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Changes in Vertical Jump Components Utilizing the Myvert Device in Female Collegiate D-1 Volleyball Players

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CHANGES IN VERTICAL JUMP COMPONENTS UTILIZING THE MYVERT DEVICE IN FEMALE COLLEGIATE D-1 VOLLEYBALL PLAYERS

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This thesis is approved as a creditable and independent investigation by a candidate for the Master's of Science in Exercise Science and Nutrition degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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This thesis is dedicated to my family and everyone who has supported me along this journey.

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CONTENTS

ABBBREVIATIONS

D-1	Division 1
in	inches
L_DS	libero and defensive specialist
MB	middle blocker
OH	outside hitter
RS	right side hitter
S	setter
VJ	Vertical Jump

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ABSTRACT

CHANGES IN VERTICAL JUMP COMPONENTS UTILIZING THE MYVERT DEVICE IN FEMALE COLLEGIATE D-1 VOLLEYBALL PLAYERS

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The purpose of this study was to determine daily and weekly variations in vertical jump (VJ) volume and VJ height over the course of a season for female collegiate division 1 volleyball players using Vert® technology. Sixteen volleyball player's external load was monitored through jump count, average VJ height, number of VJs completed over 20-inches, and the ratio of VJ height relative to maximum tested VJ height. The VJ parameters were compared between practices and games, and between the various position groups (outside hitters, middle blockers, libero/defensive specialist, setters). A large increase in jump count observed during pre-season, peaked at approximately 700 jumps in a week. The team completed more jumps during practices (84±63) than during games (36±32) ($p<0.05$). Middle blockers (MB) averaged the greatest jump count pre-season and in-season (142±89 and 80±52) ($p<0.001$). Average VJ height did not vary substantially from the mean over the 14-week season. MB maintained the highest ratio of average VJ height to maximum VJ height ($p<0.001$) compared to other positions during practices and games). Understanding the external load demands of a season helps coaches, strength and conditioning coaches, and sports medicine staff better prepare athletes and reduce injury risk.

CHAPTER 1

REVIEW OF LITERATURE

Authors	Purpose	Subjects	Monitoring Methods	Results	Major Findings
Charlton et al (2016)	To evaluate the validity of Vert device for measuring vertical displacement and jump count in volleyball athletes. Propose a potential method for quantifying external load during training load and match play within this population	n=18 male, elite junior VB athletes (~16yo, ~85kg, ~6'4")	Vert. External load calculated as Load index=(kinetic energy)X(jump count)	Vert data demonstrated on average an overestimation of vertical displacement, however no relationship between vertical displacement and measurement error was detected (*r*=1.09).	Vert has excellent precision for all jump types analyzed (0.974-1.00). Recall was excellent for block, spike and serve jumping motions (0.957-0.991) however it was lower for setting jumping motions (0.754).
Hulin et al (2014)	To review a series of studies on VJ in female and male basketball players - junior players, college players, national team players, and national professional league players	n=28 fast bowlers (26 +/-5 yrs)	External workload was estimated by number of balls bowled per week, in training and game. Internal workload was estimated multiplying sessions duration by session-RPE. Training-stress Balance ratio of acute (1 week) workload to chronic (average 4 weeks) workload	Acute: 2450+/-1688 AU External 96 =/-80. Chronic: Internal 2445 +/-1070 External 96 =/- 58 Training-stress balance Internal (%) 100 +/- 46, External (%) 102 +/- 56	Injury risk increases as the acute workload outweighs the chronic workload. Low chronic workloads did not promote positive physical adaptations required to tolerate physical demands. If training-stress balance was 200% or higher, injury risk increased three- to fourfold.
Hulin et al (2016)	To investigate whether distance covered, measured by GPS, and calculated as an acute:chronic workload ratio predicted injury in elite rugby league players.	n=53 male rugby players (age 23.4 +/-3.5 yrs)	Global Positioning System (GPS): Measured absolute total distance measured during all field training sessions and matches.	Very-high acute:chronic workload ration (>=2.11) was associated with an injury risk that was 6.9 times greater than a very-low ratio of <= 0.30, 3.4 times greater than low ratio (0.31-0.66), 2.3 times greater than a moderate ratio (1.03-1.38), and 2.0 times greater than a high ratio (1.75-2.1).	Acute:chronic workload is a greater predictor of injury than either acute or chronic workload in isolation. Compared to players that have low chronic workload, players with a high chronic workload are: 1) more resistant to injury with moderate-low to moderate-high acute:chronic workload ratios and 2) less resistant to injury when exposed to large spikes in workload or a very-high acute:chronic workload ratios ~1.5.

