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High jump demands in professional volleyball – large variability exists between players and player positions

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ABSTRACT

Purpose Training volume has been associated with jumper's knee in volleyball players, but jump variability among professionals has not been investigated and individual jump demands are unknown. The purpose of this study was to examine position-specific jump

demands required for training and competition during a professional volleyball season and to investigate the individual variability associated with jump load.

Methods Jumps performed by 14 professional players during one season of training and competition were timestamped, individually assigned, and recorded for jump height. Jump counts, heights, and frequency were analyzed to determine the specific jump load performed by players at each position during training and match play.

Results A total of 129,173 jumps were performed during 142 sessions (108 practices, 27 matches, 7 friendly matches). Setters performed the greatest volume of jumps (121 jumps/training session). Opposites performed more high intensity jumps than their teammates (median season jump height: 69% of maximum). Substantial weekly jump count variability was observed, 18 of 28 weeks included at least one player with a 2-fold increase in jump load or a player returning to volleyball after performing no jumps the previous week. Additionally, each player had at least one week with a 2-fold increase in jumps.

Conclusion Jump demands are high in professional volleyball and performance programs should be tailored to the match and training demands required at each position. Jump loads are highly variable – substantial week-to-week increases were observed for both the team and individual players. As a result, monitoring individual jump load seems necessary.

INTRODUCTION

Volleyball requires players to perform a large volume of jumps, often leading to knee complaints. The prevalence of jumper's knee, or patellar tendinopathy, is high in elite volleyball, where 44% of players report symptoms.[1] Training volume has been shown to increase the risk of developing jumper's knee in elite, junior-level players with a 3.9-fold increase per extra set of match play and a 1.7-fold increase for every additional hour of

volleyball training during the week.[2] However, time may not be a valid measure of jump load in volleyball as substantial between-player variation in jump frequency has been observed among junior-level players during one week of training.[3]

The ability to measure and monitor training load has become an essential part of addressing injury risk in elite sport. For example, the sport of baseball and its institutions have developed strict rules regarding pitch counts for adolescent players and guidelines for professionals in an attempt to avoid overuse injuries to the shoulder and elbow.[4-7] Recent advancements in technology have allowed for the creation of a commercially available inertial measurement unit (IMU) that provides a valid and reliable measure of jump-specific training and competition load in elite volleyball players.[8-10] Individual jump variability among professional players has not been investigated and the jump demands required for each player position during a full season are unknown.

Therefore, the aim of this study was to examine position-specific jump demands required for training and competition during a professional volleyball season and to investigate the individual variability associated with jump load.

METHODS

Jump data was collected from 14 players training and competing on the first team from an elite, professional volleyball club in Qatar. Player positions were recorded (middle, opposite, outside, setter). The libero did not participate in the study as his position does not require any substantial jumping. Data were obtained for all jumps performed during the 2016-17 volleyball season. The season included two matches against each of the 10 league opponents, an international tournament, and a league tournament to conclude the season. Ethics approval was obtained from the Anti-Doping Lab Qatar Institutional Review Board (E2018000268).

Players wore a commercially available IMU, Vert Classic (Model #JEM, Mayfonk Athletic, Fort Lauderdale, FL, USA). Each device was placed in an elastic waistband with the device positioned slightly inferior and lateral to the participant's umbilicus, as recommended by the manufacturer and as we described previously in a validation study.[8] Devices were given to players at the start of training, prior to any jumping. The devices were connected via Bluetooth to an Apple iPad mini 2 using the Vert Coach application (version 2.0.6, Mayfonk Athletic, Fort Lauderdale, FL, USA).[8] All jumps were timestamped, individually assigned, and recorded for jump height.[8]

Jump data were matched against attendance records to confirm player participation for each session. If a player did not participate in a session, the reason for absence was noted (injured, inactive, or trained with junior team). Occasionally, a player performed full training with the team but recorded no jumps – either from not wearing a device or because of a technical error where the jumps were not successfully registered. To impute this missing data, a session-specific jump count was calculated for each player. This was based on player-specific average jump counts and a team-weighted jump count for that particular session. All jumps performed in training were included. To determine the jump demands required during match play, only jumps performed during competition were included. Match day jumps were assigned separate sessions in the Vert Coach application, including pre-match warm-ups and a new session for each set. Jumps performed during the pre-match warm-up or between sets were not included in this match total; however, they were still included in the weekly and season jump totals.

