MR CHRISTOPHER SKAZALSKI (Orcid ID : 0000-0002-1204-0427)

Article type : Original Article

A valid and reliable method to measure jump-specific training and competition load in elite volleyball players

Christopher Skazalski[1,2], Rod Whiteley[1], Clint Hansen[3], Roald Bahr[1,2]

[1]Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

[2]Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway

[3]Department of Neurology, University of Kiel, Kiel, Germany

Running head: Valid measure of jump load in volleyball

Keywords: load monitoring, workload, injury prevention, jump load, vert, volleyball

Correspondence to:

Christopher Skazalski, PT, Aspetar Orthopaedic and Sports Medicine Hospital, Sport City Street, P.O. Box 29222, Doha, Qatar. Phone: +974 4413 2588.

E-mail: christopher.skazalski@aspetar.com

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/sms.13052

ABSTRACT

Purpose Use of a commercially available wearable device to monitor jump load with elite volleyball players has become common practice. The purpose of this study was to evaluate the validity and reliability of this device, the Vert, to count jumps and measure jump height with professional volleyball players.

Methods Jump count accuracy was determined by comparing jumps recorded by the device to jumps observed through systematic video analysis of three practice sessions and two league matches performed by a men's professional volleyball team. Jumps performed by 14 players were each coded for time and jump type and individually matched to device recorded jumps. Jump height validity of the device was examined against reference standards as participants performed countermovement jumps on a force plate and volleyball-specific jumps with a Vertec.

Results The Vert device accurately counted 99.3% of the 3637 jumps performed during practice and match play. The device showed excellent jump height inter-device reliability for two devices placed in the same pouch during volleyball jumps (r = 0.99, 95% CI 0.98 to 0.99). The device had a minimum detectable change (MDC) of 9.7 cm and overestimated jump height by an average of 5.5 cm (95% CI 4.5 to 6.5) across all volleyball jumps.

Conclusion The Vert device demonstrates excellent accuracy counting volleyball-specific jumps during training and competition. While the device is not recommended to measure maximal jumping ability when precision is needed, it provides an acceptable measure of on-court jump height that can be used to monitor athlete jump load.

INTRODUCTION

The sport of volleyball is fast-paced, hard-hitting, and requires its athletes to perform a large volume of jumps. Unfortunately, the repetitive jumping often leads to knee complaints among players. A study from 1984,[1] in which athletes who played at least five times per week were more likely to report jumper's knee complaints than those who trained less, suggested a relationship between training load and overuse knee complaints in volleyball.

More recently, the prevalence of current symptoms of jumper's knee, or patellar tendinopathy, is reported as high as 44-51% in men's volleyball.[2, 3] A four-year prospective study in elite, junior-level players reported a 3.9-fold increased risk for developing jumper's knee for every extra set of match play each week and a 1.7-fold increased risk for every additional hour of volleyball training each week.[4] Other studies have shown that players with the greatest jumping ability[3, 5, 6] and those who perform the most jumping[3] are most susceptible to developing complaints.

As a result, a method to measure and control jump load is needed. Bahr and Bahr[7] recently highlighted that using time as a measure of jump load may not be valid in volleyball. They observed substantial variation between players — jump frequency ranged from 50 to 666 jumps/week among males and 11 to 251 jumps/week among females.[7] Previously, manual counting of jumps through direct observation or video review was the only method available and is extremely time consuming.[7] Ideally, not only the number of jumps, but also jump intensity should be monitored. However, using force plates, the gold standard method for measuring jump height, is clearly not feasible in volleyball or most other sports. With improved technology, we may be able to examine jump load for individual players by monitoring not only jump count, but also jump height through the use of an inertial measurement unit (IMU). Two small studies have reported acceptable validity of a commercially available IMU with adolescent volleyball players.[8, 9] Use of the IMU has grown significantly as university programs, professional clubs, and national teams have started to monitor jump load. However, this device has never been validated with adult professional volleyball players.