Sams et al (2017)	To examine the effectiveness of an athlete monitoring program in managing athlete neuromuscular fatigue across a men's collegiate soccer season as measured by changes in squat jump height and to compare possible changes with session rating of perceived exertion training load.	18 NCAA D-1 Male soccer athletes (20+/-1 years, 179+/-6cm, 75.6+/-6.6kg)	Retrospective. Tracked absolute standing jump (SJ) height for 18 pre-game sessions across a 14-week season of Division I men's collegiate soccer. Training load in the 7 days preceding each testing session was correlated and cross-correlated to changes in SJ performance. Training Load (TL) defined as s-RPE, was collected after each training session. RPE was multiplied by minutes of session.	Only session 8 was statistically significant in SJ height compared to baseline. No significant decline in SJ height across season. Small, statistically non-significant positive correlation (r=0.18, *p*=0.48) between training load and SJ.	Potential benefits of an athletic monitoring program and collaboration between a sport science staff and coaching staff in managing neuromuscular fatigue in a season of Division I men's collegiate soccer. The stability in SJ height and positive relationship between SJ performance and accumulated TL suggests the athlete monitoring protocol and the training alterations for flagged players may have aided in prevention of excessive fatigue accumulation in the athletes studied.
Skazalski et al (2018)	To examine position-specific jump demands required for training and competition during professional volleyball season and to investigate to individual variability associated with jump load.	n=14 male, elite, professional volleyball players	IMU, Vert Classic. Recorded jump count and jump height. Calculated jump frequency.	Setters Reported the most jumps per training session (121 jumps/session), followed by middles (92 jumps/session). Setters median season jump height: 41% maximum and OH median season jump height: 69% of maximum.	Considerable variance week-to-week for average jump count per player that included increases in jump count well over 10%. Setters and MB performed high frequency of jumps during game. OH performed more high-intensity jumps.
Visnes & Bahr (2011)	To study the effects of training/game load and body composition as potential risk factors for jumper's knee	n=141 healthy students (69 males; 72 females)	Collected data over a 10-month school year. Training volume was self-reported through web-based questionnaire of number of hours of volleyball, beach volleyball, strength, jump training, and other training. Training volume was calculated as the mean number of hours per week. Match	28 of the 141 developed jumpers knee (22 males, 6 females). Those with jumpers knee recorded more hours of volleyball training, jump training, total hours training and played more sets than someone who remained asymptomatic.	A high volume of volleyball training, high match exposure, and gender were important risk factors of this cohort study indicate that total tendon loading and jumper’s knee are closely connected.

			exposure as the mean number of sets per week.		
Vlantes & Readdy (2017)	To quantify the external and internal load experienced in game during women's collegiate volleyball matches.	n=11 female collegiate volleyball players (ages 18-21.9yo, body mass = 69.43kg, height 178.95cm)	Catapult Optimeye S5 (external load) and S-RPE (internal load)	S had greatest mean player load (PL) and highest number of mean jumps (200 +/- 20.6). DS had second highest mean PL and lowest number of mean jumps (35 +/- 9.0). MB had the highest mean high impact PL and second highest mean jump total (117 +/- 24.2).	Using micro sensor technology and S-RPE to quantify match demands of collegiate volleyball players revealed a great deal about external and internal workloads at both the team and positional levels.
Wrigley et al (2012)	To evaluate the weekly training load (internal and external) of elite junior soccer players (U14, U16, U18) - to identify diff in loads across diff age groups	n=24; 8 from each age group	physiological(external) load - HR; internal load - session-RPE/modified 10-pt Borg Scale; load was calculated in AU's = session duration X session-RPE	RPE significantly higher in match-play vs field training; Match play load significantly lower than field training	In-season loads were significantly higher during game training than field training. Training loads were positively correlated with age, as the shift focus to more game emphasized practice.

CHAPTER 2

INTRODUCTION

Training load is associated with risk of injury (Soligard et al., 2016a, 2016b); however, the ability to monitor training load among athletes has been difficult. Advancements in technology have expanded opportunities for coaches and athletes to track training load (Buchheit, Simpson, & Buchheit, 2017). Monitoring training load allows coaches and athletes to better understand the demands of practices and games. This may ultimately reduce risk of injury by ensuring athletes are recovering appropriately from training. However, when the athlete becomes fatigued, the risk for injury can increase due to incorrect biomechanical movements. Fatigue can have a detrimental effect on performance as well as increase the risk for overtraining and injury (Halson, 2014).

Training load, or sometimes referred to as workload, is defined as the "cumulative amount of stress placed on an individual from multiple training sessions and games over a period of time" (Windt & Gabbett, 2017). Training load is measured as an internal load, external load, or a combination of both. Internal load is quantified by heart rate, blood lactate concentration during training, oxygen consumption, or with rates of perceived exertion in order to represent the stressors placed on the biological or psychological systems (Bourdon et al., 2017; Halson, 2014). External load is collected to objectively measure the amount of work an athlete performs in a given session, and is typically measured using global positioning systems (GPS), accelerometers, power output, speed, or time-motion analysis (Bourdon et al., 2017). For the sport of volleyball, the vertical jump is the foundation and determining factor as to if an athlete is successful at any number of skills (i.e. blocks, kills, serves, etc.) required by the sport. Similar to pitch count in baseball being used to quantify an external load, jump height and jump count can be used to objectively quantify an external load for volleyball athletes. Prior studies have reported that volleyball athletes may perform anywhere from 650 to over a 1,000 jumps per week dependent upon game level (Charlton, Kenneally-Dabrowski, Sheppard, & Spratford, 2017). Being able to monitor vertical jump components (jump height and jump count) of a volleyball player will allow appropriate progression of external training load in an effort to avoid the onset of overuse injuries common to volleyball such as patellar tendinitis and stress fractures (Halson, 2014; Soligard et al., 2016a; Visnes & Bahr, 2013; Windt & Gabbett, 2017). Often the onset of an overuse injury is caused by a sudden increase in training load (Windt & Gabbett, 2017).

