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ORIGINAL RESEARCH

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Jump performance in Asian male volleyball players: match demands across player positions in Taiwan's top-tier competition

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Abstract

Background: Jump performance is crucial in volleyball, but the match demands and positional requirements have received limited research attention in Asia. This study aims to investigate the jump demands of various playing positions in 3-, 4- and 5-set matches, expressed as the number of jumps per point, throughout an entire competitive season in Asian semi-professional male volleyball players. Additionally, this study examines the differences in jump height among sets in 4- and 5-set matches. **Methods**: Nine athletes, including five outside hitters, three middle blockers and one setter, participated in the study. Among the five outside hitters, one also played as an opposite. The participants had an average age of 25.4 $\pm$ 3.1 years, a height of 1.87 $\pm$ 0.05 m, and a body mass of 81.0 $\pm$ 5.6 kg. Jump height and count in matches were recorded by wearable devices. Data from 20 matches, totaling 9180 jumps, were analyzed. **Results**: Mean jump count per match ranged from 19.7 to 80.0 for hitters, 52.5 to 77.2 for middle blockers and 104.5 for setters. Hitters averaged 0.20 to 0.55 jumps per point, while middle blockers averaged 0.36 to 0.51 jumps per point. The setter averaged 0.60 to 0.70 jumps per point. Linear mixed models revealed that mean jump height remained consistent across all sets for all player positions in both 4-set and 5-set matches. The proportion of jumps exceeding 80% of maximal jump height was also similar across sets. **Conclusions**: This study showed that the jump count per point remained consistent regardless of the number of sets in a match. Asian male semi-professional players were able to maintain jump height levels throughout 4- and 5-set matches over a competitive season. Coaches can integrate high-intensity jump loads similar to those experienced in matches into training to prepare players for the demands of competition.

Keywords

Jump count; Jump height; Wearable device; Match load; Playing position

1. Introduction

Volleyball, a highly demanding net sport, is distinguished by intermittent high-intensity dynamic and agile movements interspersed with brief intervals of rest [1]. Elite volleyball players are commonly recognized for their remarkable jumping ability, agility and muscular power [2]. High performance in jumping ability is a crucial factor in volleyball success, as it affects various skills, such as serving, spiking and blocking, that are essential for creating scoring opportunities [3]. For instance, winning teams in the Polish professional league had significantly higher average serve and block heights than the losing teams [2].

Recent advancements in wearable technology have enabled coaches to monitor jump height and the number of jumps during training and competition without obstructing athletes [4]. Several studies have utilized wearable devices to track workload in volleyball players [5–7]. In professional male volleyball players, jump count has been found to correlate positively with session ratings of perceived exertion (RPE) [6]. Similarly, in collegiate female volleyball players, positive correlations have been observed between RPE, jump count and player load—a metric representing the sum of all accelerations across the three axes [5, 7].

Jump demands in volleyball vary significantly across different playing positions. A previous study reported that, in international men's matches, setters, middle blockers and outside hitters execute an average of 31, 23 and 17 jumps per set, respectively [8]. More recently, an investigation of a professional men's club revealed that setters, middle blockers and outside hitters perform an average of 100, 85 and 68 jumps per match, respectively [9]. The types of jumps also varied across playing positions. Middle blockers performed a higher number of block jumps, while outside hitters and opposites primarily executed attack jumps. Setters, on the other hand, performed jump sets with moderate jump height [9]. However,

these studies did not consider the total points scored in each set or match a factor that can substantially influence the frequency of jumps during both offensive and defensive plays.

Volleyball matches are typically played with a maximum of five sets, and a team must win three sets to win the match. Matches can last anywhere from three to five sets. The accumulation of fatigue from earlier sets may result in a decline in jump height, potentially impairing offensive and defensive performance in the critical later sets. For example, elite male players have shown significant declines in spike and block heights in the third set compared to the first set, although data on the fourth and fifth sets were not reported [2]. Conversely, other studies have indicated that the average jump height in a match remains consistent across 3-, 4- and 5-set competitions in professional male players [9, 10]. However, a detailed analysis of jump height within individual sets is lacking. While professional and collegiate players have demonstrated the ability to maintain jump height and force-time characteristics following a training session [11, 12], the extent to which players sustain jump performance during later sets in matches remains unclear. Jump intensity also varies across playing positions. On average, the jump height during a match is approximately 56% of the players' maximal jump height, with middle blockers achieving 64% and outside hitters reaching 62% of their maximum [9].

