Testing the Reliability and Validity of the XOS Motion Capture System at Measuring Counter Movement Vertical Jump

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Abstract: The purpose of this study was to conduct simultaneous measurement of counter movement vertical jump height using the XOS motion capture system and the Vertec system. Ten participants (body height: 170.17 cm ± 13.4, body weight: 79.76 kg ± 17.72) from the Marshall University student body comprised the testing group. Participants were instructed on proper counter movement vertical jump technique. Five practice jumps at 50% effort were conducted. Participants donned a compression suit with reflective markers. The paired *t-tests* indicated that a difference existed in counter movement vertical jump height measured between the Vertec and the XOS vertical jump was ($p < 0.001$), SEM of 1.4 with a .823 correlation and the Vertec and the XOS center of gravity was also ($p < 0.001$), SEM of 1.42 with a correlation of .788. A marked difference exists between the XOS SportMotion capture system's methods of measuring counter movement vertical jump height when compared to the Vertec measurement.

1 INTRODUCTION

Motion analysis systems are a widely used tool in performance enhancement, biomechanical analysis, and injury assessment. These systems provide users with important information to guide the improvement of function. The reliability and validity of the information of these systems is vital. Reliability is the degree to which an experiment, test, or measuring procedure produces stable and consistent results. Reliability for measurement systems like these are concerned with concepts like stability, reliability, and internal consistency (Vincent, 2009). More importantly however, these systems require validity to be able to be of value as true measurement tool. The validity of a system tells the user how well it measures what is supposedly measures.

The XOS SportMotion system (Motion Reality, Inc. Marietta, GA) is a relatively new technology platform built upon the most modern advances in 3-D Motion Capture and Analysis technology. According to the company's website, SportMotion is the world's first 3-D motion capture system specifically designed to help measure an athlete's performance, aid in rehabilitation, assist in training and become an effective teaching tool (Motion Reality 2014). The technology of the XOS SportMotion system is similar to that used to produce movies and video games, but is customized to specifically serve the functional and usability needs for athletes. The system is marketed as a convenient device to use to improve performance within the strength and conditioning and team specific areas. Several professional teams in the MBL and NFL along with NCAA-I teams use this system to improve athlete performance. It is not used typically for quantitative research purposes.

A component of the XOS SportMotion system is the measurement of counter movement vertical jump height (CMVJH). This CMVJH data, normally provided through physical measurement using a Vertec (Vertec Sports Imports, Hilliard, OH) measuring device, is typically generated through tracking the subject's center of mass (COM) (Isaacs, 1998). The difference between the resting height of COM and the peak height during the jump is presented as CMVJH. In addition to tracking COM travel, certain systems, such as the XOS motion capture system calculate CMVJH through measurement of the time the subject is off the ground. This method is employed by Jump Mat systems, and has been found to be comparable to Vertec and center of gravity (COG) tracking methods (Isaacs 1998, Pond, Verducci et al. 2003, Leard, Cirillo et al. 2007)

The Vertec CMVJ testing system is device typically used by universities and high schools to

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test athlete vertical jump height. It is considered the testing device of choice due to the low coast and high reliability. The Vertec device requires an athlete to maximally reach for the object while jumping. The measuring device is widely used in athletic testing due to its simplicity. The Vertec (Vertec Sports Imports, Hilliard, OH) consists of a series of colored plastic vanes that are placed 0.0127 m apart on a telescoping aluminum pole that can be adjusted to the subject's standing reach. The subject performs a maximal jump and swats at the plastic vanes at the peak of the jump. Vertical jump height is measured as the vertical distance between the standing reach and the highest vane displaced by the subject's hand at the peak of the jump. Jump height assessed by the Vertec is determined by subtracting the standing height or reach height by the maximum jumping height or reach height using procedures such as Sargent's, Abalakov's, and Starosta's, jump tests (Klavora, 2000; Starosta & Radzinska, 2001).