Therefore, the aim of this study was to assess the validity and reliability of this method to count jumps and measure jump height in male professional volleyball players.

METHODS

This study was conducted in two stages. The first stage examined the validity of the IMU to accurately count jumps in men's volleyball and the second stage assessed the validity of the device to measure jump height. Participants provided informed consent and were excluded if they had an injury that restricted their ability to fully participate in each respective stage of the study. Ethics approval was obtained from the Anti-Doping Lab Qatar Institutional Review Board.

Device

Participants wore a commercially available IMU, Vert Classic (Model #JEM, Mayfonk Athletic, Fort Lauderdale, FL, USA), measuring 5.3 x 2.3 x 0.9 cm. Each device was inserted into a small pouch on an elastic waistband with the device placed slightly inferior and lateral to the participant's umbilicus as recommend by the manufacturer. The devices were all connected via Bluetooth to an Apple iPad mini 2 with the Vert Coach application (Version 2.0.6, Mayfonk Athletic, Fort Lauderdale, FL, USA). All jumps were timestamped, individually assigned, and recorded for jump height prior to being downloaded and exported for analysis.

Jump count

Fourteen adult male professional volleyball players from an elite club in Qatar wore Vert devices during three practice sessions (3.4 h in total) and two league matches (nine sets, 3.7 h). Thirteen of the players wore devices and participated in practice sessions, while eight players participated in match play. The practice sessions consisted of routine, structured training including serving, hitting, and blocking drills, and incorporated various 4-on-6 and 6-on-6 team scenarios. All jumps performed from the opening point to the final match point were included in the match play analysis. Warm-up jumps were not included. All practice and match sessions were recorded by a high-definition video camera placed beyond the end line at one end of the court. This video was later analyzed by two examiners, each with greater than ten years of experience playing and working in competitive volleyball.

The two examiners watched video of the sessions and each jump was individually coded with the time, jump type, and player name. Jump types were categorized as block, attack, set, jump float, jump serve, defensive overhead, defensive bump, and miscellaneous. Examiner one, blinded from the Vert results, was the primary reviewer of the video, while examiner two simultaneously coded each jump and consulted the video for clarification on individual jumps. A jump was defined using the same definition as Charlton et al.[8] of: "any occasion where both feet of the athlete were visually inspected to leave the ground at approximately the same time." The Vert device, however, uses a minimum threshold of 15 cm before recording a jump. To account for this, all jumps that were observed on video and not recorded by the device were reassessed by both examiners and jumps estimated to be less than 15 cm were categorized as "small" and not included for analysis. Additionally, any jumps that occurred out of view of the camera were not included.

Data from visual observation of jumps and from the Vert device were synchronized using their respective timestamps. Any jumps recorded by the device but not observed upon visual observation were reexamined on video to confirm the presence or absence of a jump. Jumps recorded by the device were compared against visual observation to observe the number of true positives (jumps recorded by the Vert device and observed on video), false negatives (jumps not recorded by the device but observed on video), and false positives (jumps recorded by the device but not observed on video).

Jump height

The second stage of this study examined the Vert device for jump height validity and reliability through a series of volleyball-specific jumps and countermovement jumps. Ten male professional volleyball players and 12 male recreational athletes participated, which provided a large distribution of jump heights. Participants wore an elastic waistband with two devices placed in the same pouch to examine inter-device reliability. To assess the ability of the device to be worn in different locations on the body, each participant wore a third device placed in an elastic waistband around his chest (as if the device was placed in a sports bra) and a fourth device placed in the participant's sock (or in a compression sleeve against the lower leg if long socks were not worn).

Individuals first performed a series of easy (50%), medium (75%), and maximal effort countermovement jumps on a force plate (ForceDecks, NMP Technologies, London, UK). From a standing position, participants were instructed to place their hands on their hips, lower to a squat position, and quickly jump straight up while maintaining lower limb extension in the air.