Existing studies have predominantly examined data from a limited number of matches involving European or American teams, with scant research on matches throughout an entire competitive season in Asian players. While most research has focused on elite or collegiate players, the highest level of volleyball competition in Taiwan, the Top Volleyball League, is a semi-professional league, making it the best available context for investigating performance at the country level. Furthermore, collecting data from players in elite-level competitions often presents challenges due to restrictions on the use of wearable devices during official national and international matches. In contrast, semi-professional leagues matches allow for greater flexibility in using these technologies, enabling detailed monitoring of player performance. Therefore, this study aims to investigate the jump demands of various playing positions in 3-, 4- and 5-set matches, expressed as the number of jumps per point, over an entire competitive season in Asian semi-professional male volleyball players. Additionally, this study examines the differences in jump height among sets in 4- and 5-set matches. The hypotheses are that jump height and the proportion of jumps at greater heights may decrease in the later sets of matches. These findings could inform training strategies, particularly advancing volleyball performance in Asia, where research on match demands is limited.

2. Materials and methods

2.1 Subjects

This study employed a descriptive longitudinal approach. Nine male players from a team in Taiwan's semi-professional Top Volleyball League, the highest level of competition in the country, were recruited. The participants had an average age of 25.4 ± 3.1 years, a height of 1.87 ± 0.05 m and a body mass of 81.0 ± 5.6 kg. Based on their primary playing positions, the players were categorized into three groups: hitters (H) (outside hitters, n = 5; one of them also played as an opposite), middle blockers (M) (n = 3), and setters (S) (n = 1). The sample size was determined based on six starters and three major substitutes. During the season, the team trained three days per week, with each session lasting 3–4 hours. Match data were collected from 20 matches, comprising 73 sets, played between October 2022 and March 2023. The team competed in one or two matches each weekend, with 9 matches lasting 3 sets, 9 lasting 4 sets and 2 extending to 5 sets. The study protocol was approved by the Research Ethics Committee, Jen-Ai Hospital, Taichung, Taiwan (110-03) and adhered to the Declaration of Helsinki. Each participant signed an informed consent after receiving a thorough explanation of the procedures and associated risks from the research personnel.

2.2 Procedures

Data on jump count and height during each match were collected utilizing inertial measurement units (VERT wearable jump monitor, VERT COACH, Fort Lauderdale, FL, USA). The device was securely attached to the participant's posterior superior iliac spine using a belt provided by the manufacturer. Subsequently, data were wirelessly transmitted to an iPad via Bluetooth and analyzed using VERT COACH System application. The VERT wearable device demonstrates high reliability in measuring jump height and count during volleyball-specific actions, such as spike jumps and block jumps. Good inter-device reliability allows the VERT unit to record 99.3% of the jumps performed during volleyball practice and competition. Although VERT overestimated jump height by an average of 5.5 cm, it is a convenient and acceptable measure of on-court jump count and height [13]. Both the jump count and height of each jump were recorded, with jumps exceeding 120 cm excluded from the analysis [9].

After removing outliers, the maximal jump height for each player was determined by averaging their 10 highest jumps of the season. This approach, as suggested by Skazalski *et al.* [9], was used to account for potential variation in the VERT device. The number of jumps exceeding 80% of the maximal jump height in each player was then calculated for each set.

2.3 Statistical analyses

The mean, standard deviation (SD), percentage and maximal values of the variables were presented. Matches were categorized into three groups based on set count: 3-set, 4-set and 5-set matches. For each set count group, the jump count per point for a specific player position was determined by dividing his total jumps by the total points scored by both teams in the set. Additionally, the mean jump height was computed for each set and match.

To investigate set-to-set differences, the total jump count, average jump height and number of jumps exceeding 80% of the maximal jump height for a particular player position were consolidated for each set within each match group (3-set, 4-set and 5-set matches). Set-to-set differences were then analyzed using a linear mixed model with set as a fixed effect, accounting for the repeated measurements and unequal

number of jumps in each set. Additionally, the Chi-square test was applied to analyze differences in the proportion of jumps exceeding 80% of the maximal jump height across sets for each player position. The data were analyzed using SPSS for Windows, version 23.0 (IBM, Armonk, NY, USA). The significance level was set at $p < 0.05$.

3. Results

The number of matches, total jump count, and number of jumps exceeding 80% of the maximal jump height of each player position are presented in Table 1. A total of 9180 jumps were analyzed, including 780 jumps (8.5%) exceeded the participants' respective 80% maximal jump height.