In addition, jump count and jump volume can be valuable information for sports medicine professionals. Following injury, athletic trainers and strength and conditioning coaches can utilize this information to develop a rehabilitation prescription to systematically progress the athlete through rehabilitation and return to play. It is important to appropriately manipulate training load for injury reduction and performance enhancement, however there is still a lack of reliable tools available for coaches to monitor such progress.

Currently, methods available to monitor volleyball training loads are limited to time-consuming, retrospective video analysis or expensive software (Bourdon et al., 2017; Charlton et al., 2017). Accelerometers with the appropriate software have been found to be a reliable tool that are inexpensive and user-friendly when compared to other devices (Charlton et al., 2017), often used to objectively quantify external training loads (Bourdon et al., 2017). Vert® is a relatively new device in the market of athlete monitoring that uses an accelerometer to measure vertical jump height. It provides jump count, vertical jump height, average vertical jump height, and peak vertical jump height. The Vert® is a wearable device that live feeds vertical jump data to a Bluetooth device, and has been found to be a reliable measurement tool when compared against VertCon video analysis (Charlton et al., 2017). To our knowledge no study has used Vert® to track changes of vertical jump components of a female Division I (D-I) volleyball player during practices and games throughout an entire season. The data collected throughout this study will allow us to measure total jump volume in order to establish a better understanding for sports-medicine staff and strength and conditioning professionals of the total accumulated volume demand that is required of D-1 volleyball athletes.

The long term goal of this study is to observe changes in the components of vertical jump for a D-I collegiate female volleyball player over the course of a season utilizing the Vert® device. These observations will provide an understanding of the demands of practices and games for coaches, strength and condition coaches, and sports medicine staff (Buchheit et al., 2017). A better understanding will allow better practices of monitoring athlete's adaptation to training loads, and could help guide return to play progressions (Halson, 2014). Our primary objective is to evaluate the usefulness of the Vert® device as a monitoring tool for volleyball. Once this data is collected, we will be able to better understand the demands a season places on a volleyball player, and we will be able to help coaches better plan training in future seasons. This study has two primary aims. The first is to determine daily and weekly variations in jump volume over the course of the season. We hypothesize that jump volume to be greater in the pre-season compared to in-season. We also hypothesize to see an increase in jump height during the season. Comparing the different positions, we hypothesize no difference between OH and MB to be observed, but these two positions would yield greater vertical jump components than the other positions. Lastly, we hypothesize the performance variables will be greater during games compared to practices. The second aim of the study is to determine the degree to which players are able to maintain an average vertical jump height relative to maximum vertical jump measurements during practices and games. We hypothesize that athletes would maintain an average vertical jump within 90% of their tested maximum vertical jump height, during practice and game.

After testing these hypotheses, Vert® may be a device that takes monitoring training one step closer to providing a reliable and user-friendly device to coaches. We anticipate the data will be able to provide feedback to coaches as to as to how athletes are adapting to training. Markers of decrease in performance will be seen as a sign of fatigue, which can relate to acute or chronic fatigue based on when and how this occurs. Steady improvements in performance will be seen as proper recovery and adaptation to training. Knowing these training loads of practice and game will guide strategies of reducing injury rates and heightening the overall performance for volleyball players.

CHAPTER 3

METHODS

The objective of this study is to monitor the changes in various vertical jump components using the Vert® device over the course of a season for female, D-I volleyball players. The device is an accelerometer that athletes can wear around their waist that tracks jump height, average vertical jump height, peak vertical jump height, and average vertical jump height of heights greater than 20". The device feeds into an iPad or other Bluetooth device, and all data is uploaded to the Vert® website with downloadable Excel files. The listed variables will be compared between practice and games, between the various position groups (e.g. outside hitters, middle blockers, libero/defensive specialists, setters), and changes in these variables over the season will be analyzed for statistical significance.

This study used data from 14 female D-I volleyball players. Ages ranging between 18 to 22 years old. Each player was assigned their own Vert® device. Players wore the device around their waist with the accelerometer centered on the lower back. The accelerometer utilizes Bluetooth technology to communicate with the Vert® software application on an iPad. Through this app, sessions were created and labeled as a practice or game, and dated. An assistant volleyball coach was in charge of starting and ending all sessions, including practice, game warm-ups, and games. The same assistant coach created and began each session. All players turned on their devices in close proximity to the iPad in order for a good connection to be established. All data was synced through the app. When the assistant coach ended the session, the data was automatically uploaded to the Vert® website (myvert.com) where two excel files were available for access and download. One file has every single recorded jump with its corresponding height and time-marker. The other file is a summary with all the variables of interest such as average vertical jump height, peak vertical jump height, and jump count. For this study, the head volleyball coach downloaded the files and de-identified the players' identity prior to sharing the files. The data were sorted by practice, game and by the variables of interest. Vertical jump was also tested using the VerTec protocol during pre-season, mid-season, and post-season in order to compare the tested maximum vertical jump to the recorded peak vertical jumps of the Vert®. Statistical analysis of the data will be done using *the Jmp® (v.14.0, SAS Institute, Inc.)*. A one-way analysis of variance was utilized to compare pre-season to in-season and to compare OH to MB. All data are reported as mean ± SD.

