







Investigation into the accuracy of subjective load parameters in comparison to analytical load measurements in NCAA Division I women's volleyball

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ABSTRACT

Monitoring athletes' workload has become common practice in sports and differs depending on the sport's physical demands. Within volleyball, an inertial measurement unit can be utilized to track the number of jumps performed by players. However, other methods of measuring jump frequency are needed for teams without access to this equipment. The purpose of this study was to determine if volleyball athletes can accurately predict the number of jumps performed after training and matches when given a perceptual scale and if player position, session rating of perceived exertion (sRPE), and perceived sets played affected the players' accuracy. Less than half of the team's jump count estimations (23.2%) were within 25 of the actual number of jumps and over half of the players' responses (58%) were within 50 of the measured number of jumps. A generalized estimating equation (GEE) with a binary response was used to investigate the impact of position, sRPE, and sets played. Position was the only variable to have a significant impact on jump count accuracy. Based on these results, a perceptual scale could be useful in better understanding players' jump counts following training, but number of jumps allotted to each jump range and position could impact accuracy.

Keywords: Performance analysis of sport, Physical conditioning, Jump count, Workload, Sports performance, Collegiate sports.

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INTRODUCTION

Volleyball is in the top ten of the most popular sports worldwide and has over 18,000 athletes participating at the collegiate level in the United States (Baugh et al., 2018). With such high participation rates, better understanding of athlete injury within the sport are of value to reduce time lost (Soligard et al., 2016). Epidemiologically centred research focused on injuries sustained by volleyball players, report that volleyball athletes are at the greatest risk for acute ankle injuries and overuse injuries in the knee and shoulder (Baugh et al., 2018; Ferretti et al., 1984; Reeser, 2006). Specifically, these common lower body injuries predominantly take form as ankle sprains or patellar tendinitis of the knee (Cuñado-González et al., 2019; Reeser, 2006). While ankle sprains are often an acute injury, the development of patellar tendinitis is an injury that develops overtime due to continuous loading of the knee without sufficient recovery (Couppé et al., 2008; Richards et al., 1996). Of particular interest, is how the onset of patellar tendinitis is impacted by training volume and correspondingly, jump frequency (Bahr & Bahr, 2014; Cuñado-González et al., 2019; Visnes & Bahr, 2012).

Jumping is a primary movement performed repetitively by players during training and matches, with the exception of defensive specialists (liberos), (Bahr & Bahr, 2014; Skazalski et al., 2018a). Over the course of a professional season, Skazalski and colleagues (2018) recorded 129,173 jumps performed across 142 sessions (practices and matches), equating to a team total of 910 jumps per session (Skazalski et al., 2018a). For comparison, research in basketball players observed an average of 371 jumps over the course of approximately 7.19 sessions (practices and games) (Ghali et al., 2020). Given the higher volume of jumping in volume, the prevalence of symptoms of jumper's knee are greater in volleyball athletes compared to basketball (Lian et al., 2005).

Interestingly, research examining jump frequency in volleyball athletes has provided evidence that training volume (number of hours per week) may not be as indicative of risk for jumper's knee, as individual player jump volume. While a team may train the same number of hours in a week, particular players may jump more than others during each training session, resulting in more loading of the knee and ankle joints, putting them at an increased risk for injury (Bahr & Bahr, 2014). Specifically, Ferretti and colleagues (1984) determined that frequency of play was a significant factor contributing to incidence of jumper's knee (patellar tendinitis) in volleyball players, with a peak incidence occurring in athletes who played five or more times a week (Ferretti et al., 1984). However, Visnes & Bahr (2013) determined match exposure and every extra hour of training to be sports-related predictors for developing jumper's knee (Visnes & Bahr, 2012). Players who developed jumper's knee, recorded 10.5 ± 6.2 h/week of volleyball training prior to the start of the study, while the asymptomatic players only participated in 7.6 ± 4.6 h/week.