The mean and maximal values of jump count and height per match for each player position are presented in Table 2. For hitters, middle blockers and setters, the maximal jump counts were 117, 124 and 158, respectively. Notably, H1, H2, H3, M2 and M3 exhibited similar mean jump heights, ranging from 60.3 to 64.5 cm, while S1 had the lowest mean jump height at 49.3 cm.

Table 3 presents the mean and maximal jump counts per point in 3-, 4- and 5-set matches for each player position. No significant differences in jump count per point were observed across the match types for any player position. The hitters averaged 0.20 to 0.55 jumps per point, while the middle blockers averaged 0.36 to 0.51 jumps per point. The setter averaged 0.60 to 0.70 jumps per point. The maximal jump count per point for hitters, middle blockers and the setter was 0.72, 0.81 and 0.89, respectively.

The mean jump height for each set in 4- and 5-set matches for each player position is shown in Figs. 1,2, respectively. In 4-set matches, linear mixed models indicated that the mean jump height remained consistent across all sets for all player positions (Fig. 1). Similarly, the mean jump height did not vary across sets in 5-set matches for any player position (Fig. 2). The proportion of jumps exceeding 80% of maximal jump height was similar across sets in both 4- and 5-set matches for all player positions (Table 4). Overall, in 4-set matches, hitters performed 14.6% of jumps exceeding 80% of their maximal jump height, while middle blockers executed 9.0%. In 5-set matches, these percentages were 7.4% for hitters and 13.0% for middle blockers.

TABLE 1. Number of matches, total jump count, and number of jumps exceeding 80% of the maximal jump height in each player position during a competitive season.

Position	Matches (n)	Total jump count (n)	Number of jumps >80% max height (n)
H1	20	1233	186
H2	18	1443	90
H3	12	548	46
H4	17	630	41
H5	14	364	21
M1	19	967	73
M2	19	1347	63
M3	8	559	47
S1	20	2089	213

H1, H2, H3, H4 and H5 are hitters; M1, M2 and M3 are middle blockers; S1 is a setter.

TABLE 2. Mean and maximal jump count and jump height per match in each player position during a competitive season.

Position	Jump count (n)		Jump height (cm)	
	Mean ± SD	Max	Mean ± SD	Max
H1	60.9 ± 20.4	79	61.7 ± 1.7	64.3
H2	80.0 ± 20.7	117	62.1 ± 3.2	67.7
H3	45.7 ± 27.7	97	60.3 ± 15.2	86.9
H4	42.0 ± 22.8	81	53.0 ± 6.2	64.8
H5	19.7 ± 7.7	36	49.9 ± 7.2	62.8
M1	52.5 ± 37.1	124	54.9 ± 8.4	75.1
M2	70.9 ± 28.3	108	60.3 ± 4.0	65.5
M3	77.2 ± 17.6	108	64.5 ± 3.1	69.5
S1	104.5 ± 32.3	158	49.3 ± 1.6	52.8

H1, H2, H3, H4 and H5 are hitters; M1, M2 and M3 are middle blockers; S1 is a setter. SD: standard deviation; Max: maximal value.

TABLE 3. Mean and maximal jump count per point in 3-, 4- and 5-set matches for each player position during a competitive season.

Position	3-set (n)		4-set (n)		5-set (n)	
	Mean ± SD	Max	Mean ± SD	Max	Mean ± SD	Max
H1	0.43 ± 0.09	0.63	0.38 ± 0.09	0.56	0.45 ± 0.05	0.53
H2	0.55 ± 0.11	0.63	0.49 ± 0.11	0.72	0.45 ± 0.15	0.63
H3	0.39 ± 0.12	0.63	0.26 ± 0.17	0.60	0.38 ± 0.14	0.58
H4	0.28 ± 0.13	0.50	0.27 ± 0.15	0.58	0.20 ± 0.20	0.50
H5	0.22 ± 0.12	0.59	0.21 ± 0.14	0.62	0.29 ± 0.05	0.32
M1	0.45 ± 0.24	0.74	0.36 ± 0.22	0.73	0.51 ± 0.14	0.72
M2	0.46 ± 0.16	0.69	0.45 ± 0.13	0.65	0.49 ± 0.14	0.81
M3	0.47 ± 0.12	0.67	0.41 ± 0.12	0.58	-	-
S1	0.60 ± 0.14	0.89	0.60 ± 0.13	0.81	0.70± 0.10	0.84

H1, H2, H3, H4 and H5 are hitters; M1, M2 and M3 are middle blockers; S1 is a setter. SD: standard deviation; Max: maximal value.

