jumps). This metric reflected lateral and forward/backward accelerations, representing defensive movements. The RHIE was defined as the frequency of completing three or more high-intensity accelerations (>2.79 m/s) within 21 seconds [15]. An in-game referred to match play only, excluding pre-match warm-ups and inter-set breaks, which were carefully excluded from the analysis.

## 2.3 Data analysis

All variables were expressed as means and standard deviations. The normality of the data distribution was assessed using the Shapiro-Wilk test. Independent $t$-tests were used to compare the external load between starters and non-starters across positions. The match data were categorized based on the number of sets played (3-set, 4-set and 5-set matches), and the average values from all matches were used for positional analysis. One-way analysis of variance (ANOVA) was used to examine differences in load between positions, followed by *post-hoc* analysis using Tukey's test. To assess the effect size of statistical differences, Cohen's $d$ was used for independent $t$-tests, while Cohen's $f$ was used to interpret the effect sizes of group differences in ANOVA. Cohen's $d$ values represent the standardized mean differences between two groups, with effect size thresholds defined as small ($0.2 \leq d < 0.5$), medium ($0.5 \leq d < 0.8$) and large ($d \geq 0.8$) [26]. Similarly, Cohen's $f$ values represent the magnitude of differences across multiple groups, with effect size thresholds defined as small ($0.1 \leq f < 0.25$), medium ($0.25 \leq f < 0.4$) and large ($f \geq 0.4$) [26]. To calculate the external load per set for each position, the values for each variable were divided by the total number of sets per match. In the case of 5-set matches consisting of 15-point sets, the set value was adjusted to 0.6 sets for integrated analysis. All statistical analyses were performed at a 0.05 significance level using SPSS-PC (version 25.0, IBM, Armonk, NY, USA).

# 3. Results

## 3.1 General characteristics of participants

Table 1 presents the demographics of the participants. The players had an average age of 27.5 ± 4.5 years ($p = 0.367$), an average height of 192.2 ± 9.1 cm ($p < 0.001$) and an average body mass of 82.9 ± 9.4 kg ($p < 0.001$). They had an average of 6.5 ± 3.9 years of professional experience ($p = 0.536$).

## 3.2 In-game external loads of starters and non-starters

Table 2 shows in-game external loads of starters and non-starters by position. Across all positions, starters generally had higher external loads than non-starters, although the magnitude of differences varied by position. For the L position, starters recorded significantly higher values than non-starters for total jumps ($p = 0.029$), MR jumps ($p < 0.001$), HR jumps ($p = 0.011$), PEE ($p < 0.001$) and EE ($p < 0.001$). For the S position, starters had significantly higher loads than non-starters for total jumps ($p < 0.001$), LR jumps ($p = 0.017$), MR jumps ($p < 0.001$), HR jumps ($p < 0.001$), PEE ($p < 0.001$) and EE ($p < 0.001$). Finally, for the OPP/OH and MB positions, starters outperformed non-starters with significantly higher loads in total jumps ($p < 0.001$), LR jumps ($p < 0.001$), MR jumps ($p < 0.001$), HR jumps ($p < 0.001$), EE ($p < 0.001$) and RHIE ($p < 0.001$).

## 3.3 External load demands of starters according to game sets

Table 3 shows the external loads required by starters according to the number of game sets by position. The data shows that all positions required greater external loads as game sets increased. Across all positions, MT was consistent, but significant differences were observed in total jumps ($p < 0.001$), LR jumps ($p < 0.001$), MR jumps ($p < 0.001$), HR jumps ($p < 0.001$), PEE ($p < 0.001$), EE ($p < 0.001$) and RHIE ($p < 0.001$). Specifically, the S recorded the highest total jumps and MR jumps, followed by the MB, OPP/OH, and L. The OPP/OH players attempted the most LR jumps, followed by the MB, L, and S. For HR jumps and RHIE, the MB recorded the highest values, followed by the OPP/OH, S, and L. The L had the highest PEE, followed by the OPP/OH, MB and S. Finally, total EE was predominantly higher in the OPP/OH and MB positions.