Next, participants performed a series of three vertical jumps using a Vertec (Sports Imports, Hilliard, OH, USA). The Vertec is a commonly used apparatus for measuring vertical jump ability in volleyball players and is comprised of a vertical post containing horizontal vanes that can be pushed out of the way to measure jump height and reach of athletes. Each jump was performed with four repetitions; two submaximal attempts at 50% effort and two maximal attempts. The jumps included a 1-hand reach to Vertec, 2-hand reach to Vertec, and a spike approach jump which included a two or three step approach and a 1-hand reach to Vertec.

During jump height validation, a Vert device would intermittently not detect a jump resulting in no height being reported from that particular device. This occurred most frequently with devices placed in the participant's sock. All jump heights measured by devices were included in this analysis. Additionally, a participant would occasionally ask to perform one additional repetition of a maximal effort jump test and these jumps were also included in the final analysis.

Vert device data was analyzed against force plate and Vertec measurements across a range of test conditions to determine the device bias (mean difference, 95% CI) and minimum detectable change (MDC). Data was also assessed using intraclass correlation coefficients (ICC, two-way mixed, consistency). Analyses were conducted using SPSS version 21 (IBM Corporation, New York, USA).

RESULTS

Jump count

A total of 3637 jumps were observed on camera and included for analysis (Table 1). An additional 87 jumps were excluded because they occurred off camera (n = 10) or were categorized as "small" jumps (i.e. estimated to be less than 15 cm; n = 77) (Table 1). Of the included jumps, 3612 (99.3%) were correctly identified by the Vert device (Table 2). The device accurately identified 99.0% to 100% of jumps during blocking, attacking, setting, serving, bumping and other defensive overhead attempts.

Few false negatives (n=25, 0.7%) and false positives (n=12, 0.3%) were observed across all jumps, resulting in one false positive per 303 jumps or 5.17 player hours of training and match play. The false positives occurred when players stopped their spike approach (n=4), dove for a ball (n=2), attempted a defensive bump/dig (n=1), or tossed the belt off-court (n=1). The remaining four instances resulted from suspected device/syncing errors in which a jump was recorded for a player who made no distinct movements.

Jump height

Information on Vert device bias, MDC, and ICC of the devices can be found in Table 3. The Vert device showed good correlation with the Vertec during volleyball-specific jumps, but consistently overestimated jump height by an average of 5.5 cm (12% of mean jump height). MDC was stable across all volleyball jump types and effort levels, ranging from 8.8 cm to 9.8 cm (18% to 24% of mean jump height). Figure 1 shows the correlation between the Vert device and force plate measurements during countermovement jumps (see also Table 3), as well as the relationship between the Vert device and Vertec measurements during three different volleyball jumps (Table 3).

The Vert device showed excellent inter-device reliability for two devices placed in the same pouch and worn around the waist during volleyball jumps ($r = 0.99$, 95% CI 0.98 to 0.99) with no bias between the devices (Table 3 and Figure 2). However, placing the device at other locations on the body impacted jump height measures substantially. Devices placed on the waist and chest corresponded well, while placement of the device within a sock resulted in unacceptable recordings (Table 3 and Figure 2).

DISCUSSION

This is the first study to examine validity of the Vert device in professional male volleyball players and with 3637 jumps, individually matched to video analysis, it is the largest to explore jump count accuracy across any level of volleyball. The device demonstrates excellent accuracy in counting volleyball-specific jumps during both practice and match play. Our results also show that while the device provides a good measure of on-court jump intensity at the group level, it should not be used to measure maximal jumping ability when precision is needed.