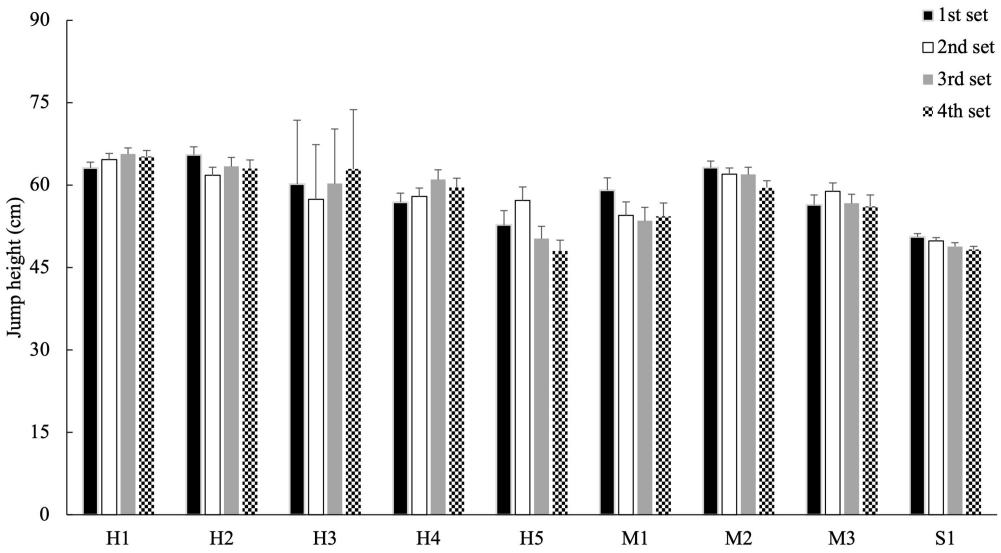

FIGURE 1. Jump height for each set in 4-set matches in each player position. (Data are represented as mean ± SD). H1, H2, H3, H4 and H5 are hitters; M1, M2 and M3 are middle blockers; S1 is a setter.

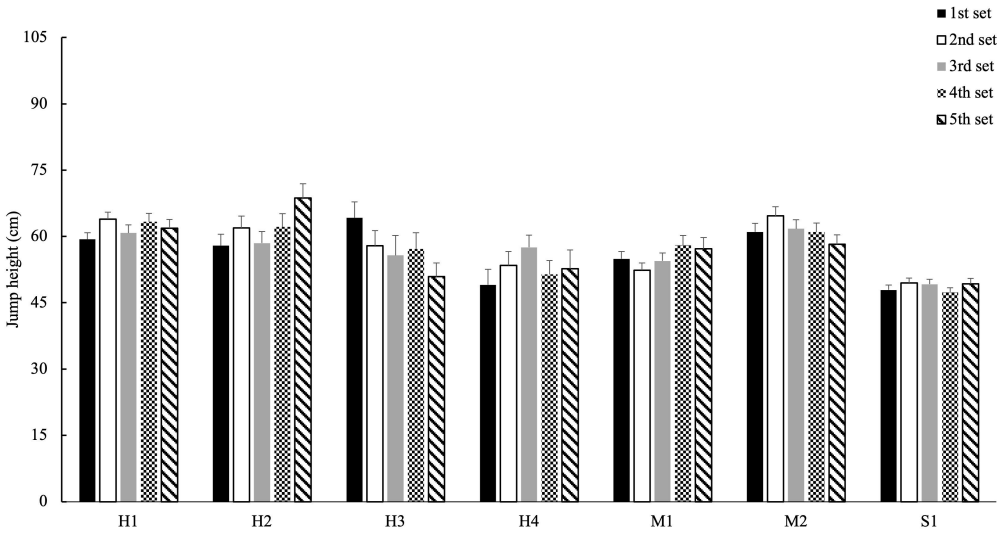

FIGURE 2. Jump height for each set in 5-set matches in each player position. (Data are represented as mean ± SD). H1, H2, H3, H4 and H5 are hitters; M1, M2 and M3 are middle blockers; S1 is a setter.

TABLE 4. Number and percentage (in parenthesis) of jumps exceeding 80% of the maximal height in each set for each player position in 4- and 5-set matches.