Volleyball specific wearable technology to monitor training was developed using inertial measurement unit (IMU). Vert (Mayfonk Athletic, Fort Lauderdale, FL, USA) is a hip worn device that tracks various jump parameters (jump count, jump height, landing impact and kinetic energy), which are all registered via energy (from contacting the ground) traveling up the kinetic chain and being registered by the device at centre of mass. Validity and reliability of Vert's jump counting capabilities are well established in the literature (Borges et al., 2017; Brooks et al., 2018; Charlton et al., 2017; MacDonald et al., 2017; Skazalski et al., 2018a). Currently over 450 teams at the collegiate, professional and Olympic level teams utilize the technology but with 113 collegiate men's teams and 1,071 collegiate women's in the NCAA alone, there is an apparent wide range of teams and athletes not utilizing this device to track external load (Baugh et al., 2018), potentially cost being a limited factor to widespread adoption. One alternative to the use of Vert, when attempting to track player jump count in volleyball, is video analysis. However, this analysis requires recording of all practices and matches to be reviewed after play, which can be very time intensive, especially considering

multiple players, are jumping at the same time (Bahr & Bahr, 2014). Therefore, for teams who do not have the resources to implement any of these jump-tracking practices, an easy, inexpensive, sports-specific alternative could be beneficial. Although sRPE by time is often used for monitoring workload in sport, it fails to provide insight into jump count as it can be influenced by other fatiguing factors like mechanical load (change of direction, acceleration, and decelerations) and total impacts (digs and jumps). Linell (2015) only observed a moderate correlation when examining sRPE and mechanical load ($r = 0.581$) and total impacts ($r = 0.640$). Therefore, the purpose of this study is to determine if Division I women's volleyball players can accurately estimate jump frequency utilizing a perceptual scale following practice and matches as an alternative method to IMU systems. We hypothesized that players will not be able to accurately estimate jump count and position will play a role in accuracy with those who jump less being more accurate. Lastly, higher ratings of sRPE and perceived sets played will also result in greater inaccuracy compared to those with lower.

MATERIAL AND METHODS

Participants

Thirteen female NCAA Division I volleyball players competing on a team in the South-eastern Conference participated in the present study (Table 1). The age of participants ranged between 18 and 22 years old. The completion of a set number of practice sessions and matches in which Vert data was collected and surveys were completed was included in the analysis. All participants signed an informed consent form prior to the start of the study and approval from the University of Mississippi Institutional Review Board was obtained.

Table 1. Participant demographics and results from question 1 of pre-study questionnaire.

Variables	Mean \pm SD	Range
Age (years)	19 \pm 1.2	18 - 22
Height (cm)	180.3 \pm 9.7	165.1 – 190.5
Body Mass (kg)	75.1 \pm 14.0	55.2 - 97.3
Q1 (months)	21.5 \pm 15.2	2 - 42

Note. Q1. Experience monitoring personal jump count during training. $N = 13$.

Procedures

Participants completed a pre-study survey directed at assessing the extent of their experience with the VERT technology, along with determining their self-perceived ability to predict jump frequency following training. Following completion of the pre-study survey, all participants were familiarized with the four-question, post-training workload survey they complete following all of their practices and matches for the remainder of the season.

Preliminary survey

With the consideration that this is a novel investigation, the surveys were created by the researcher and are not direct replicas of surveys used in previous research. Therefore, the development of the pre-study survey was done by following specific steps as specified by Kyriazos & Stalikas (2018). An expert panel comprised of the team's head coach (former volleyball Olympian), two Division I assistant volleyball coaches, the team strength coach (6 years using Vert system with the volleyball team), the performance lab director for Vert, and a scientist with experience in survey development was sent the survey prior to its use in the study to rate the questions and provide feedback. Following the panel's feedback, the pre-study survey was adjusted. In addition, further refinement of the pre-study questionnaire followed in line with suggestions from Podsakoff et al. (2003) and Flake and Fried (2019) in an effort by the researcher to avoid bias and questionable

measurement practices when dealing with the development and utilization of subjective measurements (Podsakoff et al., 2003).