As such the reliability and validity of the XOS SportMotion system is not known. To date, no studies testing the reliability of the XOS system's measurement methods in comparison to the gold standard Vertec measurement system exist (Hutchinson Issacs 1998, Petushek 2010, Pond 2003). From a research perspective, the gold standard is either 3-D motion analysis or force plate. The question at hand is how reliable and valid is the XOS SportMotion system. The purpose of this study is to conduct simultaneous measurement of CMVJH using the XOS motion capture system and the Vertec system. The comparison of these results will help determine the reliability and validity of the XOS system in measuring jump height compared to a verified measurement system.

2 METHODS

Prior to experimental testing, project approval was obtained from the Marshall University Institutional Review Board. Ten participants (body height: 170.17 cm ± 13.4, body mass: 79.76 kg ± 17.72) from the Marshall University student body comprised the testing group. Participants included four male (body height: 177.80 cm ± 9.51, body mass: 81.13 kg ± 8.45) and six females (body height: 165.09 m ± 14.67, body mass: 78.85 kg ± 23.77). All subjects signed informed consent and were able to withdraw at any time during the course of the study.

Clothing/ Strap	# of Markers	Location
1 Shirt	12	2 markers top of shoulders 3 markers across top of back 2 markers in center of back 1 marker on sternum 2 markers on side of each upper arm
1 Belt	4	2 markers side of waist 2 markers back of waist
1 Cap	4	2 markers on top of head 2 markers in front
2 Wrist Straps	2/wrist	1 marker on outside of wrist 1 marker on inside of wrist
2 Knee Straps	2/knee	1 maker centered below knee on leg 1 marker on outside of shin
2 Shoe Covers	4/foot	2 markers on top of shoe 1 maker at center of heel 1 maker centered on outside of foot

Figure 1: "Marker placement".

The XOS Sport Motion system (Motion Reality, Inc. Marietta, GA) is an infrared tracking system that provides instant three-dimensional motion feedback to assist in the training and performance evaluation of athletes for all levels. The XOS system housed in this laboratory utilizes 24 cameras. Each XOS Sport Motion system contains three options for specific data collection: golf, baseball, and free play. The option selected determines the size of the calibration space and the number of cameras used. The golf option uses the smallest space and only eight of the 24 cameras. The free play option uses the largest space and all 24 camers. The free play option allows the user to be creative with the data collected. Items that can be tested include vertical jump, broad jump, and tracking of weight lifting technique. This study utilized the free play option. Multiple requests for further information on the process by which the system processess and calculates were not met due to the proprietary nature of this information.

The XOS Sport Motion system was calibrated each testing day according to the systems required means. This is a two phase process. The first phase begins with placing the reflective wand on three specific locations spaced 3 meters apart followed byplacing the wand in locations around the oustide of the free play area in a vertical direction. The system notifies the user when all 24 of the cameras have recognized the wand and the location plaements. The second phase is the typical sweeping of the inside of the calibrated space. The system then combines these to actions to calibrate the space. The system is ready for data collection with a successful calibration.

Users of the XOS Sport Motion don a compression suit with 36 reflective markers located at specific locations (See Figure 1). Four additional markers are attached to the suit as part of the global reference component. Two global markers are placed on the anterior chest at the shoulder joint area. The other two global markers are placed in the general location of the hip, usually over the greater trochanter. This makes a total of 40 reflective markers associated with the compression suit. The additional four markers are removed once an avatar is generated. These markers allow the XOS system to generate an avatar model that is displayed to allow the athlete to view the skill for feedback. The avatar comes in only two versions: a male and female avatar. The avatar adjusts its look based upon the distribution of the markers in the known pattern for the individual

The 28 reflective markers used for data collection are not placed on the joint axis as required by most infrared tracking systems. Rather, the markers are placed in unique placements to fit a specific pattern (See Figure 1). The interesting component here is that the locations per the user guide manual are very generalized locations. However, during training the representatives used anatomical reference points for the location of several of the markers.