Position	1st set	2nd set	3rd set	4th set	5th set	*p* value[a]
4-set match						
H1	27 (19.1%)	32 (23.9%)	38 (24.7%)	25 (17.9%)	–	0.401
H2	17 (9.2%)	16 (8.2%)	16 (10.2%)	15 (8.9%)	–	0.411
M1	9 (13.4%)	3 (5.5%)	11 (21.6%)	4 (10.8%)	–	0.098
M2	12 (6.6%)	6 (3.8%)	10 (6.9%)	7 (5.0%)	–	0.611
M3	8 (16.7%)	8 (10.8%)	12 (19.7%)	5 (11.1%)	–	0.435
5-set match						
H1	4 (10.3%)	1 (2.4%)	5 (7.9%)	1 (2.5%)	2 (5.7%)	0.470
H2	5 (7.7%)	6 (9.8%)	3 (4.8%)	4 (8.2%)	6 (14.3%)	0.539
M1	14 (29.2%)	10 (19.6%)	6 (18.8%)	11 (20.4%)	10 (25.6%)	0.725
M2	7 (10.0%)	2 (3.5%)	4 (6.6%)	2 (3.2%)	3 (5.6%)	0.462

H1 and H2 are hitters; M1, M2 and M3 are middle blockers. [a]*Chi-square test.*

4. Discussion

To our best knowledge, this study is the first to investigate jump count per point and jump height variations across sets in volleyball matches during a competitive season. Notably, the jump count per point remained consistent regardless of the number of sets in a match. Additionally, our findings revealed that Asian male semi-professional volleyball players were able to maintain jump height levels throughout 4- and 5-set matches over the course of a competitive season.

Jump performance is a crucial determinant of volleyball technique and overall match success. Existing research highlights the importance of this ability, with a study reporting a positive correlation between block jump height and block efficiency in the Polish professional league [2]. Another study focused on the men's First Spanish Division revealed that superior jump height was inversely associated with serving errors [14]. Consequently, the ability to sustain optimal jump performance plays a critical role in maintaining technical and tactical proficiency during volleyball matches.

In the context of our well-trained participants, this study found that they were able to maintain jump height across sets in both 4- and 5-set matches. These findings are consistent with a study in the Portuguese First Division, where male players sustained both jump height and count throughout the sets, although the data were limited to four 3-set and one 4-set matches [15]. Notably, a study on professional male volleyball players revealed varied patterns across positions, with middle blockers maintaining 63%, 65% and 66% of their maximal jump height in 3-, 4- and 5-set matches, respectively. Outside hitters exhibited jump heights ranging from 60% to 64%, while opposites maintained jump heights between 73% and 77% across the same match durations. Although the average jump height across an entire match remained similar regardless of the number of sets played, jump height in individual sets was not reported [9]. Interestingly, collegiate male volleyball players showed an increase in countermovement jump height after each set during a 5-set match [16]. Conversely, elite male players in the Polish volleyball league experienced a decline in spike and block height in the third set compared to the first, although data for the fourth set were unavailable [2].

It is noteworthy that volleyball players do not consistently utilize their maximal jump capacity throughout matches. Professional male players across different positions have been reported to average between 73.7% and 76.2% of their maximal jump height during matches [15]. Similarly, another study indicated that opposites averaged 76%, middle blockers 64%, outside hitters 62% and setters 56% of their maximal jump height [9]. In the 4-set matches of our study, hitters performed 26.2% of their jumps with heights surpassing 80% of their maximal capacity, while middle blockers executed 8.2%. In 5-set matches, these percentages were 5.9% for hitters and 11.7% for middle blockers. These variations may stem from factors such as strategic dummy jumps, actions related to receptions and serves, or attacks executed without approaching steps. Furthermore, players may have adapted their efforts strategically based on the game situation to sustain performance levels throughout the match.

A unique contribution of this study is the presentation of jumps per total point, a methodology that allows the results to be applied to matches with diverse scoring situations. This approach provides coaches without access to wearable technology with a practical estimate of jumping loads across various player positions. Our findings reveal that setters exhibit a higher frequency of jumps compared to middle blockers and hitters, which is consistent with previous studies on elite volleyball players [4, 15]. The consistent number of jumps per point across 3-, 4- and 5-set matches suggests that our results are generalizable to varied scoring scenarios. Notably, only setters showed a higher frequency of jumps per point in 5-set matches compared to 3- and 4-set matches. This difference may be attributed to an increased number of volleys per point in 5-set matches, placing greater demands on setters. In contrast, the distribution of attack and block load may have been more balanced among hitters and middle blockers, leading to similar numbers of jumps per point in these positions. Data from Portugal's first division indicated that setters jump most fre-

quently, averaging 31.7 jumps per set, while middle blockers and outside hitters averaged 20.7 and 13.3 jumps per set, respectively [15]. This data align with our results when the two teams combined scored 45 points per set. Similarly, a study on men's professional clubs in Qatar found that setters had the highest number of jumps (100), followed by middle blockers (85), opposites (82), and outside hitters (68) in matches [9]. The maximum number of jumps in a 5-set match was 128 for setters, 115 for middle blockers, and 88 for outside hitters [9], which is consistent with our findings.