CHAPTER 4

RESULTS

4.1 Jump Count

Over the 14 weeks that included pre-season and in-season, there was a total of 46,899 jumps recorded from games and practices. As seen in Figure 1A, the majority of the jump count occurred within the first two weeks of preseason, peaking with close to 700 jumps week 2. In Table 2, it was observed that the team averaged significantly (p<0.05) less jumps per session in-season (59 ± 48) compared to pre-season (99 ± 77). During preseason and in-season, MB averaged the most jumps per session with 142 ± 89 and 80 ± 52*, respectively. Setters accumulated the least number of jumps during pre-season (48 ± 46) and in-season (30 ± 24), and did not have any significant difference of in-season jump count compared to pre-season jump count. Figure 1B compares jump count of practices and games. In Table 3 it can be observed that the team averaged significantly (p<0.05) less jumps per game (36 ± 32) than per practice (84 ± 63). Setters were the only position to not have significantly less jumps per session in games compared to practices. MB averaged the most jumps during practices (116 ± 71) and during games (49 ± 36). OH averaged the second most jumps per session with 92 ± 52 during practices and 41 ± 32 during games. Changes in MB and OH jump count can be observed in Figure 2. MB and OH peaked in jump count within the first week of preseason. MB peaked at ~300 jumps, and OH peaked at ~230 jumps.

4.2 Jump Height

Over the course of the season, average vertical jump height appears to be consistent in Figure 3. In Table 2, The team did have a statistically significant (p<0.05) average vertical jump height during the in-season period (15.9 ± 3.9 inches) compared to pre-season (15.2 ± 3.0 inches). Besides the team overall, MB was the only position to have a significantly greater average vertical jump height in-season (18.1 ± 3.0 inches) compared to pre-season (16.8 ± 2.2 inches). As seen in Table 3, MB and OH had significantly (p<0.05) greater average vertical jump heights during games (19 ± 3.0 inches and 17.3 ± 3.2 inches) compared to practices (17.3 ± 2.7 inches and 15.9 ± 2.3 inches). Figure 3B shows average vertical jump heights varied between pre-season and in-season as well as between practice and games for MB and OH. In Figure 4, the average vertical jump height relative to the athlete's tested maximum vertical jump height was a ratio of 0.71 ± 0.14 (Table 2), which is significantly different from the hypothesized ratio of 0.9 ($p<0.05$). There was not substantial variation from the mean ratio across the season. And no significant differences of the average ratio were observed in Table 2 of in-season compared to pre-season. RS had the greatest average ratio of 0.83 ± 0.11 during pre-season and 0.74 ± 0.17 during in-season. MB had the second greatest average ratio of 0.77 ± 0.08 during pre-season and 0.77 ± 0.11 during in-season. In Table 3, the team did have a significantly (p<0.05) greater average ratio during games (0.74 ± 0.16) compared to practices (0.69 ± 0.13 inches). MB was the only position to have a significantly (p<0.05) greater ratio during games (0.80 ± 0.12) compared to practices (0.76 ± 0.10). During practices and games, MB averaged the greatest ratio of average vertical jump height to maximal vertical jump height.

CHAPTER 5

DISCUSSION

The primary purpose of this study was to observe changes in the components of vertical jump (jump count and jump height) for a D-I collegiate female volleyball player over the course of a season utilizing the Vert® device. The primary aim from these observations was to determine the daily and weekly variations of vertical jump count and height. This would provide information on the external training load of a volleyball athlete that could help monitor and prescribe training progressions, and provide goals for return to play protocols. The usefulness of the Vert® device as a monitoring tool for volleyball will also be evaluated.

During the observation period, we expected greater jump volume in preseason compared to in-season. Practices during preseason are more frequent and of higher intensity whereas during in-season the number of jumps can vary depending the number of sets played during a game (i.e., 3 or 5 sets) and on the focus of training days between games. During the preseason period, the players recorded a mean jump count of ~200 jumps for the first week, which increased to ~700 jumps during the second week. Numerous studies have related a greater than 10% increase in training load (jump count) being associated with an increased risk of injury (Halson, 2014; Soligard et al., 2016a; Visnes & Bahr, 2013; Windt & Gabbett, 2017), and therefore this sudden increase was concerning. Similar increases were observed between weeks 6 and 7 and weeks 10 and 11. Fortunately, no injuries were reported following these weeks. Only one other study has utilized the Vert® to record jump count and jump height in professional male volleyball players. Skalzalski et al (2018) reported at least a 10% increase in week-to-week jump load in nine of the 27-week season and at least a 30% increase in six of the 27-weeks. They also reported one player increased his weekly jump count twofold 18 out of the 27 weeks of their season. The present study observed a much larger increase in the mean team jump volume during the two weeks mentioned above. However, these are team jump count totals and do not show individual totals or how many of those jumps were of high intensity (greater height). Recent studies have highlighted the challenge to account for individuals who are at risk of experiencing increases greater than 10% training load spikes (Bahr & Bahr, 2014; Skazalski, Whiteley, & Bahr, 2018). The Vert® data is available during practice but that would require a staff member (e.g., sports medicine, team manager) to be assigned to monitor the accumulated jumps. Analyzing the data after practice is the most common practice, but prevents the ability to monitor athletes and limit jump volume during practice preventing increases in jump volume greater than 10%. The present study demonstrated that athletes commonly exceed daily variations in jump count greater than 10%. As mentioned above, weekly variations in volume greater than 10% increase the risk for injuries, but there is limited research reporting on the relationship between daily variations in training load and injury, there may be a concern for such large variations in training load.