Jump count is recorded accurately

The number of jumps included in this study were substantially greater than two previous studies which examined jump count validity in junior-level players.[8, 9] We found a small prevalence of false positives (0.7%) compared to the study by Charlton et al. (12%).[8] The use of different definitions to classify and include jumps for analysis likely contributes to this apparent discrepancy. Charlton et al. included all jumps, regardless of jump height. In the current study, we did not include jumps that we perceived to be less than the device's 15 cm detection threshold. MacDonald et al.[9] also compensated for the device's minimum threshold by only counting jumps that subjectively were believed to be higher than this cutoff. MacDonald et al. reported that the device overestimated the total number of jumps observed via visual observation by nearly 6% during match play, but were unable to report false positives and false negatives as jumps were not matched individually. For the purpose of managing jump load, the Vert device does an excellent job at accurately counting jumps in professional players. The high level of accuracy allows coaches and staff to trust the daily, weekly, and season-long jump counts provided by the device when planning individual and team-wide training and recovery sessions.

Jump height is slightly overestimated and limitations exist when measuring jumps of similar heights

The Vert device showed excellent inter-device reliability for two devices placed at the waist, consistent with previous research in junior-level athletes.[8] However, the large MDC during countermovement and volleyball jumps limits the use of the device for jump height testing. The device does not appear to represent a valid method to detect differences of less than 5 cm during jump testing and should not replace more accurate methods for measuring maximal jumping ability (e.g. force plates). The Vert device may not be alone as the measurement error using other vertical jump testing methods, including jump and reach tests, contact mats and belt mat systems, also is too large to detect small differences in jump height.[10]

Force plate testing has long been used as the gold-standard for measuring jump height.[11-13] However, practical challenges and costs associated with using force plates have resulted in adoption of other reference-standards for on-site testing apparatuses, such as that commonly used to measure jump and reach tests (i.e. the Vertec). The Vertec has been found to be a valid method of measuring jump height with high reliability.[10, 14] However, research examining validity and reliability of the Vertec is limited, uses different methodology,[10, 11, 14, 15] and leaves conflicting views about the validity of the Vertec and other on-site jump height methods (e.g. contact mats, accelerometers, belt mats) to be able to detect small changes in jump height. In the present study, the Vert device demonstrated a 2-fold larger MDC during jumps compared to the Vertec than compared to a countermovement jump on the force plate. This is no surprise, as increased jump height variability by the Vertec compared to a criterion reference, including a force plate, has been reported in previous studies.[11, 14] However, use of the Vertec allowed testing of volleyball-specific jumps which have been recommended when testing volleyball players and have been shown to have high reliability, equal to that of squat and countermovement jumps.[16]

The Vert device provides an acceptable measure of jump intensity – possible use for load monitoring

Despite the relatively large MDC, which limits use of the Vert device for jump testing, the device does report jump height accurately enough to gauge general jump intensity and discriminate between jumps of different gross intensity levels. For example, we cannot confidently discriminate between two jumps similar in height (e.g. Vert recording of 72 cm and 75 cm) and identify which jump is higher; however, we can be highly certain that a recorded jump of 85 cm is higher than a jump of 72 cm because the 13 cm difference falls outside the bounds of the MDC observed across all volleyball jumps. This provides an opportunity to categorize jumps based on different height ranges and monitor jump loads not only by total jump count, but also by different intensities.

Device placement should be near the center of mass

In preparing for this study, it was observed that some athletes prefer to wear the device in a location that is convenient for them. This resulted in players wearing the device around the waist, others placing it in a sock, and some placing the device within their sports bra. These findings reveal good results for placement on the chest compared to the waist. As the device is intended to be worn near the center of mass, it is no surprise that placement of the device in the sock had poor results and did not yield valid, accurate results.

We do not know whether differences in device placement can explain the apparent discrepancy in jump height accuracy between the studies available. MacDonald et al.,[9] placing the device in the lumbar region, found that the device underestimated jump height by 2.5 cm (maximal jumps) to 4.1 cm (submaximal jumps). In contrast, placing the device in front, our study and that by Charlton et al.[8] found the device to overestimate jump height across all volleyball jumps, by 5.5 cm and 3.6-4.3 cm, respectively.