## 3.4 External load demands per single set

Table 4 illustrates the external load demands required for a single set by position. Among all positions, the S recorded the highest total jumps with 27.4 and MR jumps with 15.7. These were followed by the MB, OPP/OH and L ($p < 0.001$ for both). The MB performed the most HR jumps with 14.7, followed by the OPP/OH, S and L ($p < 0.001$). The L showed the highest PEE with 7.8, followed by the OPP/OH, MB and S ($p < 0.001$). EE was most frequent in the OPP/OH, who recorded 19.6 followed by the MB, S and L ($p < 0.001$). Finally, the MB recorded the highest RHIE with 0.9, followed by the OPP/OH, S and L ($p < 0.001$).

# 4. Discussion

This study aimed to investigate the in-game external load differences between starters and non-starters among men's professional volleyball players and to quantify the positional and set-specific load demands of starters. The findings showed that starters had consistently higher external loads than non-starters across all positions, highlighting positional differences in the relative importance of specific load elements such as jumps, PEE and RHIE. These findings emphasize the necessity of designing position-specific training programs tailored to the load demands of starters in order to optimize player performance and effectively manage load. Ultimately, this study enhances position-specific performance optimization and efficient load management strategies in professional volleyball.

No previous studies have compared the load of starters and non-starters in volleyball, but this study is consistent with findings from other team sports [5, 6, 9]. For example, Reche-

**TABLE 1. General characteristics of participants.**

| Variable | Total (n = 21) | L (n = 3) | S (n = 4) | OPP/OH (n = 8) | MB (n = 6) | *p*-value |
|---|---|---|---|---|---|---|
| Age (yr) | 27.5 ± 4.5 | 26.7 ± 4.6 | 24.5 ± 5.5 | 27.8 ± 3.6 | 29.6 ± 4.7 | 0.367 |
| Height (cm) | 192.2 ± 9.1 | 175.0 ± 1.0 | 187.0 ± 3.4 | 195.5 ± 4.5 | 199.8 ± 3.1 | <0.001 |
| Body mass (kg) | 82.9 ± 9.4 | 66.7 ± 4.2 | 76.7 ± 2.2 | 86.1 ± 5.7 | 90.8 ± 4.4 | <0.001 |
| Professional career (yr) | 6.5 ± 3.9 | 5.7 ± 3.8 | 4.5 ± 3.4 | 6.6 ± 3.4 | 8.2 ± 4.8 | 0.536 |

*L, libero; S, setter; OPP/OH, opposite/outside hitter; MB, middle blocker.*
*The p-values indicate comparisons between positions.*

Soto *et al.* [9] analyzed 38 official matches involving 22 professional soccer players and reported that starters who played more than 90 minutes had higher values for load variables such as player load, metabolic power, energy expenditure and high metabolic load events than substitutes. The observation that starters have higher load demands than non-starters is not surprising. However, the key contribution of this study lies in objectively distinguishing and quantifying the loads of starters and non-starters in volleyball, a set-based sport characterized by frequent substitutions. This methodology provides a valuable framework for future research in volleyball and other set-based sports.

In this study, the in-game load of starters varied depending on the number of game sets and playing positions, which is consistent with findings from previous research on volleyball load [10, 15]. Vlantes and Readdy [10] analyzed 15 matches involving 11 collegiate volleyball players over the season and reported a 25% increase in PL for 4-set matches compared to 3-set matches and a 31% increase for 5-set matches, with the highest increase in the MB position. Similarly, this study found that 4-set matches had a 23–33% increase in PL compared to 3-set matches, while 5-set matches had a 24–37% increase in PL compared to 3-set matches. However, the most significant increase in this study was observed for the OPP/OH position, which differs slightly from previous research [10].