Workload survey development

The workload survey was administered following each practice and match through which sRPE, perceived sets played, jump count, and any self-counting of jumps is inquired. For sRPE, the modified Borg scale was utilized, with the scale ranging from 1, signifying very light activity, to 10, signifying maximal exertion (Borg, 1990). This sRPE as a measure of internal load has been used previously in volleyball specific studies (Kraft et al., 2020; Mendes et al., 2018; Vlantes & Readdy, 2017), as well as in other sports, such as soccer and running (Costa et al., 2022; Mann et al., 2019). Following sRPE, the players were asked to provide how many sets it felt like they had just played. The players were given a scale (<1 to 10), which is based on their responses when asked how many perceived sets they felt like they had played following their hardest and longest practice and match. The highest response given was 6, thereby resulting in the cap on the scale to be 10. Without measuring the player's duration of activity, this is a sports-specific measurement designed to see how it interacts with the other dependent variables being questioned. Thirdly, the players were prompted to estimate their jump range. The ranges for this question were generated based off the compilation of jump averages provided by Vert from fall and spring jump counts of 50 volleyball teams that use Vert, along with average jump numbers from the previous season data of the team being used in this study. The jump frequencies provided to the player's had a minimum of <25, and a maximum of >350, with each interval being separated by 25 jumps. Lastly, the players were asked if they counted jumps in their head during the preceding practice or match. This question served as insurance that the players accuracy or inaccuracy in predicting jump count is not based on any sort of self-counting.

Procedures

Participants were familiarized with the workload survey and a mock example of how each participant would receive the survey on their phone following training was conducted. The automated message containing the workload survey was sent out by the researcher to each participant via the Teams messenger app (Teammates Pty. Ltd., Australia). Once all participants received the message, they were asked to fill out the survey and sent it back ensuring they had a full understanding of the protocol prior to the start of the study. Following familiarization, the study began the next practice and concluded at the end of the season. Ten to fifteen minutes before the end of each practice and match, the participants received the questionnaire as an automated message. Therefore, the participants had access to the survey once they returned to their phones following practices and matches. Considering post-practice and match cool-downs and meetings, players had access to the survey approximately 15 minutes after training and matches. Thus, players that had not completed the survey 30 minutes after the survey opening received a reminder to complete the survey. If the survey had not been submitted by the 45-minute mark, the player's survey was considered missed data. The collection of subjective workload perception approximately 20 minutes following training was modelled after previous studies (Kraft et al., 2020; Vlantes & Readdy, 2017).

In addition to the collected survey responses, analytical workload data was collected via Vert, an IMU device (Mayfonk Athletic, Fort Lauderdale, FL, USA). Each player wore a Vert device during practices and matches in a waistband specified to them by their jersey number. All of the jump count data collected by each players Vert device and was extrapolated from the Vert team database and loaded into an excel sheet to be de-identified.

Analysis

Responses collected from the pre-study survey are seen in Table 2. Determining the accuracy of the players jump range selection was done by block coding each jump range. Every day, after the collection of surveys and jump count data, each player's accuracy (accurate = jump count falls in range selected) was established. In this case, we would note the percent of times individuals selected the correct jump block, were off by 1 block, 2 blocks, and 3 or greater jump blocks, and report those percentages. The effect that months of experience players have had monitoring jump count during training has on player accuracy throughout the study was determined by running a binary logistic regression. Additionally, a generalized estimating equation (GEE) was utilized to determine if the players' jump count accuracy differed based on player position, session rating of perceived exertion (sRPE), or perceived sets played. Each predictor variable was implemented into the GEE as an individual factor. Furthermore, to account for the small population size of this study, use of bias-corrected empirical SE estimators & df estimation methods were used, rather than the empirical sandwich estimator, ensuring small type one error rates. All analyses were conducted using SPSS version 26 (IBM Corporation, New York, NY, USA).