Methodological considerations

As this study is the first to examine validity of the device in male professional volleyball players, extrapolation of the results to different levels of play or to female athletes may be limited. When examining device placement, every effort was made to simulate placement of the device as if it were tucked into the sports bra of a female player; however, use of a properly fitted sports bra may yield different results. Additionally, the accuracy of the Vertec during jump testing is dependent on accurate initial reach measurements, timing and coordination of participants to hit the vanes at the apex of their jump, and is limited in precision with the smallest incremental heights bound by the spacing between each horizontal vane.

It is important to note that while performing the jump height validation with our professional players, there was an issue where not all of the data recorded on the Vert devices synced properly with the iPad. As a result, some data was lost, limiting the total number of jumps available for analysis from our professional cohort. Detailed analysis revealed the only substantial difference between the professional and recreational groups was an observation of greater jump heights in the professional group; the very reason for including both groups in the jump height validation.

CONCLUSION

This is the first study to validate the Vert device with professional male volleyball players. The device demonstrates excellent accuracy counting volleyball-specific jumps during training and competition and also provides an acceptable measure of on-court jump height that can be used to monitor athlete jump intensity.

PERSPECTIVE

The Vert device provides excellent accuracy counting volleyball-specific jumps and provides an acceptable measure of on-court jump height. The ability to record jump height during volleyball training and competition and its contribution to jump load was previously impossible when jump load monitoring was limited to time-consuming methods of manual counting and coding of jumps through direct observation. Coaches and staff working with professional volleyball players, as well as elite junior-level players, can now use this device to monitor jump load and incorporate into individual and team-wide training and recovery sessions.

ACKNOWLEDGEMENTS

The authors would like to thank the volunteers for their participation, Dr. Phil Graham-Smith for technical assistance, and Erin Skazalski for data coding and video analysis.

References

1 Ferretti A, Puddu G, Mariani PP, Neri M. Jumper's knee: an epidemiological study of volleyball players. Phys Sportsmed. 1984: 12: 97-106.

2 Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. Am J Sports Med. 2005: 33: 561-567.

3 Lian O, Refsnes PE, Engebretsen L, Bahr R. Performance characteristics of volleyball players with patellar tendinopathy. Am J Sports Med. 2003: 31: 408-413.

4 Visnes H, Bahr R. Training volume and body composition as risk factors for developing jumper's knee among young elite volleyball players. Scand J Med Sci Sports. 2013: 23: 607-613.

5 Visnes H, Aandahl HA, Bahr R. Jumper's knee paradox--jumping ability is a risk factor for developing jumper's knee: a 5-year prospective study. Br J Sports Med. 2013: 47: 503-507.

6 Lian Ø, Engebretsen L, Øvrebø RV, Bahr R. Characteristics of the leg extensors in male volleyball players with jumper's knee. Am J Sports Med. 1996: 24: 380-385.

7 Bahr MA, Bahr R. Jump frequency may contribute to risk of jumper's knee: a study of interindividual and sex differences in a total of 11 943 jumps video recorded during training and matches in young elite volleyball players. Br J Sports Med. 2014: 48: 1322-1326.

8 Charlton PC, Kenneally-Dabrowski C, Sheppard J, Spratford W. A simple method for quantifying jump loads in volleyball athletes. J Sci Med Sport. 2016.

9 MacDonald K, Bahr R, Baltich J, Whittaker JL, Meeuwisse WH. Validation of an inertial measurement unit for the measurement of jump count and height. Phys Ther Sport. 2017: 25: 15-19.

10 Nuzzo JL, Anning JH, Scharfenberg JM. The reliability of three devices used for measuring vertical jump height. J Strength Cond Res. 2011: 25: 2580-2590.