The findings of this study revealed that the S performed the highest number of jumps overall, with MR jumps being the most frequent among all positions. These findings align with previous research [10, 15] and reflect the unique demands of the setter's role. In volleyball, S acts as the coordinator of the game, primarily responsible for delivering accurate sets. Since almost every ball must pass through the setter to create precise sets during attacks, it is unsurprising that this position records the highest number of jumps. In addition, their frequent involvement in blocking is another reason why S makes the most jumps. The height of squat jumps and block jumps, primarily performed by setters, has been reported to typically range between 40–50 cm [27], which aligns with the MR jump height defined in this study. Taken together, S needs to enhance their muscular endurance to perform frequent jumps and focus on increasing specific training within the mid-height range.

Meanwhile, this study found that the positions performing the most HR jumps exceeding 50 cm were the OPP/OH and MB positions, consistent with previous studies [28]. High jumps above 50 cm are predominantly observed during spike jumps and counter-movement block jumps [27]. A systematic review of volleyball spike kinematics reported that elite men's volleyball players achieve an average spike jump height of 62–68 cm [29]. The frequent high intensity jumping demands for MB players can be attributed to their critical roles in performing strong blocks, executing quick attacks, and occasionally employing trick jumps to deceive opponents.

The results of this study showed that the OPP/OH and MB positions recorded the highest numbers of EE and RHIE. These findings are consistent with previous research [10, 15], suggesting that players in these positions are exposed to significant high-intensity movement demands. Although further investigation is warranted, players in these positions frequently transition from defense to attack or perform defensive actions immediately following an attack. For MB and OPP/OH players, high-intensity training to perform explosive movements consecutively during matches and effective recovery strategies are crucial.

One of the key findings of this study is that the PEE frequency was highest in the L position. Although L players rarely perform jumps due to their limited involvement in offensive or blocking actions, previous studies have utilized the EE metric, which combines HR jumps with planar instantaneous movements. This study emphasized PEE to capture better high-acceleration movements that exclude vertical actions. While further research is necessary, the higher PEE values observed in the L and OPP/OH positions, both heavily involved in receiving [30, 31], support the concept that PEE effectively reflects defensive movements associated with receiving. Therefore, L and OPP/OH players should emphasize training programs focused on rapid directional changes and high-speed movements on the horizontal plane. Taken together, the relative importance of individual load elements such as jumps, PEE and RHIE varies by position, underscoring the need to consider positional characteristics when designing training programs and managing loads.

Table 4 shows the load requirements per single set for each position, which can serve as valuable reference values for volleyball coaches and strength and conditioning specialists. On average, a single set lasting approximately 30 minutes shows that the S performs 27.4 jumps, including 15.7 MR jumps. Players in the MB and OPP/OH positions execute 14.5 and 13.5 HR jumps, respectively, with RHIE recorded at 0.9 and 0.6 instances. Conversely, the L records the lowest jump counts but demonstrates significant activity in defensive roles by performing an average of 7.8 PEE per set.

**TABLE 2. Comparison of in-game external loads between starters and non-starters by position (mean ± SD (standard deviation)).**