Participants for this study donned the compression suit. 36 permanent and 4 temporary global markers were placed according to company standards. Participants were instructed on proper CMVJ (counter movement vertical jump) technique and use of the Vertec (Vertec Sports Imports, Hilliard, OH) during CMVJ testing. Reach height for the Vertec was established using the following body position: erect stance, both feet together and flat on the ground, both arms fully extended overhead, and the head and eyes level (Issacs 1998). Instructions on the CMJ technique were then provided. This technique required subjects to start in an upright position with the feet parallel to each other and hip to shoulder width apart. The subject then performed a quick countermovement drop into a quarter-squat position by flexing the hips and knees into a semi-squat position while swinging their arms back to prepare for the jump. After reaching their preferred depth of descent, subjects explosively extended at the knees and hips, and plantar flexed at the ankles in an effort to attain a maximal jump height. During the concentric and flight phases of the jumps, subjects were required to maintain a level head position (i. e., not looking

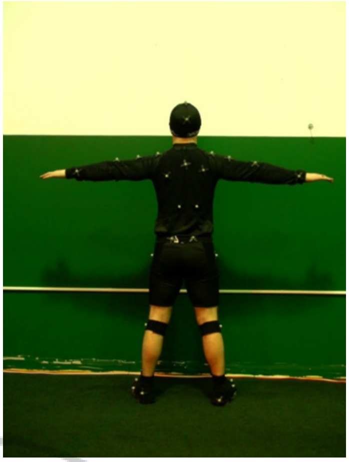

Figure 2: “T-position”.

upward at the Vertec vanes) while reaching upward with both hands simultaneously (Issacs 1998).The arms swing forward above their head as they jump straight up into the air, landing on both feet at the same time (Harman 1990). Arm swing has been shown to influence vertical jump height (Lees 2004) and performance biomechanics (Lees 2004).

Five practice jumps at 50% effort were conducted to ensure understanding of appropriate technique. A rest period of at least 60 seconds between each jump occurred during familiarization to provide feedback on improving the participant’s technique along with recovery. After familiarization was complete, participants left the room to allow for a noise elimination procedure which is required by the XOS system. This part of the avatar generation process required by the system. Upon completion of the noise elimination, the participants re-entered the room and took their place within the calibrated space. The system began the process of generating an avatar model for each participant at this time. This was accomplished by having the participant stand within the calibrated space in a “t-position” as the system went through the process of recognizing the reflective marker pattern. The t-position finds the subject standing in an erect posture with the feet approximately shoulder width apart while the shoulders are abducted to approximately ninety degrees (See Figure 2). The participant’s avatar is generated after the system recognizes the reflective markers being in the correct configuration and locations.

With the avatar generated, participants again entered the calibrated space and conducted three CMVJ trials separated by 60 seconds of rest. During these trials, jump height was measured simultaneously by the XOS system and the Vertec. Vertec data was collected by the same researcher who provided the instruction on CMVJ technique. The XOS data measured the calculated center of gravity travelled and vertical jump height through proprietary software. Data was analyzed using SPSS (IBM, Armonk, New York). Descriptive statistics, paired *t-tests*, and intraclass correlation coefficients (ICC 1,3 and ICC 2,3) analysis were completed. Significance was set at the 0.05 level. ICC 1,3 was run to investigate the reliability and validity for each type of CMVJ test. An ICC 2,3 determined the reliability of the XOS Sport Motion CMVJ testing against the Vertec.

3 RESULTS

Descriptive statistics are presented in Table 1. The paired *t-tests* indicated that a difference existed in CMVJ height measured. The significance for the comparison between CMVJ height measured between the Vertec and the XOS VJ (XOS vertical jump) was ($p < 0.001$), SEM(standard error of the mean) of 1.4 with a .823 correlation The significance for the comparison between CMVJ height measured between the Vertec and the XOS COG (XOS center of gravity) was also ($p < 0.001$), SEM of 1.42 with a correlation of .788.

The vertical jump height measured with the Vertec ranged from 31.75 cm to 82.55 cm. The vertical jump height measured with the XOS VJ ranged from 23.68 cm to 61.47 cm. The reliability (ICC 1,3) of the Vertec measures was 0.97. The SE_m(Standard error of Measurement) for the Vertec measures was 0.0004. A MCD (minimal clinical difference) for the Vertec was 3.58. The reliability (ICC 1,3) of XOS VJ measures was 0.936. The SE_m for the XOS VJ measures was 0.016 with an MCD of 2.69. The reliability (ICC 2,3) for the Vertec and the XOS VJ was .871.

