TESTING THE RELIABILITY AND VALIDITY OF THE XOS MOTION CAPTURE SYSTEM AT MEASURING COUNTER MOVEMENT VERTICAL JUMP

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The purpose of this study is to conduct simultaneous measurement of CMVJH 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 CMVJ 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 CMVJ height measured between the Vertec and the XOS VJ was (p= .000), SEM of 1.4 with a .823 correlation and the Vertec and the XOS COG was also (p= .000), SEM of 1.42 with a correlation of .788. A marked difference exists between the XOS SportMotion capture system's methods of measuring CMVJ height when compared to Vertec measurement.

KEY WORDS: CMVJ, MEASUREMENT, INSTRUMENTATION, RELIABILITY

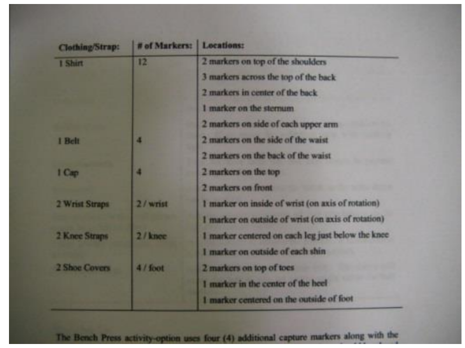
INTRODUCTION: Motion analysis systems are a widely used tool in performance enhancement, biomechanical analysis, and injury assessment. These systems provide users with important information to guide the improvement of function. The reliability and validity of the information of these systems is vital. 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.

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)(2). 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 COG tracking methods (Isaacs 1998, Pond, Verducci et al. 2003, Leard, Cirillo et al. 2007)

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. 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.

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 weight: 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 weight: 81.13 kg ± 8.45) and six females (body height: 165.09 m ± 14.67, body weight: 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:	Locations:
1 Shirt	12	2 markers on top of the shoulders
		3 markers across the top of the back
		2 markers in center of the back
		1 marker on the sternum
		2 markers on side of each upper arm
1 Belt	4	2 markers on the side of the waist
		2 markers on the back of the waist
1 Cap	4	2 markers on the top
		2 markers on front
2 Wrist Straps	2 / wrist	1 marker on inside of wrist (on axis of rotation)
		1 marker on outside of wrist (on axis of rotation)
2 Knee Straps	2 / knee	1 marker centered on each leg just below the knee
		1 marker on outside of each shin
2 Shoe Covers	4 / foot	2 markers on top of toes
		1 marker in the center of the heel
		1 marker centered on the outside of foot

The Bench Press activity-option uses four (4) additional capture markers along with the

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 system (Figure 1. Maker placement) was calibrated each testing day according to the systems required means. Participants donned a compression suit with 28 reflective markers located at specific locations with (See Figure 1). The markers 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). 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.

Participants were instructed on proper CMVJ (counter movement vertical jump) technique and use of the Vertec (Vertec Sports Imports, Hilliard, OH) during CMVJ testing. 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. 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 (Figure 2. "T-position")
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.

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= .000), 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= .000), SEM of 1.42 with a correlation of .788.

Table 1. Descriptive Statistics

Device	Gender	Mean ± Std. Dev.
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

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 1.29 cm. 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 3.25 cm with an MCD of 9.00. The reliability (ICC 2,3) for the Vertec and the XOS VJ was .871.

The vertical jump height measured with the Vertec ranged from 31.75 cm to 82.55 cm, again. 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 1.29 cm. An MCD for the Vertec was 3.58. 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 6.82. The reliability (ICC 2,3) for the Vertec and the XOS COG was .833.

DISCUSSION: All three means of measurement showed individual reliability. However, the validity of the XOS system's measurements did not prove as valid 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.

CONCLUSIONS: Based on initial data analysis, there is a marked difference between the XOS SportMotion capture system's method 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.

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