Per position, middle blockers (MB) performed more jumps (142 ± 89 jumps per session) during pre-season than other positions. Outside hitters (OH) recorded the second most, averaging 111 ± 61 jumps per session, and setters had the least with 48 ± 46 jumps per session. Interestingly, both Skalzalski et al (2018) and Vlantes & Readdy (2017) found their setters accumulated the most jumps out of all the position groups with 121 jumps per session and 200 ± 20.6 jumps per 3-set match, respectively. In both studies, MB recorded the second most jump count. In the present study, MB performed more jumps during the preseason (Figure 2), with the largest spike seen within the first 5 days of pre-season not during the second week of training. This again demonstrates the challenge in generalizing training loads among players.

Skalzalski et al (2018) found setters to average the greatest number of jumps per session, but most of those jumps performed were within 30-50% of their tested maximum vertical jump. MB and OH tend to have greater VJ jump height compared to setters, therefore impacting greater loads and stress. Vert® categorizes the higher intensity jumps as those greater than 20 inches. MB averaged more high intensity jumps than any other positions, with 47 ± 39 high-intensity jumps per session in pre-season. During in-season, this average significantly decreased to 35 ± 29 high-intensity jumps per session. Vlantes and Readdy (2017) quantified player load using the Catapult Optimeye S5, which is another type of accelerometer. Their findings showed MB had the greatest percent of high impact player load, even though setters recorded the most jumps.

As the players transitioned from pre-season to in-season, MB and OH significantly decreased the average number of high intensity jumps performed per session ($p<0.05$). Overall, the team averaged significantly less jumps per session in-season compared to pre-season. Throughout the 14-week season, with limited practices and less jumps performed, the team was able to maintain an average vertical jump height throughout the 14-week season. In this study, average VJ height did not vary throughout the season – there was no increase or decrease seen for the team's average. MB was the only position that significantly increased average VJ height from pre-season to in-season. To our knowledge, this is the first study to track the change in average vertical jump height over a season for female, D-1 collegiate volleyball players.

The secondary aim of this study was to determine the degree to which players are able to maintain an average vertical jump height relative to maximum vertical jump measurements during practices and games. We anticipated that the players would maintain a jump height during practice within 90% of their maximal vertical jump. We recorded that athletes maintained closer to 70%. This lower ratio, is more likely due to the fixed net height, resulting in athletes not having to perform a maximal vertical jump. The greatest ratio was observed from MB and OH because blocking and attacking the ball for a "kill" may require a greater vertical jump depending on the height the ball is set at. When we compare the two positions and their ability to maintain that ratio, MB performed at a greater percentage than OH. Skazalski et al (2018) distributed the total jump count to the percent jump height of their maximum jump height, and found most jumps for all the positions during practices were within 70-80%. Setters accumulated the most jumps, but most performed were at a much lower percentages around 30-39% during practice and 40-

49% during games. Maximum test VJ was a standing vertical jump, which is more specific to MB, whereas OH often have a 2-step approach into a jump therefore yielding a greater vertical jump.

Coaches, strength and conditioning professionals, and sports medicine staff need to consider more than external load in order to get a better understanding of the impact of the sport on the athletes when developing training programs (Vlantes, Travis G., Readdy, 2017). Future studies should also include an internal load measurement, such as session rating of perceived exertion, along with the external load measurements that Vert® provides to track fatigue state and if athletes are recovering from sessions. This study only included pre-season and in-season periods, future studies should look to expand to year round in order to track if off-season loads for vertical jump are preparing the players for the high demands observed during pre-season.

PRACTICAL APPLICATIONS

Vert® is proving to be a useful tool to coaches and researches in creating a better understanding of the demands of the sport of volleyball. It is an easy to use tool that allows a coach to monitor jump volume and jump height. Individual loads can be monitored for large training volume spikes in volume but does require time and personnel to analyze and track. More research is needed in order to associate injury rates with these spikes within this population.

Table 1. Subject Characteristics

	Height (cm)	Weight (kg)	Age
Team (n=14)	176 ± 3	71.38 ± 6.85	19.96 ± 1.53
MB (n=5)	178 ± 3	70.24 ± 8.28	20.40 ± 1.82
OH (n=3)	177 ± 3	74.06 ± 3.94	20.33 ± 2.08
L_DS (n=2)	172 ± 4	76.23 ± 10.09	19.50 ± 2.12
RS (n=1)	178	72.45	18
S (n=3)	173 ± 4	67.00 ± 7.64	19.67 ± 0.58

Table 2. Comparison of pre-season to in-season by team and player position.

	Pre-Season	In Season
Jump count		
Team	99 ± 77	59 ± 48*
MB	142 ± 89	80 ± 52*
OH	111 ± 61	64 ± 44*
L_DS	43 ± 36	29 ± 35
RS	94 ± 72	44 ± 41*
S	48 ± 46	30 ± 24
Average jump height, (inches)		
Team	15.2 ± 3.0	15.9 ± 3.6*
MB	16.8 ± 2.2	18.1 ± 3.0*
OH	16.3 ± 2.1	16.3 ± 2.8
L_DS	12.1 ± 2.5	12.9 ± 3.5
RS	15.4 ± 2.1	14.5 ± 3.3
S	13.0 ± 2.5	12.8 ± 2.7
Jumps >20+inches		
Team	26 ± 32	19 ± 23*
MB	47 ± 39	35 ± 29*
OH	32 ± 21	20 ± 17*
L_DS	3 ± 8	4 ± 10
RS	6 ± 4	7 ± 7
S	1 ± 2	1 ± 3
Average jump height/max vertical jump (inches)		
Team	0.70 ± 0.13	0.71 ± 0.15
MB	0.77 ± 0.08	0.77 ± 0.11
OH	0.70 ± 0.09	0.71 ± 0.13
L_DS	0.59 ± 0.13	0.62 ± 0.16
RS	0.83 ± 0.11	0.74 ± 0.17
S	0.65 ± 0.12	0.66 ± 0.15

*, $P<0.05$ different from Pre-season

Table 3. Comparison of practice to games by team and player position.