RESULTS

Thirteen NCAA DI women's volleyball players were included in the study. Participant demographics are reported in Table 1, along with the results from question 1 on the pre-study survey, pertaining to the players' reported months of experience monitoring jump count during volleyball training.

All thirteen players completed the pre-study questionnaire prior to starting the study. The majority of the players had previous experience using Vert, which was anticipated given its utilization by the team in previous seasons. Concerning their awareness of their jump count, most players reported never or rarely looking at or being aware of their jump count during training, but almost always checking the Vert for their jump count post training. Lastly, the majority of players reported that predicting their jumps would be slightly difficult, but they were predominantly slightly to moderately confident they could do it.

The response rate on the post-training survey was 96%. The average response time on the post-training survey, across all players, was 28.75 minutes for matches and 33.75 minutes for practices. It should be noted that players did not have access to their phones until approximately 15 minutes after training, on average. Over the course of 6 weeks, data was collected from 24 training sessions (20 practices and 4 matches). Overall, with the consideration of missed player data over the course of the study, 284 data points were used for analysis.

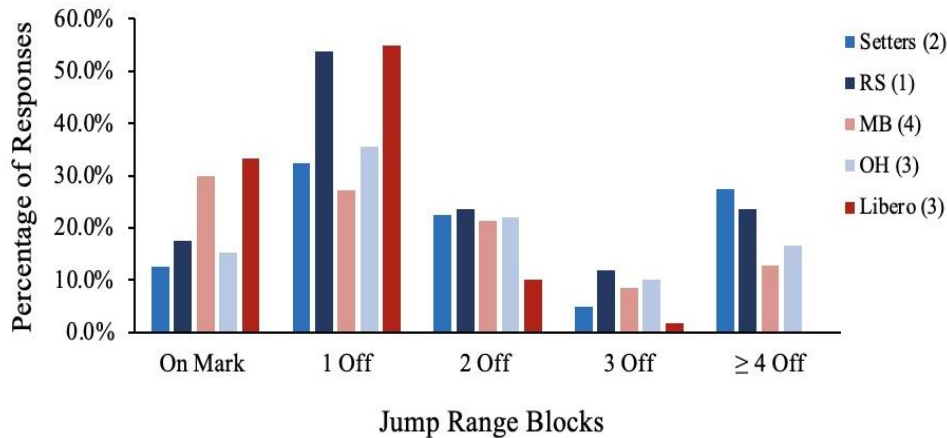
Table 2. Average jump volume among player positions.

Position	N	Mean \pm SD	Range
Setter	2	185.4 \pm 109.4	6 - 427
Right side hitter	1	106.9 \pm 48.8	20 - 215
Middle blocker	4	125.7 \pm 71.5	7 - 270
Outside hitter	3	114.5 \pm 51.9	35 - 238
Libero	3	48.9 \pm 19.0	26 - 85
Total	13	113.1 \pm 78.1	6 - 427

Player jump volume data across positions are reported in Table 2. Out of all practices, setters jumped the most and had the greatest jump frequency range, followed by middle blockers, outside hitters, and right side.