Individual jump frequency (jumps/h) was calculated for each training session throughout the season. This was determined from the first jump until the last jump performed by the team during each session. Jump frequency during matches was calculated from the cumulative set times and did not include pre-match warm-ups or rest times between sets. Additionally, an adjusted jump frequency during matches was calculated for middles. This reflected the jump frequency by middles during the $7/12^{ths}$ of the serve and serve receive rotations they completed on the court during match play – as they were substituted off the court in favor of a libero in the back row.

To compare the jump heights performed between individuals and position groups, maximum jump height was determined for each player based on all jumps performed during the season. Jumps were sorted from highest to lowest for each player. Occasionally, a jump was registered with an errant height, not physiologically possible for the player. Jumps greater than 120 cm were considered to be in error and were confirmed to be outliers for each player based on season values. Each of these jump height values were replaced with the individual's median jump height when included in further analyses. After addressing substantial outliers, some variability remained in the maximum jump height values. As a result, the median of the top 15 remaining jumps was used to determine each player's maximum jump height.

Jump counts were used to describe the essential jump demands in professional volleyball, as well as the individual player and position variability. Match jump counts were presented with 95% confidence intervals (CI). Individual jump count average during match play was calculated from matches the player participated in, irrespective of their status as starters or substitutes. That is, any match a player participated in, either as a starter or coming off the bench, had these jumps included as a match exposure, while those who did not step on the court were not included. Jump frequency was expressed as the number of jumps per hour and each player's average weekly jump count was presented alongside the interquartile range (IQR). Jump heights were expressed as a percentage of maximum jump height for each player.

RESULTS

A total of 129,173 jumps were performed during training and competition over one professional volleyball season (Table 1). These jumps were observed during 142 sessions (108 practices, 27 matches, 7 friendly matches). Of the 1,988 possible player sessions, 1,833 (92.2%) included the full number of actual jumps performed, while 155 (7.8%) were imputed using player and session averages. In 23 of these 155 sessions the player trained with the junior team rather than the first team and the remaining 132 sessions were lacking jump

data as a result of a device syncing error or because the player did not wear a device that session.

Jump count

Setters performed the most jumps per training session (121 jumps/session), followed by middles (92 jumps/session), opposites (75 jumps/session), and outside hitters (62 jumps/session). The match demand for each position is presented in Table 2. Setters (92 jumps/h) demonstrated the highest jump frequency in training, followed by middles (70 jumps/h), opposites (58 jumps/h), and outsides (49 jumps/h). Setters also had the highest jump frequency during matches (67 jumps/h), followed by middles (57 jumps/h), opposites (53 jumps/h), and outsides (47 jumps/h). When adjusted for each middle position only playing 7/12^{ths} of a match, the middles had the highest jump frequency (98 jumps/h of on-court time).

Weekly jump count averages, ranges, and variance are shown for each individual in Table 1 and are depicted over the 28-week team season in Figure 1. Weekly average jump count per player fluctuated considerably throughout the season ranging from a 44% week-on-week decrease to a 2.4-fold week-on-week increase. Nine of 27 weeks had an increased team average jump count of 10% or more compared to the previous week while six out of 27 weeks had at least a 30% increase (Figure 1). Substantial individual weekly jump count variability was observed with each player having at least one week in which he performed a 2-fold increase in jumps compared to the prior week. Additionally, 18 of 28 weeks included at least one player with a 2-fold increase in weekly jump count (12 weeks) or at least one player returning to training after performing no jumps the previous week (11 weeks).