	Practice	Game
Jump count		
Team	84 ± 63	36 ± 32*
MB	116 ± 71	49 ± 36*
OH	92 ± 52	41 ± 32*
L_DS	41 ± 39	13 ± 15*
RS	71 ± 55	18 ± 13*
S	35 ± 36	36 ± 26
Average jump height,		
inches	15.4 ± 3.3	16.4 ± 3.8
Team	17.3 ± 2.7	19 ± 3.0*
MB	15.9 ± 2.3	17.3 ± 3.2*
OH	12.8 ± 3.3	12.6 ± 3.1
L_DS	14.3 ± 2.6	15.3 ± 4.0
RS	12.6 ± 2.8	13.5 ± 2.3
S		
Jumps >20+inches		
Team	24 ± 28	15 ± 19*
MB	43 ± 33	26 ± 24*
OH	26 ± 19	17 ± 14*
L_DS	4 ± 11	2 ± 7
RS	7 ± 7	4 ± 4
S	1 ± 3	2 ± 3
Average jump height/max vertical jump (inches)		
Team	0.69 ± 0.13	0.74 ± 0.16*
MB	0.76 ± 0.10	0.80 ± 0.12*
OH	0.69 ± 0.11	0.75 ± 0.14
L_DS	0.61 ± 0.15	0.61 ± 0.16
RS	0.75 ± 0.14	0.79 ± 0.20
S	0.64 ± 0.14	0.69 ± 0.14

*, $P<0.05$ different from Practice

FIGURES

FIGURE 1 The average jump count by week (A) and by day (B) for the entire volleyball team.

Figure 1A.

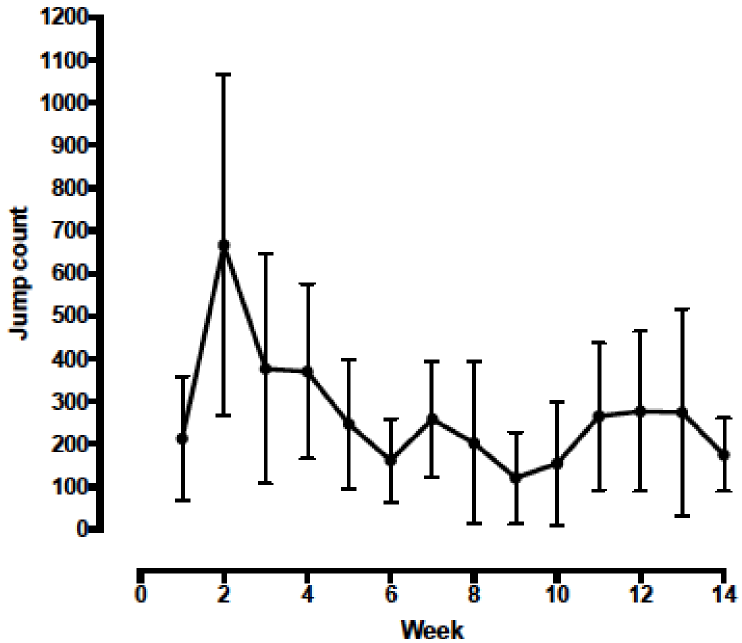


Figure 1B.

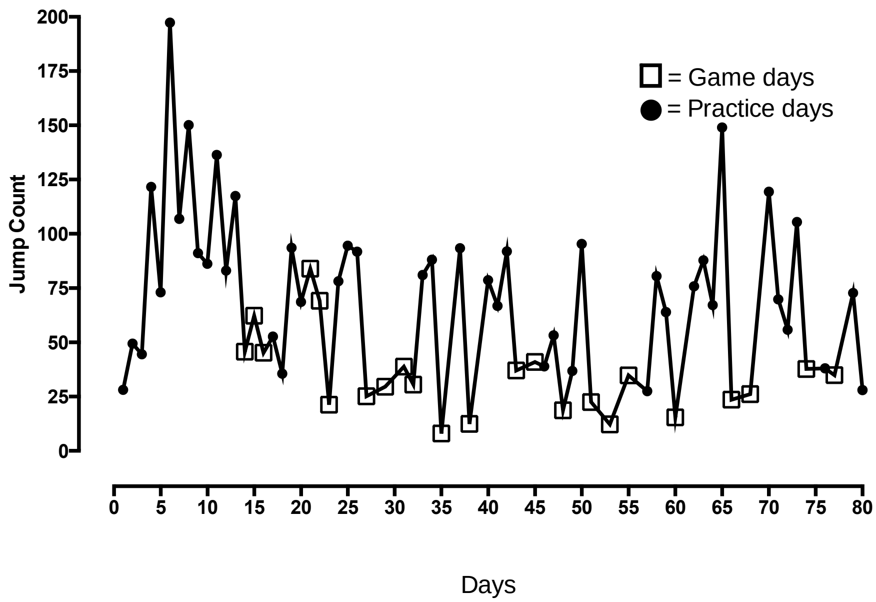


FIGURE 2 Average jump count for each day of the season for middle blockers (MB) and outside hitters (OH). Open symbols are game days, closed symbols are practice days.