Our participants played matches on back-to-back days during eight weekends. Playing consecutive matches did not appear to influence jump count or height in well-trained volleyball players. For instance, elite male volleyball players from the Portuguese First Division showed no significant differences in average jump height or the number of jumps per minute between matches played on consecutive days, regardless of the number of sets played [10]. Similarly, collegiate male volleyball players maintained their countermovement jump height after a 3-set match on two consecutive days, despite changes in some kinetic variables [17]. Although a study found that elite players reported higher RPE scores after matches in congested weeks (two or more matches in a week) compared to weeks with only one match, jump count and height were not reported [18]. Therefore, this study pooled data from all matches for analysis.

Studies have shown that volleyball players exhibit a higher jump count during training compared to competitions, both in total number and on a per-hour basis [9, 19]. While the total number of jumps in training sessions seems to align with the demands observed in matches, the intensity of these jumps may differ. For instance, match analysis revealed that professional outside hitters performed most of their jumps at 70–79% of maximal height, whereas during training sessions, they had the highest percentage of jumps at 60–69% of maximal height [9]. A similar pattern was noted for middle blockers and opposites [9]. By leveraging match data, coaches can compare competition-specific metrics with training session outcomes, enabling a more tailored, data-driven approach to athlete preparation [20]. To optimize training, coaches and conditioning professionals should ensure that programs incorporate an appropriate number of high intensity jumps to meet the specific demands of match play, thereby preparing athletes effectively for competition.

5. Limitations of the study

This study has several limitations. Firstly, it did not differentiate between types of jumps, such as those performed during attacks and blocks versus receptions and serves. Additionally, celebration or null jumps were included in the analysis, as the wearable device could not distinguish them from other offensive or defensive movements. Players also adjusted their jumping efforts based on the game situation, and the number of each type of jump could vary depending on the tactics of the team or opponents. Furthermore, participants may have played through various injuries during the season, which could have impacted their jump performance in certain matches. Finally, since the data were collected from a single Asian semi-professional team, comparisons of match demands across positions were limited due to small sample sizes. As a result, caution is advised when applying these findings to players at different competition levels.

6. Conclusions

This study showed that Asian semi-professional male volleyball players are capable of maintaining their jump ability throughout 4- and 5-set matches. The consistency in jump count per point and percentage of jumps exceeding 80% of the maximal height across matches lasting various number of sets suggests that coaches and conditioning professionals can incorporate similar high-intensity jump loads in training programs to align with the demands of actual match scenarios. Practitioners across all leagues and younger divisions should focus on developing power and strength endurance, as this study revealed that players maintain consistent jump effort throughout the entire match, even during the fifth set. Monitoring players using the VERT device is a valuable tool for individual performance tracking during training and matches. This is crucial for in-season training optimization, as the results showed significant variations in player workload in matches. This highlights the need for balancing training loads: players performing excessive jumps may be overstimulated, increasing the risk of overuse injuries, while players with lower workloads may require additional training to ensure balanced adaptation and optimal performance. Furthermore, this monitoring is beneficial not only during matches but also in training, particularly for injury prevention. Coaches can use this tool to identify players experiencing excessive load and adjust accordingly, while also addressing undertraining in less-active players. Such training optimization contributes to both injury prevention and performance progression.

AVAILABILITY OF DATA AND MATERIALS

The data for this study is available in figshare, https://figshare.com/articles/dataset/volleyball_match_jump_VERT_data/28378100?file=52227263.

AUTHOR CONTRIBUTIONS

MHH and CKC—conceptualized and designed the study. MHH—acquired, analyzed and interpreted the data and drafted the manuscript. CKC and CHC—interpreted the data and edited the final draft of the manuscript. All authors read and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the Research Ethics Committee, Jen-Ai Hospital, Taichung, Taiwan (110-03) and adhered to the Declaration of Helsinki. Each participant signed an informed consent after thorough explanations of the procedures and associated risks by the research personnel.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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