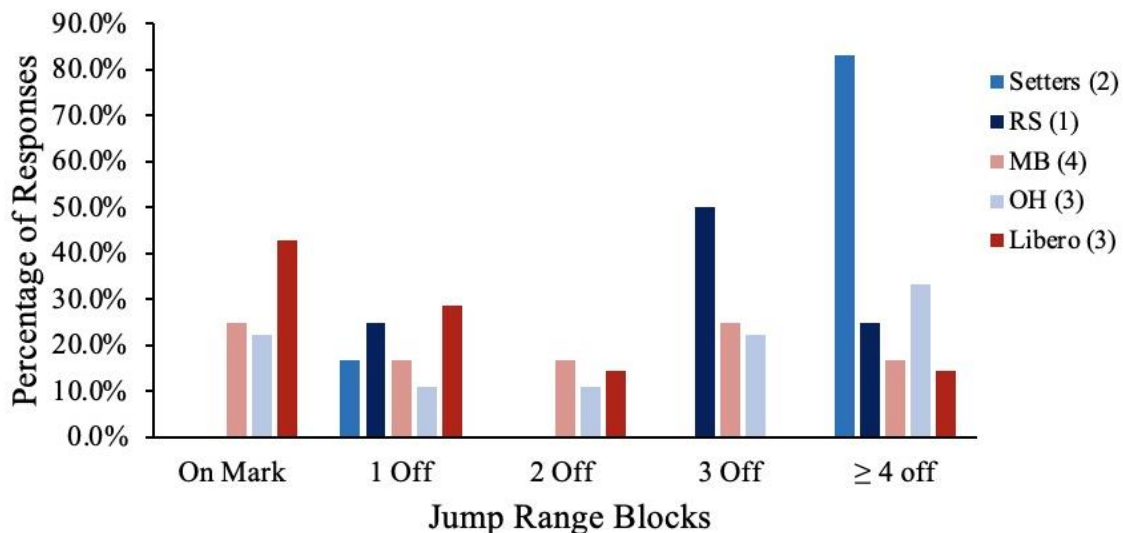
Liberos were found to have the lowest jump volume, as well as the lowest range between the maximum and the minimum number of jumps performed across all practices and matches.

Player accuracy on the post-training survey was defined as players selecting the jump range that their actual number of jumps performed (reported by Vert) fell into. Results of player accuracy are separated by position and illustrated in Figure 1, for all practices, and Figure 2, for all matches. We found that 58% of the player's jump range selections, over the course of the study, were within 50 jumps of the actual number of jumps they performed, with the remaining 42% of selections being 2 or more jump ranges off from the number of jumps actually performed by the players.



Note. Player percent accuracy for correct jump range selection (on mark) or inaccurate by 1, 2, 3, or 4 or more jump ranges. Player positions: setters, RS = right side, MB = middle blockers, OH = outside hitters, and liberos, and the number next to each position indicates the number of players playing that position.

Figure 1. Players jump range selection accuracy for practices.



Note. Jump count estimation accuracy across matches (total measures = 38).

Figure 2. Player jump range selection accuracy for matches.

A binary logistic regression revealed that months of experience monitoring personal jump count during training, reported by the players prior to the start of the study, had a nonsignificant effect ($p = .533$) on player accuracy. Furthermore, the results from the GEE are shown in Table 3. The only predictor variable that reached significance ($p < .05$) was player position. Therefore, there was a significant interaction found between jump count estimation accuracy and position ($p < .001$), but not for sRPE and accuracy ($p = 0.62$) or perceived sets played and accuracy ($p = .93$). Additionally, the small, yet positive coefficient in the interaction between player position and accuracy, based on how the positions were coded, is likely due to low accuracy among setters (coded as 1) and the high accuracy among liberos (coded as 5). More specifically, out of all of the players jump count estimations, setters were only 10.8% accurate, followed by right sides (13.6%), outsides (16.2%), and middle blockers (27.4%), with liberos having the highest accuracy with 32.8% of responses being accurate. Thus, all of the hitting positions' accuracies fell between that of the setters and liberos.

Table 3. GEE outputs for the predictor variables' interactions with player estimation accuracy.

Accuracy	Coef.	Std. Error	z	$p > z $	95% Conf. Interval	
Position	0.263	0.07	3.76	* $< .001$	0.125	0.4
sRPE	-0.079	0.161	-0.49	.623	-0.394	-0.236
Perceived Sets Played	-0.014	0.161	-0.09	.931	-0.331	0.303
Constant	-1.639	0.534	-3.07	.002	-2.687	-0.593

Note: *Indicates the independent variable has a statistically significant ($p < .05$) effect on accuracy.