11 Buckthorpe M, Morris J, Folland JP. Validity of vertical jump measurement devices. J Sports Sci. 2012: 30: 63-69.
12 Hatze H. Validity and reliability of methods for testing vertical jumping performance. J Appl Biomech. 1998: 14: 127-140.
13 Vanrenterghem J, De Clercq D, Van Cleven P. Necessary precautions in measuring correct vertical jumping height by means of force plate measurements. Ergonomics. 2001: 44: 814-818.
14 Leard JS, Cirillo MA, Katsnelson E, et al. Validity of two alternative systems for measuring vertical jump height. J Strength Cond Res. 2007: 21: 1296.
15 Magnúsdóttir Á, Karlsson B. Comparing three devices for jump height measurement in a heterogeneous group of subjects. J Strength Cond Res. 2014: 28: 2837-2844.
16 Sattler T, Sekulic D, Hadzic V, Uljevic O, Dervisevic E. Vertical jumping tests in volleyball: reliability, validity, and playing-position specifics. J Strength Cond Res. 2012: 26: 1532-1538.

FIGURE LEGENDS

Figure 1. Jump height during three different volleyball jumps (Vert versus Vertec) and a countermovement jump with force plate (Vert versus force plate). The dashed line represents the line of best fit and the dotted line represents the line of equality (x=y).

Figure 2. Relationship of Vert devices during volleyball jumps (submaximal and maximal efforts) based on location of device on body. The dashed line represents the line of best fit and the dotted line represents the line of equality (x=y).

Table 1. Jump description and session demographics of jump count validation during volleyball practice and match play

	Practice	Match	Total
Total session time (minutes)	204	224	428
Player hours	37.5	24.5	62.0
Participants	13	8	14
Number of sessions	3	2 (9 sets)	5
Included jumps			
Total jumps (observed on video)	2521	1116	3637
Observed on Vert & video	2503	1109	3612
Observed on video/not on Vert	18	7	25
Recorded on Vert/not on video	7	5	12
Excluded jumps			
Occurred off camera	6	4	10
"Small" jumps - not recorded by Vert[1]	76 (2.9%)	1 (0.1%)	77 (2.1%)
Set	59	1	60
Block	8	0	8
Spike	2	0	2
Defensive overhead	5	0	5
Defensive bump jump	2	0	2

[1]"Small" jumps that were not recorded by Vert but were observed on video and estimated to be less than the 15 cm threshold used by Vert.

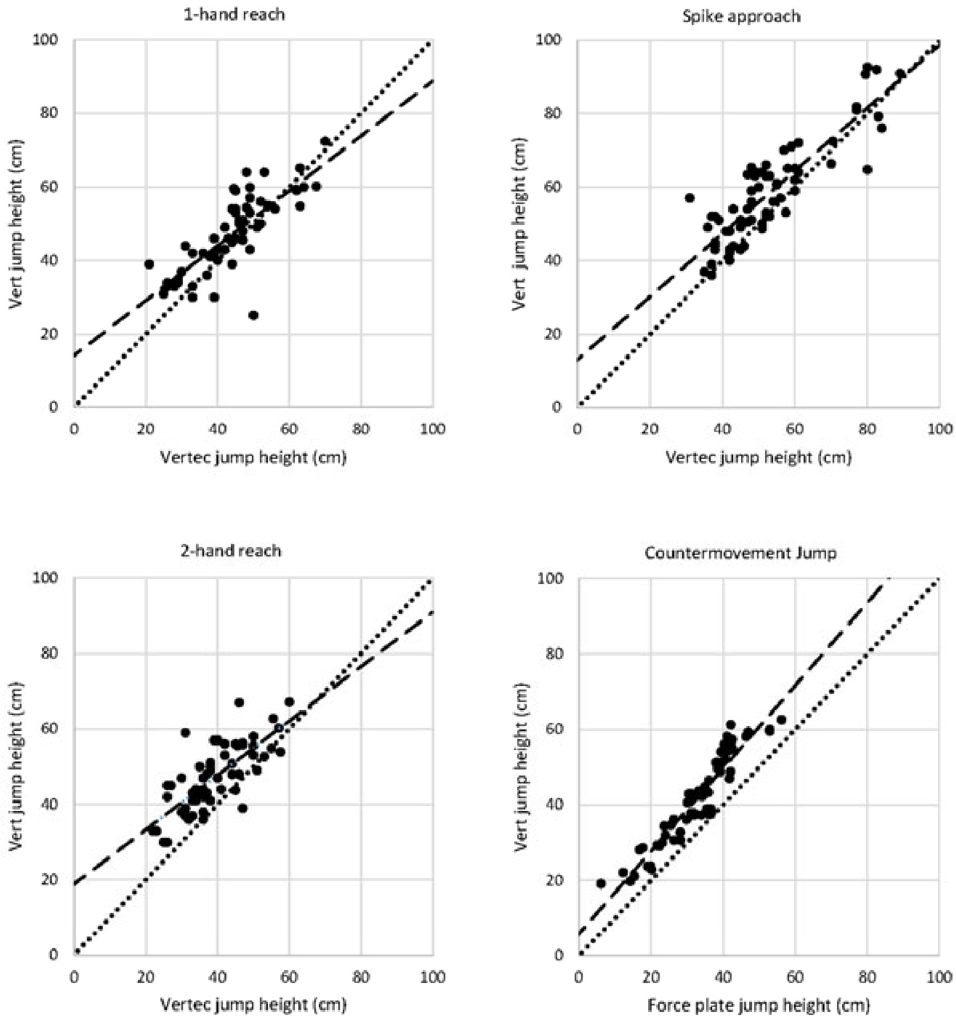
Table 2. Jump count accuracy of the Vert device compared to video analysis based on jump type and session type