| Variables | Match time (min) | Player load (AU) | Total jumps (reps) | LR Jumps (reps) | MR Jumps (reps) | HR Jumps (reps) | PEE (reps) | EE (reps) | RHIE (reps) |
|---|---|---|---|---|---|---|---|---|---|
| L (n = 86) | | | | | | | | | |
| Starter (n = 36) | 116.9 ± 21.7 | 431.9 ± 84.5 | 13.5 ± 6.5 | 10.1 ± 5.7 | 3.2 ± 1.8 | 0.3 ± 0.6 | 29.8 ± 8.1 | 30.1 ± 8.1 | 0.3 ± 0.6 |
| Non-starter (n = 50) | 117.5 ± 21.9 | 286.8 ± 91.4 | 9.6 ± 9.9 | 8.5 ± 9.4 | 1.1 ± 1.4 | 0.0 ± 0.1 | 9.2 ± 6.9 | 9.3 ± 6.9 | 0.5 ± 0.9 |
| *p*-value | 0.911 | <0.001 | 0.029 | 0.335 | <0.001 | 0.011 | <0.001 | <0.001 | 0.211 |
| Cohen's *d* | 0.03 | 1.65 | 0.47 | 0.21 | 1.30 | 0.71 | 2.72 | 2.76 | 0.26 |
| S (n = 73) | | | | | | | | | |
| Starter (n = 36) | 116.9 ± 21.7 | 316.9 ± 68.7 | 105.9 ± 26.6 | 7.6 ± 5.6 | 60.7 ± 16.8 | 37.6 ± 12.2 | 12.2 ± 4.3 | 49.8 ± 14.1 | 0.6 ± 0.7 |
| Non-starter (n = 37) | 116.4 ± 21.6 | 263.8 ± 74.0 | 23.0 ± 19.5 | 11.9 ± 9.2 | 5.8 ± 7.1 | 5.1 ± 9.4 | 7.3 ± 4.6 | 12.4 ± 12.8 | 0.5 ± 1.1 |
| *p*-value | 0.920 | 0.002 | <0.001 | 0.017 | <0.001 | <0.001 | <0.001 | <0.001 | 0.850 |
| Cohen's *d* | 0.02 | 0.74 | 3.55 | 0.56 | 4.26 | 2.98 | 1.10 | 2.78 | 0.11 |
| OPP/OH (n = 224) | | | | | | | | | |
| Starter (n = 106) | 117.2 ± 21.5 | 433.9 ± 102.1 | 81.5 ± 20.4 | 17.8 ± 15.8 | 10.8 ± 6.3 | 52.8 ± 16.8 | 22.9 ± 13.5 | 75.7 ± 20.8 | 2.2 ± 1.7 |
| Non-starter (n = 118) | 116.7 ± 21.5 | 375.0 ± 128.5 | 39.5 ± 31.2 | 27.0 ± 22.1 | 6.2 ± 8.0 | 6.2 ± 8.4 | 9.2 ± 6.6 | 15.4 ± 12.8 | 0.6 ± 0.9 |
| *p*-value | 0.870 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cohen's *d* | 0.01 | 0.046 | 1.54 | 0.49 | 0.62 | 3.39 | 1.26 | 3.36 | 1.10 |
| MB (n = 138) | | | | | | | | | |
| Starter (n = 70) | 117.3 ± 21.6 | 384.2 ± 82.6 | 86.3 ± 21.8 | 13.9 ± 8.8 | 15.8 ± 8.3 | 56.5 ± 17.3 | 17.2 ± 12.6 | 73.7 ± 26.3 | 3.6 ± 3.1 |
| Non-starter (n = 68) | 117.1 ± 21.8 | 289.1 ± 92.5 | 21.8 ± 19.2 | 9.5 ± 8.9 | 3.7 ± 4.3 | 8.6 ± 11.5 | 4.7 ± 4.3 | 13.3 ± 13.9 | 0.3 ± 0.7 |
| *p*-value | 0.958 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Effect size (Cohen's *d)* | 0.03 | 1.01 | 2.97 | 0.50 | 1.82 | 3.14 | 1.30 | 2.80 | 1.42 |

*L, libero; S, setter; OPP/OH, opposite/outside hitter; MB, middle blocker; LR, low-range; MR, mid-range; HR, high-range; PEE, planar explosive efforts; EE, explosive efforts; RHIE, repeated high-intensity efforts; AU, arbitrary unit.*