Jump height

Jump heights observed during the season varied based on player position and session type (Figure 2 and Table 2). Setters (median season jump height: 41% of maximum) performed most of their jumps at lower heights, while opposites (median season jump height: 69% of

maximum) performed the greatest number of higher jumps throughout the season. Maximum player jump height averaged 92 cm (range: 82-102 cm) across the team.

DISCUSSION

This is the first study to examine the season demands and variability in jump load in elite, male professional volleyball players. Despite a relatively stable average weekly team jump load from the beginning to the end of the season, substantial week-to-week increases were observed both for the team and within individual players. Additionally, large positional differences were observed for jump counts and jump heights during training and competition.

Substantial week-to-week jump load variability observed at both the team and individual level

Research in other sports has reported greater injury risk associated with large week-to-week changes in training load and has suggested that in order to minimize risk of injury, week-to-week changes should be limited to no more than a 10% increase in training load.[11-14] During the observed season, there was an increased week-to-week team jump load of at least 10% in one-third of the weeks and an increased week-to-week team jump load of at least 30% in six of 27 weeks. Some jump load variation is expected over a long professional season and even the most well-intentioned coaches trying to minimize spikes in team loads will have high and low weeks of varying intensity levels.

One surprising finding during this study was that all 14 players had at least one week in which his weekly jump count increased 2-fold or greater. This happened to eight of the players during the transition from preseason to the first week of the regular season. Additionally, there were 18 of 28 weeks in which at least one player increased his weekly jump load by 2-fold or returned to the club following an injury/absence in which he performed no jumps the previous week. While a coach may plan team training loads and

adjust jump loads accordingly, one of the greatest challenges may be accounting for the at-risk individuals, rather than the team as a whole. The present findings expand on those by Bahr and Bahr[3] who observed substantial between-player differences in jump volume and frequency during one week of training among elite adolescent players. Substantial session, weekly, and within-player jump volume differences existed in the present study. This highlights the large individual jump load variability observed in professional volleyball players and we suggest this infers a need to monitor individual player jump loads.

Setters, followed by middle blockers, perform high volume and frequency of jumps

Setters and middle blockers performed the largest volume of jumps during training and had the highest weekly jump averages. Sheppard et al.[15] performed an analysis of spike jumps, block jumps, and jump serves during 16 international volleyball matches, providing additional insight on the specific jumps required during match play. In particular, middle blockers performed a greater number of block jumps while setters performed very few attack jumps.[15] While these studies cannot be compared directly – as not all jumps were analyzed in the former study and no data from trainings were included, insight can be gained on the type of jumps each of these positions must perform during competition.

One additional observation was that middle blockers performed a high frequency of jumps/hour during match play, especially when adjusted for their limited match participation secondary to being substituted out of the back row in favor of a libero. This unique aspect of match jump demands for middles (bouts of high jump frequency with periods of rest) should be considered when designing training programs.

Opposites perform more high intensity jumps than their teammates

Opposites performed more high intensity jumps than other position groups. This was evident during training and even more pronounced during match play, when the majority of their jumps were greater than 70-80% of their maximum jump height. This is not surprising,

as the opposite hitter is often the 'go-to' attacker when a kill is needed and maximal jump height is required. This finding may be unique to the men's game, as younger levels and women's volleyball often place their best players and attackers in the outside positions. Further research is needed.

Methodological considerations

This is the first study to examine the jump demands and individualized nature of jump load in elite, professional volleyball players. While this study includes over 120,000 jumps, extrapolation of the results to other national leagues, teams and levels of competition may be limited. Different coaching styles and training regimens may also limit generalizability, but the take-home message remains – there is a need to monitor individual jump load. Every attempt was made to record all jumps performed during the season. However, missing data were imputed using player- and session-specific season averages. The imputed data were not used in the calculations of training and match jump count averages, jump frequencies, or jump height averages and should have minimal impact on the weekly jump counts, as they accounted for a small percentage of all player sessions.