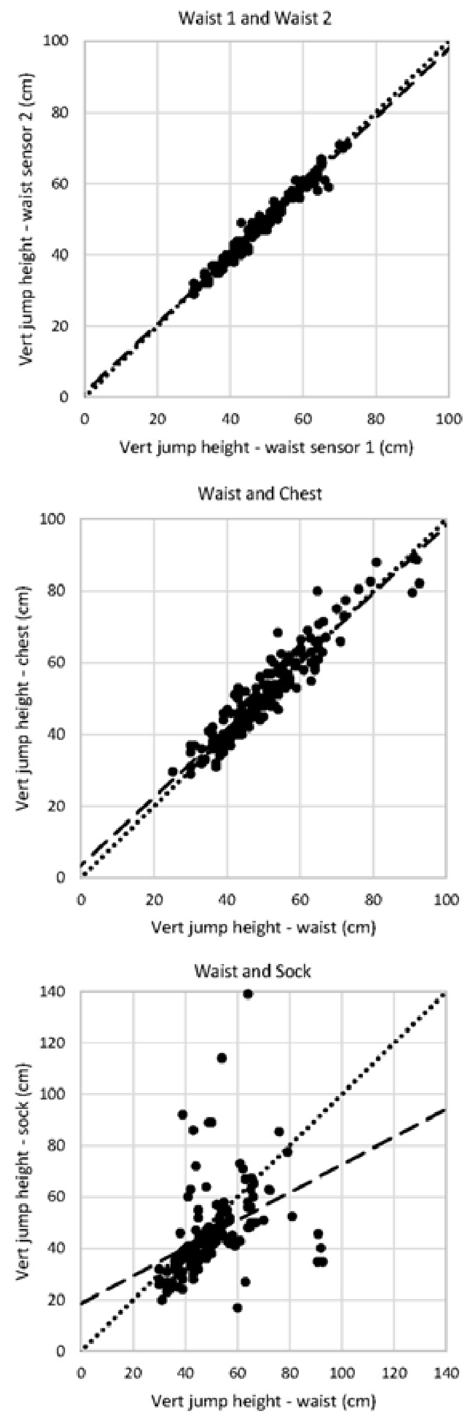
	Video	True positives (n, %)		False negatives (n, %)		False positives (n, %)	
Jump type							
Block	1266	1259	(99.4%)	7	(0.6%)	0	(0.0%)
Attack	1170	1162	(99.3%)	8	(0.7%)	0	(0.0%)
Set	426	424	(99.5%)	2	(0.5%)	0	(0.0%)
Jump float	347	344	(99.1%)	3	(0.9%)	0	(0.0%)
Jump serve	308	305	(99.0%)	3	(1.0%)	0	(0.0%)
Defensive overhead	32	32	(100.0%)	0	(0.0%)	0	(0.0%)
Defensive bump	25	25	(100.0%)	0	(0.0%)	1	(3.8%)
Miscellaneous	63	61	(96.8%)	2	(3.2%)	11	(15.3%)
Session type							
Practice	2521	2503	(99.3%)	18	(0.7%)	7	(0.3%)
Match	1116	1109	(99.4%)	7	(0.6%)	5	(0.4%)
Total	3637	3612	(99.3%)	25	(0.7%)	12	(0.3%)