DISCUSSION

The main purpose of this study was to determine if NCAA Division I volleyball players could accurately estimate their jump frequency utilizing a perceptual scale following practices and matches as a cost effective alternative to wearable sensors. Additionally, the study aimed to identify how and if player experience with monitoring jump count, session rating of perceived exertion, position, and perceived sets played during training, affected their jump range selection accuracy. Overall, for the majority of the training sessions, the players were unable to accurately estimate their jump frequency using a scaling of 25 jump increments (Figure 1-2). When considering accuracy as selecting a range within 50 jumps of the number of jumps performed by the players (including the percentage from '1 off'), player selection accuracy increased to over 50% of player responses (Figure 1-2).

The players' months of experience using any type of jump count methodology during training, was not found to have a significant effect on player jump count estimation accuracy. Therefore, a player's ability to accurately estimate the number of jumps performed in training was not dictated by their previous amount of experience tracking their jump count. This could potentially be due to the variability in jump frequency that players experience across practices and matches. Skazalski and colleagues (2018) illustrated that, over the course of a season, low and high weekly jump counts for right sides, outsides, middles and setters can vary from below 100 jumps to upwards of 500 jumps (Skazalski et al., 2018a). Similar frequencies were also reported by Bahr and Bahr (2014) with recorded jump frequencies ranging from 0 to 379 jumps across players, over the course of a week of training (Bahr & Bahr, 2014). Similar variability in jump frequency for positions across training sessions was also observed in the current investigation. For example, the recorded jump range for the starting setter was 42-427 jumps and one of the outside hitters ranged from 29-187 jumps across all training sessions. A lack of consistency in the number of jumps performed by specific positions could lead to the inaccuracy for jump count estimation. The positions that have more jump count variability, also recorded the highest jump volumes. Vlantes and Ready (2017) determined that setters have the greatest

mean player load, in addition to performing the highest number of jumps (Vlantes & Readdy, 2017). Furthermore, Skalzalski et al. (2018) reported setters as having the greatest volume of jumps out of all position groups with an average of 121 jumps performed per session, and the middles are next closest position performing an average of 92 jumps per session (Skazalski et al., 2018b). Theoretically, the higher the volume of jumping an athlete completes in training, the more difficult it will be for an athlete to accurately perceive jump volume following training. In support of this, liberos (position that performs the lowest volume of jumps) were found to be the most accurate in selecting their jump count following training and had lower jump volume range (26-85) (Table 2). This suggests a lower volume of jumps performed could make it easier on the player to accurately estimate the total number of jumps completed. Bahr and Bahr (2014) found similar jump frequency (number of jumps performed per hour of training) variability across a week of training and matches in male players, with setters ranging from 20.3-128.2 jumps and liberos only ranging from 5.7-29.2 (Bahr & Bahr, 2014). Thus, greater variability in jump frequency across trainings between positions plausibly has an effect on accuracy. Potentially modifications to the current scale and recording frequency (every hour vs. post-practice) could improve accuracy across positions given improved accuracy with lower jump volumes.