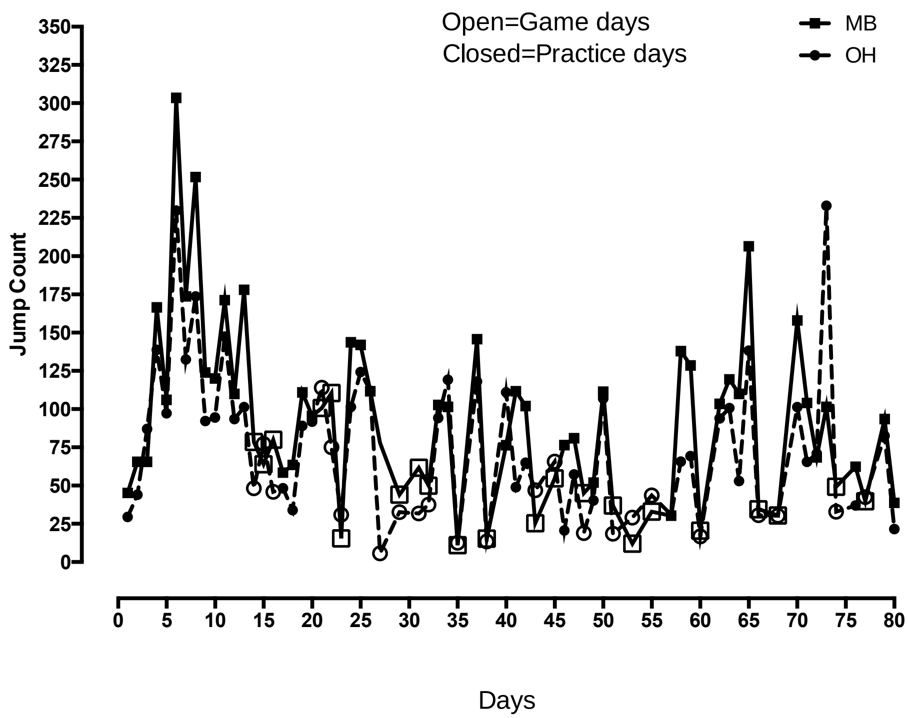


FIGURE 3 Average jump height for team (A) and for MB and OH (B).

Figure 3A.

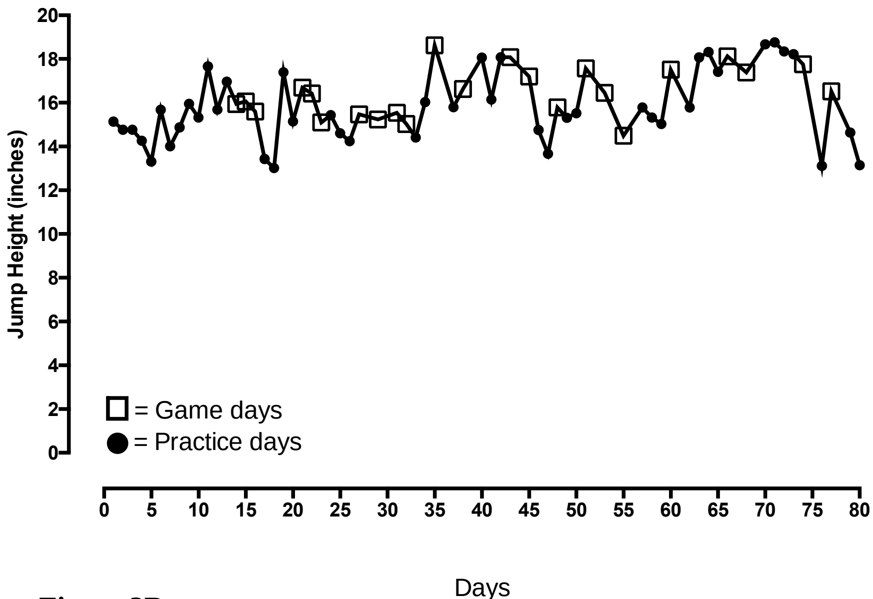


Figure 3B.