Table 3. Bias, MDC, and reliability of the Vert device based on jump type, effort level, athlete type, and device placement on the body

	Vert bias (cm)[1]		MDC (cm)	ICC[1]		Number of jumps
Volleyball jump type (Vert vs Vertec)						
All volleyball jumps	5.5	(4.5 to 6.5)	9.7	0.85	(0.80 to 0.89)	188
Spike approach	5.4	(3.8 to 7.1)	9.5	0.88	(0.81 to 0.92)	68
1-hand reach	3.2	(1.4 to 5.0)	9.8	0.78	(0.66 to 0.86)	60
2-hand reach	8.0	(6.4 to 9.6)	8.8	0.75	(0.61 to 0.84)	60
Effort level (Vert vs Vertec, volleyball jumps)						
Maximal effort	4.6	(3.2 to 6.0)	9.7	0.86	(0.80 to 0.90)	98
Submaximal effort	6.6	(5.2 to 8.0)	9.5	0.72	(0.60 to 0.80)	90
Athlete type (volleyball jumps)						
Professional volleyball player	2.2	(1.0 to 3.4)	11.6	0.82	(0.68 to 0.90)	41
Recreational athlete	6.5	(5.6 to 7.4)	8.7	0.79	(0.72 to 0.84)	147
Vert placement (volleyball jumps)						
Waist vs Vertec	5.5	(4.5 to 6.5)	9.7	0.85	(0.80 to 0.89)	188
Chest vs Vertec	6.6	(5.7 to 7.5)	8.1	0.90	(0.86 to 0.92)	170
Sock vs Vertec	1.2	(-1.5 to 4.0)	23.0	0.44	(0.30 to 0.57)	139
Inter-device reliability by Vert placement (volleyball jumps)						
Waist vs Waist	-0.3	(-0.6 to 0.0)	2.3	0.99	(0.98 to 0.99)	147
Chest vs Waist	0.9	(0.3 to 1.5)	5.9	0.94	(0.92 to 0.96)	170
Sock vs Waist	-4.6	(-7.4 to -1.7)	23.6	0.39	(0.24 to 0.52)	139
Countermovement jump (Vert vs force plate)						
Force plate	9.1	(8.1 to 10.0)	5.5	0.93	(0.89 to 0.96)	65

ICC, Intraclass correlation coefficient (two-way mixed, consistency); MDC, Minimum detectable change
[1] 95% Confidence intervals are shown in parenthesis


1-hand reach
Spike approach
2-hand reach
Countermovement Jump
Vert jump height (cm)
Vertec jump height (cm)
Force plate jump height (cm)
0
20
40
60
80
100


Waist 1 and Waist 2
Vert jump height - waist sensor 2 (cm)
Vert jump height - waist sensor 1 (cm)
Waist and Chest
Vert jump height - chest (cm)
Vert jump height - waist (cm)
Waist and Sock
Vert jump height - sock (cm)
Vert jump height - waist (cm)