PERSPECTIVE

This study highlights the large jump demands and considerable individual and position-specific jump load variability present in professional volleyball. Coaches may plan to minimize large spikes in weekly team loads; however, it seems important to monitor individual player load as spikes in individual loads were substantial. We do not know how this relates to injury risk, as future studies are needed.

This study describes the jump demands needed to compete at the elite level. This information is important when designing fitness and performance programs. Programs should be tailored to the match and training demands required for different position groups. Additionally, jump loads performed in training should prepare players for what they

will do during competition. Adjustments can be made for younger players as fewer jumps are performed during match play at the youth levels.[16]

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FIGURE LEGENDS

Figure 1. Weekly jump count variance for all players during one club season (n = 14 players). The 6 weeks with a week-on-week increase in average player jump count of >30% are denoted with an asterisk (*). The box represents 50% of the dataset, the ends of the box show the 1st and 3rd quartiles, whiskers extend to the furthest data point within 1.5*IQR from the 1st and 3rd quartiles, and circles represent data points further than 1.5*IQR. A horizontal line within the box signifies the median and an 'X' represents the mean.

Figure 2. Distribution of jump height from training (n = 108 sessions) and matches (n = 27) during one professional club volleyball season broken down by player position.

Table 1. Individual jump variability during one professional club volleyball season – including season jump totals, session and weekly jump averages, and jump frequency

		Session jump count average			Weekly jump count				Jump frequency (jumps/hour)		
	Total jumps	All	Training	Match	Average (IQR[1])	High	Low	Variance	All	Training	Match (adj.[2])
Opposites											
Opposite 1	10175	76	73	82	363 (109)	562	83	479	54	55	53
Opposite 2	8085	78	82	-	289 (194)	499	0	499	60	62	-
Outsides											
Outside 1	9591	70	71	62	343 (115)	485	154	331	52	54	43
Outside 2	8623	64	70	42	308 (139)	502	13	489	47	54	29
Outside 3	6229	45	51	27	222 (81)	362	73	289	36	39	18
Outside 4	5939	72	77	56	213 (349)	527	0	527	51	55	38
Outside 5	4922	58	59	-	179 (187)	414	0	414	45	45	-
Outside 6	3848	55	56	64	136 (277)	496	0	496	45	46	43
Middles											
Middle 1	13565	110	115	87	484 (181)	755	141	614	81	89	58 (100)
Middle 2	13311	94	97	81	475 (147)	762	333	429	69	74	55 (94)
Middle 3	8029	79	81	-	287 (179)	524	20	504	61	61	-
Middle 4	6783	72	75	33	242 (200)	574	114	460	57	58	32 (55)
Setters											
Setter 1	18282	128	134	100	653 (205)	1047	277	770	94	105	67
Setter 2	11791	107	109	-	421 (187)	708	139	569	80	82	-
All players	129173	80	83	71	330 (231)	1047	0	1047	61	64	47

[1]IQR, interquartile range; [2]adj., adjusted match frequency for middles to represent their jumps per hour during the 7/12^{ths} of a match they spent on the court.

Session averages and jump frequency based on player participation during 142 sessions (108 practices, 27 matches, 7 friendly matches).

Injuries were responsible for the four players with weekly lows of 0 jumps.

Match jump count average and jump frequency determined from jumps performed during match play (pre-match warm-up jumps not included).

Table 2. Positional jump demands for 3-set, 4-set, and 5-set volleyball matches and average jump height used during match play over one professional men's club volleyball season

	Jump count					Jump height			
	All matches[1]		3-set	4-set	5-set	All matches[2]	3-set	4-set	5-set
Opposite	82	(72 to 92)	59	89	116	76%	73%	77%	77%
Outsides	68	(62 to 75)	55	74	88	62%	60%	64%	60%
Middles	85	(77 to 93)	67	89	115	64%	63%	65%	66%
Setter	100	(89 to 110)	76	110	128	56%	56%	56%	57%

[1] 95% confidence intervals are shown in parenthesis

[2] Jump height as a percentage of maximum jump height (median)