sRPE is taken and multiplied by the length of the training session, as done by Kraft et al. (2020) in their recent study on volleyball players to produce a training load value (Kraft et al., 2020). Yet, practices and matches may be potentially impacted by a multitude of factors including drill selection (decelerations, jumping, diving, etc.), rest periods, and duration. Subsequently this can make it difficult to determine the injury risk relationship. Interestingly, Vlantes and Readdy (2017) found that, while jump volume is low, liberos recorded the highest sRPE overall for 15 matches (Vlantes & Readdy, 2017). However, that was not found to be a significant variable when considering predicting jump count. sRPE and perceived sets played were not found to significantly affect jump count selection accuracy in the current study. However both variables could still be useful tools for gathering an all-encompassing view of the athlete's workload. Subjective measures, such as these, are relatively inexpensive and easy to implement and monitor among players. In their systematic review, Saw and colleagues (2016) determined that subjective measures (i.e., mood/perceived stress scales/questionnaires) detect acute and chronic training loads among athletes with greater sensitivity, compared to objective measures (i.e., blood markers, heart rate, oxygen consumption, etc.) (Saw et al., 2016). In addition, sRPE is a valid tool for assessing internal workload and has been used in a multitude of studies on volleyball athletes (Duarte et al., 2019; Kraft et al., 2020; Vlantes & Readdy, 2017). Although, the relationship with sRPE by time may not be sensitive enough to determine risk for development of knee tendonitis. Conversely when training volume (expressed as hours spent training) has been shown to increase the risk of developing jumper's knee in volleyball athletes (Visnes & Bahr, 2012). Therefore, the aim with this variable was to potentially control for the static times accrued during training by assessing how long the player had felt the practice had been, based on their perception of how many sets they felt like they had played, rather than just timing the practice from beginning to end.

Research investigating injury rates in NCAA women's volleyball players has shown that the majority of the injuries incurred are to a lower extremity and primarily resort from overuse (Baugh et al., 2018). This is believed to be the cause of long-term habitual loading of the patellar tendon, without proper rest, resorting in onset of patellar tendinitis (Couppé et al., 2008). While specific jump volumes for volleyball positions have not been established to put players at an increased risk for injury, Visnes and Bahr (2013) did establish that volume of training in volleyball increases the risk of developing jumper's knee, for every addition hour or set played (Visnes & Bahr, 2012). Thus, allowing teams to track jump volumes among players could aid in specifically establishing the appropriate jump volume per position, over the course of training, to best reduce the risk of overloading, knee injuries in volleyball athletes. While objectively measuring jump volume in

players via an IMU would be the most accurate practice available, further research on widely accessible inexpensive methods to monitor this variable to improve load management in volleyball is warranted. The current post-training survey used in this study provides insight into variables that affect jump count estimation accuracy in players and could be improved based on findings to be used in further research in this area.

Some limitations exist in the current study. First, the team in this study was using the Vert device technology prior to the study. Therefore, while experience with the technology varied, every player had some exposure to identifying their jump count during training via Vert. This would impact the generalizability of the study results to apply to teams with no experience using Vert technology. Another substantial limitation was COVID-19 limiting match data and the number of home matches with potential differentiation between match and practice team data. Lastly, because there was only one team included in this analysis, the use of additional teams to increase the sample size and potential applications would be beneficial in future research.

CONCLUSIONS

While advancements in microtechnology now allow for tracking of jump count, such technology requires financial resources and time to interpret data in order to be effectively implemented. Thus, the inexpensive and simple nature of subjective collection of training load is an alternative to objective microsensor tracking but there is no insight on jump count. On the formulated post-training survey, the aim was to assess volleyball athletes' ability to gauge their jump frequency following training and match play, using a perceptual scale, in addition to assessing internal training loads via RPE and perceived sets played. This preliminary data, in this area of research, yields evidence that volleyball players may not be able to accurately estimate their jump volume when given a perceptual scale, without previous experience monitoring jump count or feedback period where athletes are provided jump count following training or matches. Future studies could implement a feedback window, where athletes are provided jump count, so athletes potentially have a better gauge how many jumps they performed going forward and see if accuracy improves. Further studies need to be conducted in which more data is collected, across more than one team, to discern the reliability of this survey in assessing jump volume. Potentially the proposed perceptual scale may need to be modified or administrated multiple times during a practice to improve player accuracy.

AUTHOR CONTRIBUTIONS

The idea for this study and design was proposed by Pierce. Pierce collected and analysed the data and drafted the manuscript. Loprinzi, Jessee, Andre and Valiant provided mentorship, aided in data analyses, results interpretation and writing process. Phillips and Nelson critically reviewed and edited the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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