The vertical jump height measured with the XOS COG ranged from 30.734 cm to 62.23 cm. The reliability (ICC 1,3) of the Vertec measures again was 0.97. Again, the SE_m for the Vertec measures was 0.0004. An MCD for the Vertec was 0.005. The reliability (ICC 1,3) of XOS COG measures was 0.945. The SE_m for the XOS COG measures was 2.46 cm. And, a MCD calculated at 3.54. The reliability (ICC 2,3) for the Vertec and the XOS COG was .833.

Table 1: Descriptive Statistics.

Device	Group	Mean ± Std. Dev. (cm)
Vertec		
	All	49.66 ± 12.56
	M	59.16 ± 13.41
	F	43.32 ± 6.82
XOS VJ		
	All	39.38 ± 13.46
	M	53.41 ± 8.83
	F	30.03 ± 5.53
XOS COG		
	All	43.46 ± 9.42
	M	52.87 ± 5.65
	F	37.24 ± 5.23

4 DISCUSSION

All three means of measurement demonstrated adequate individual reliability. This means that the each of the systems measured CMVJH consistently. However, the validity of the XOS system's measurements did not prove as great as the Vertec. An interesting situation was noted with two of our subjects that demonstrated part of the problem with the internal consistency with the XOS system. Two subjects (subject 5 and 9) had Vertec measurements of 82.55 cm for their CMVJ. XOS SportMotion calculated the XOS VJ at 66.55 cm and 53.34 cm for subject 5's CMVJ heights. Subject 9's CMVJ height at 82.55 cm was calculated at 54.61 cm. These differences show that there is a lack of consistency within the calculation of XOS VJ height.

XOS SportMotion system has two definitions attached to the label "COG". One is used to calculate the COG path (actual and floor projected) and the other is used for the calculation of the vertical and horizontal jump functions. In the vertical jump function, the 3D location designated as the COG is actually approximated to the origin of the waist body in the skeleton (See Figure 1). During the scaling process, the system optimizes this location based on the placement of the markers, for both capture and scaling, identified during said scaling process. The vertical distance measurement is the difference between the take-off height and peak height of this COG location; where the take-off frame is calculated as the frame where both feet have been deemed to have left the floor plane. The feet are calculated to have left the floor when both heels are more than 4 inches above the floor plane. The heel is approximated as the points located 3 inches below each ankle. Landing occurs at the frame where at least one of the heel locations is back within 4 inches of the floor plane. This method of calculation does not take in to account that most individuals will land on the forefoot to provide a triple absorption of force through ankles, knees, and hips (Motion Reality 2014). With information provided by Motion Reality, Inc, the XOS system software appears to calculate jump height by using total time the subject spends off the ground. These XOS COG data seems to calculated with the following equation:

$$VJ^{ht} = (\frac{t^2 * g}{8}) ,$$

where t represents time off the ground and G the gravitational constant to confirm or refute this assumption (Isaacs 1998, Pond, Verducci et al. 2003, Leard, Cirillo et al. 2007). However, we could not get this confirmed by the company.

The company's marker placement may be a source of error when it comes to the reliability and validity of the XOS Sport Motion. The traditional infrared 3-D motion analysis system requires the placement of reflective markers at the joint centers to assist in determining segment lengths, kinematics, and kinetics. The XOS system is looking for specific patterns and not locations to develop the avatar. The company instructions on marker location are part of the issue.

The shirt has 12 markers placed on it. Two markers are placed on the top of shoulders, three markers across top of back, two markers in center of back, one marker on sternum, and two markers on side of each upper arm. The instructions don't give clear expectations of this placement. The shoulder makers are placed on the AC joint. The three markers on the top of the back are equally distributed across the back. The center markers on the back again are distributed equal at the mid-back level of the participant. The marker on the sternum is located on the upper portion. And the two markers on the side of the arm are placed at the elbow and at a location that is 1/3 down the upper arm from the shoulder marker. Unless you had knowledge of the location from training by company representatives you would not know the locations the system expects in order to recognize and generate the avatar.