**TABLE 3. External load demands of starters across 3-set, 4-set and 5-set matches by position (mean ± SD).**

| Variables | Match time (min) | Player load (AU) | Total jumps (reps) | LR Jumps (reps) | MR Jumps (reps) | HR Jumps (reps) | PEE (reps) | EE (reps) | RHIE (reps) |
|---|---|---|---|---|---|---|---|---|---|
| L (n = 36) | | | | | | | | | |
| 3-set match (n = 13) | 91.6 ± 5.3 | 338.9 ± 38.7 | 10.9 ± 4.2 | 8.0 ± 3.1 | 2.8 ± 1.8 | 0.2 ± 0.4 | 23.8 ± 5.6 | 23.9 ± 5.8 | 0.5 ± 0.5 |
| 4-set match (n = 10) | 122.0 ± 7.1 | 442.0 ± 29.4 | 14.5 ± 4.5 | 10.9 ± 4.0 | 3.1 ± 1.3 | 0.5 ± 0.7 | 30.6 ± 5.3 | 31.1 ± 5.2 | 0.1 ± 0.3 |
| 5-set match (n = 13) | 138.4 ± 9.6 | 516.9 ± 37.9 | 15.4 ± 8.9 | 11.5 ± 8.0 | 3.6 ± 2.0 | 0.2 ± 0.6 | 35.3 ± 8.1 | 35.5 ± 7.8 | 0.3 ± 0.8 |
| Match average | 116.9 ± 21.7 | 431.8 ± 84.6 | 13.5 ± 6.5 | 10.1 ± 5.7 | 3.2 ± 1.8 | 0.3 ± 0.6 | 29.8 ± 8.1 | 30.1 ± 8.1 | 0.3 ± 0.6 |
| S (n = 36) | | | | | | | | | |
| 3-set match (n = 13) | 91.6 ± 5.3 | 240.5 ± 31.4 | 78.7 ± 16.3 | 7.0 ± 8.5 | 44.5 ± 13.1 | 27.2 ± 9.3 | 10.1 ± 4.3 | 37.2 ± 10.8 | 0.4 ± 0.5 |
| 4-set match (n = 10) | 122.0 ± 7.1 | 337.7 ± 25.1 | 114.1 ± 6.2 | 8.1 ± 3.1 | 66.2 ± 6.2 | 39.8 ± 3.5 | 13.6 ± 4.5 | 53.4 ± 4.9 | 0.8 ± 0.8 |
| 5-set match (n = 13) | 138.4 ± 9.6 | 377.4 ± 41.0 | 126.9 ± 21.1 | 7.8 ± 3.5 | 72.8 ± 12.6 | 46.3 ± 11.7 | 13.2 ± 3.6 | 59.5 ± 12.7 | 0.5 ± 0.9 |
| Match average | 116.9 ± 21.7 | 316.9 ± 68.8 | 105.9 ± 26.6 | 7.6 ± 5.6 | 60.8 ± 16.8 | 37.6 ± 12.2 | 12.2 ± 4.3 | 49.8 ± 14.1 | 0.6 ± 0.7 |
| OPP/OH (n = 106) | | | | | | | | | |
| 3-set match (n = 38) | 91.7 ± 5.1 | 328.7 ± 52.1 | 62.1 ± 14.0 | 13.2 ± 11.7 | 8.9 ± 5.7 | 40.0 ± 12.0 | 16.8 ± 10.3 | 56.7 ± 14.2 | 1.6 ± 1.3 |