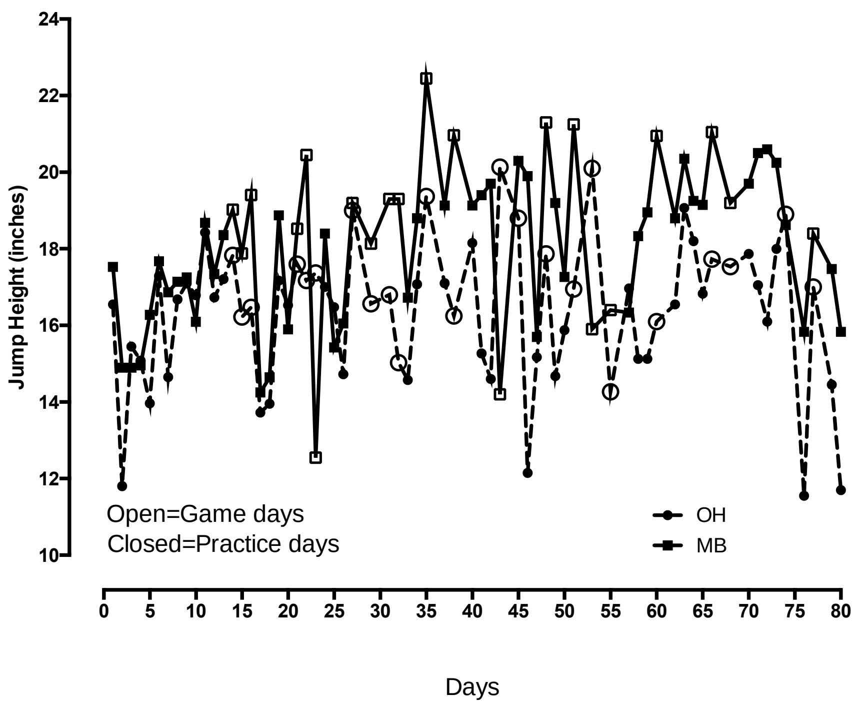


FIGURE 4. Average jump height divided by maximal vertical jump height for each day of the season for the team (A) and for middle blockers (B) and outside hitters (B).

Figure 4A.

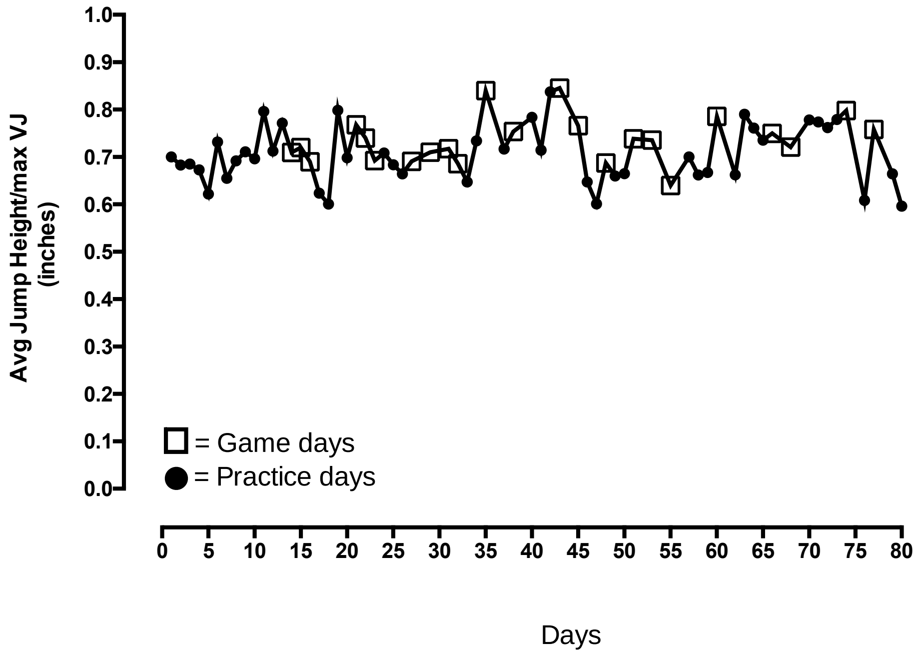
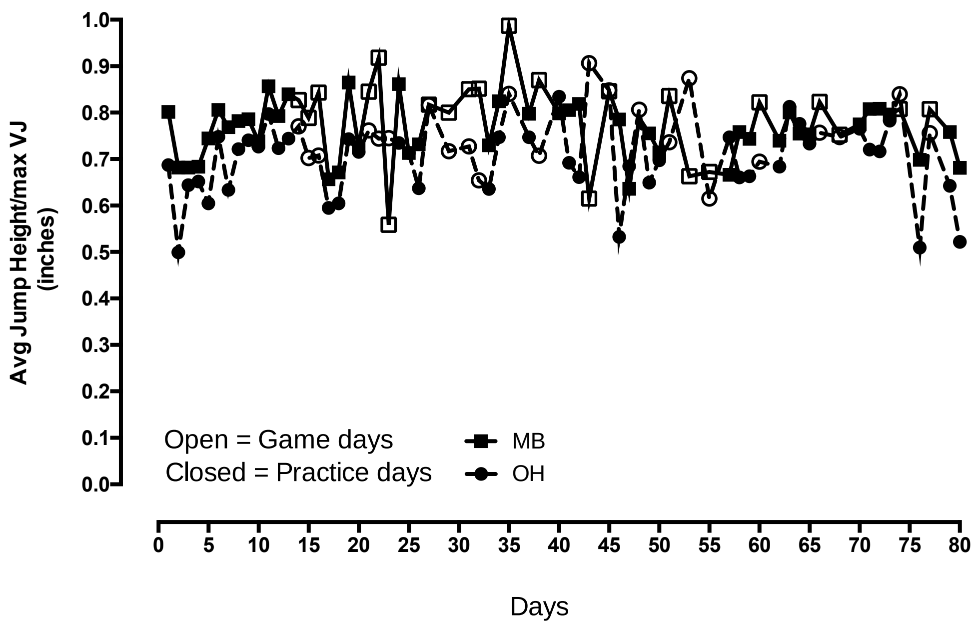


Figure 4B.



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