The belt worn at the waist requires four markers: two on the side and two on the posterior side. The system expects these markers at the ASIS and L4-L5 location. The cap also has 4 markers. 2 are located at the front and 2 on top. An issue occurs with overweight individuals at the ASIS markers. The markers on the belt rotate downward toward the floor due to the material of the belt. The altered positions make it difficult for the cameras to see the markers. The cap has four markers as well. The instructions list 2 at the front and 2 on the top of the head. However, the system wants one marker at either temple, one on top of the head, and one at the back of the head. This posterior head marker becomes an issue with females having long hair.

The wrist, knees, and feet straps the company uses also present challenges for the system to recognize. Each of the wrist and knee straps has two markers for each of the extremities. The wrist strap help the system understand pronation and supination of the forearm. In order to accomplish this, the system needs to see an offset of the markers at the wrist. However, the instructions provided by the company lists that one marker be attached on outside of wrist and one marker on inside of wrist. The system does have a hard time determining which marker is on the outside and which is on the inside of the wrist. As a result, the avatar does not always generate a correct model or the model will have a "twitch" in the hand and wrist area. The feet require the subject to wear shoes and covers are placed over the participant's shoes. Each shoe cover has four markers. The four markers are instructed to be located at on top of shoe, at center of heel, and centered on outside of foot. In reality, the two markers need to be located on the great toe and 5th digit, one marker is located at the center of the heel, and one marker is located on the 5th metatarsal. An issue here is the size of the shoe covers does not allow for the larger feet of many athletes. This makes it difficult for appropriate marker locations to be provided.

The system introduces error into the calculations provided to users in a couple ways. The calculation of the jump height provides much of the error. Marker placement is also a source of error. Both of these lend to decrease reliability and validity on the XOS Sport Motion system.

5 CONCLUSIONS

Based on initial data analysis, there is a marked difference between the XOS SportMotion capture system's methods of measuring CMVJ height when compared to Vertec measurement. XOS SportMotion does provide a reliable means of measuring CMVJ; however, the measurements provided are not at the same level of validity as the Vertec system. Individuals using the XOS

SportMotion system need to keep this in mind when using this particular component to evaluate athlete performance. Interpretation of these results confines generalization to recreationally active college-aged students. Future studies should test other suitable populations such as the athletes.

REFERENCES

Feltner, M.E. Bishop, E.J., and Perez, C.M. (2004). Segmental and kinetic contributions in vertical jumps performed with and without an arm swing. Res. Q. Exerc. Sport 75:216–230. 2004.

Harman, E.A., Frykman, P.N., Roesnstein, R.M. (1990) The effects of arms and countermovement on vertical jumping. Med. Sci. Sports Exerc. 22: 825–833.

Hutchinson A.T. and Stone, A.L. (2009) Validity of Alternative Field System for Measuring Vertical Jump Height. JEPonline. Vol. 12(3) June 2009.

Isaacs, L. D. (1998). "Comparison of the vertec and Just Jump Systems for measuring height of vertical jump by young children." Percept Mot Skills **86**(2): 659-663.

Lees, A., Vanrenterghem,J. and Clercq, D.D. (2004) Understanding how an arm swing enhances performance in the vertical jump. J. Biomech. 37: 1929.

Klavora, P. (2000) Vertical-jump: a critical review. Strength and Conditioning Journal, 22(5), 70-75.

Leard, J. S., M. A. Cirillo, E. Katsnelson, D. A. Kimiatek, T. W. Miller, K. Trebincevic and J. C. Garbalosa (2007). "Validity of two alternative systems for measuring vertical jump height." J Strength Cond Res **21**(4): 1296-1299.

Motion Reality, I. (2014). Personal communication. S. Konz.

Petushek, E.J., VanderZanden, T., Wurm, B., and Ebben, W. P. (2010) Comparison of Jump Height Values Derived from a Force Platform and Vertec. International Symposium on Biomechanics in Sports: Conference Pr;, Vol. 28.

Pond, J., F. Verducci and B. Scheilhauf (2003). Reliability and Validity of the Just Jump System. M.S., San Francisco State University.

Starosta, W. and Radzinska, M. (2001) Comparison of jumping ability measured by different methods in sportsmen. Biology of Sport 18, 245-251.

Vincent, W.J. and J. Weir. Statistics in Kinesiology 4th ed. 2012. Human Kinetics. Champaign, IL