| 4-set match (n = 29) | 122.1 ± 7.0 | 485.2 ± 63.8 | 89.3 ± 12.9 | 20.2 ± 14.1 | 10.5 ± 5.3 | 58.5 ± 12.9 | 28.9 ± 13.7 | 87.5 ± 13.0 | 2.8 ± 1.8 |
| 5-set match (n = 39) | 138.4 ± 9.3 | 498.4 ± 76.2 | 94.6 ± 15.3 | 20.7 ± 19.4 | 12.9 ± 7.1 | 61.0 ± 16.1 | 24.5 ± 14.1 | 85.5 ± 17.6 | 2.2 ± 1.8 |
| Match average | 117.2 ± 21.5 | 433.9 ± 102.1 | 81.5 ± 20.4 | 17.9 ± 15.8 | 10.8 ± 6.3 | 52.8 ± 16.8 | 22.9 ± 13.5 | 75.7 ± 20.8 | 2.2 ± 1.7 |
| MB (n = 70) | | | | | | | | | |
| 3-set match (n = 25) | 91.6 ± 5.3 | 290.2 ± 37.4 | 69.0 ± 16.3 | 11.6 ± 8.2 | 13.1 ± 6.2 | 44.4 ± 12.6 | 12.0 ± 7.0 | 56.4 ± 16.5 | 2.4 ± 1.7 |
| 4-set match (n = 19) | 122.3 ± 7.0 | 410.1 ± 37.1 | 90.9 ± 17.2 | 15.3 ± 8.9 | 15.7 ± 7.7 | 60.0 ± 15.7 | 18.3 ± 14.5 | 78.3 ± 26.1 | 3.5 ± 3.5 |
| 5-set match (n = 26) | 138.9 ± 9.4 | 455.6 ± 42.9 | 99.6 ± 21.3 | 15.3 ± 9.4 | 18.6 ± 9.8 | 65.7 ± 16.0 | 21.3 ± 14.1 | 87.0 ± 25.8 | 4.9 ± 3.5 |
| Match average | 117.3 ± 21.6 | 384.2 ± 82.6 | 86.3 ± 22.7 | 14.0 ± 8.9 | 15.8 ± 8.3 | 56.5 ± 17.3 | 17.2 ± 12.7 | 73.7 ± 26.3 | 3.6 ± 3.1 |
| *p*-values and *post hoc* results by position | $p > 0.999$ ($df = 3$, $F = 0.007$) | $p < 0.001$ ($df = 3$, $F = 15.815$) b < d < c = a | $p < 0.001$ ($df = 3$, $F = 132.287$) a < c = d < b | $p < 0.001$ ($df = 3$, $F = 8.451$) b < a < d < c | $p < 0.001$ ($df = 3$, $F = 343.201$) a < c < d < b | $p < 0.001$ ($df = 3$, $F = 122.406$) a < b < c = d | $p < 0.001$ ($df = 3$, $F = 14.046$) b < d < c < a | $p < 0.001$ ($df = 3$, $F = 129.124$) a < b < c = d | $p < 0.001$ ($df = 3$, $F = 74.130$) a = b < c < d |
| Effect size (Cohen's *f*) | 0.01 | 0.44 | 1.26 | 0.32 | 2.04 | 1.22 | 0.46 | 0.78 | 0.58 |

*L, libero; S, setter; OPP/OH, opposite/outside hitter; MB, middle blocker; LR, low-range; MR, mid-range; HR, high-range; PEE, planar explosive efforts; EE, explosive efforts; RHIE, repeated high-intensity efforts; AU, arbitrary unit; SD, standard deviation. a: libero; b: setter; c: opposite/outside hitter; d: middle blocker.*

**TABLE 4. External load demands of starters per single set by position (mean ± SD).**

| Variables | Match time (min) | Player load (AU) | Total jumps (reps) | LR Jumps (reps) | MR Jumps (reps) | HR Jumps (reps) | PEE (reps) | EE (reps) | RHIE (reps) |
|---|---|---|---|---|---|---|---|---|---|
| L (n = 36) | 30.4 ± 1.8 | 112.1 ± 9.8 | 3.5 ± 1.5 | 2.6 ± 1.3 | 0.8 ± 0.5 | 0.1 ± 0.1 | 7.8 ± 1.7 | 7.8 ± 1.6 | 0.1 ± 0.2 |
| S (n = 36) | 30.4 ± 1.8 | 82.0 ± 8.8 | 27.4 ± 4.3 | 2.0 ± 1.8 | 15.7 ± 3.2 | 9.7 ± 2.4 | 3.2 ± 1.1 | 12.9 ± 2.8 | 0.1 ± 0.2 |
| OPP/OH (n = 106) | 30.4 ± 1.8 | 112.3 ± 17.4 | 21.1 ± 3.9 | 4.6 ± 3.9 | 2.8 ± 1.6 | 13.7 ± 3.6 | 5.9 ± 3.4 | 19.6 ± 4.2 | 0.6 ± 0.4 |
| MB (n = 70) | 30.4 ± 1.8 | 99.2 ± 10.6 | 22.4 ± 4.8 | 3.7 ± 2.3 | 4.1 ± 2.0 | 14.7 ± 3.8 | 4.4 ± 3.0 | 19.1 ± 5.8 | 0.9 ± 0.7 |
| *p*-values and *post hoc* results by position | $p > 0.999$ ($df = 3$, $F = 0.001$) | $p < 0.001$ ($df = 3$, $F = 50.937$) b < d < a = c | $p < 0.001$ ($df = 3$, $F = 230.646$) a < c < d < b | $p < 0.001$ ($df = 3$, $F = 8.558$) a = b < d < c | $p < 0.001$ ($df = 3$, $F = 465.738$) a < c < d < b | $p < 0.001$ ($df = 3$, $F = 174.523$) a < b < c = d | $p < 0.001$ ($df = 3$, $F = 20.035$) b < d < c < a | $p < 0.001$ ($df = 3$, $F = 75.597$) a < b < c = d | $p < 0.001$ ($df = 3$, $F = 80.959$) a = b < c < d |
| Effect size (Cohen's *f*) | 0.03 | 0.72 | 1.67 | 0.32 | 2.38 | 1.45 | 0.49 | 0.96 | 0.61 |

*L, libero; S, setter; OPP/OH, opposite/outside hitter; MB, middle blocker; LR, low-range; MR, mid-range; HR, high-range; PEE, planar explosive efforts; EE, explosive efforts; RHIE, repeated high-intensity efforts; AU, arbitrary unit; SD, standard deviation. a: libero; b: setter; c: opposite/outside hitter; d: middle blocker.*

This study is the first to analyze volleyball match loads by distinguishing between starters and non-starters. Notably, it provides practical value by objectively quantifying the external load demands per set for starters. However, there are some limitations. First, while pre-match warm-up time and inter-set breaks were excluded from the analysis, timeouts and VAR (video assistant referee) review periods were not deducted from the total match duration. As a result, the load demands per set may have been slightly underestimated. Second, this study focused on a single team of the seven teams in the KOVO league, limiting the generalizability of the findings to the entire league or other competitive environments. Third, this study did not separately track playing time, which refers to the actual time players spent actively participating on the court, excluding activities in the warm-up zone. Future research should address these limitations by including a broader range of teams and leagues to generate more generalized results. Additionally, considering the limited research on volleyball-specific markers, future studies could explore the relationship between physiological, physical and wellness markers and playing performance, as suggested by Oliveira *et al*. [32].

## 5. Conclusions

The current study is the first to analyze in-game volleyball load by distinguishing between starters and non-starters and to quantify the external load demands per set for starters. The findings revealed significant differences in match load between starters and non-starters, with the relative importance of individual load elements varying by position. These outcomes provide practical insights for coaches and trainers to understand each position's physical demands better, underscoring the need to design training programs optimized for the specific roles of volleyball players. Although this study was limited to a single team and could not entirely exclude some non-playing periods, it provides fundamental data that can contribute to load management and performance optimization in professional men's volleyball.

### AVAILABILITY OF DATA AND MATERIALS

The data sets that were used and analyzed in the current study are available from the corresponding author upon reasonable request.

### AUTHOR CONTRIBUTIONS

EW and MS—Conceptualization; SY—methodology; SY and MS—formal analysis, investigation, writing-review and editing, supervision; EW and SY—software; MS—data curation; EW, SY and MS—writing-original draft preparation. All authors have read and agreed to the published version of the manuscript.

### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research ethics committee of the Sungkyunkwan University Institutional Review Board reviewed and approved the study according to the Declaration of Helsinki (No. 2024-05-028). Informed consent was obtained from all study participants.


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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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