RELIABILTY OF ELECTROMAGNETIC TRACKING IN DESCRIBING PITCHING MECHANICS

David W Keeley[1], Gretchen D Oliver[1], Christopher P Dougherty[2], and Michael R Torry[3]

Health, Kinesiology, Recreation and Dance, University of Arkansas, Fayetteville, USA[1]
Department of Orthopedic Surgery, The Agility Center, Bentonville, USA[2]
School of Kinesiology and Recreation, Illinois State University, Normal, USA[3]

The purpose of this study was to establish the reliability of an electromagnetic tracking device (ETD) in analyzing young baseball pitchers. Two data collection sessions in which throwing kinematics were recorded were conducted across a five day span. Joint kinematics were calculated using the International Shoulder Group recommendations. Correlation analyses examining inter-day reliability of the ETD showed that the system was within acceptable limits ($r > 0.73$). Throughout the selected instances of the pitch cycle, the ETD used in the current study was shown to be reliable across multiple data collection session with ICCs ranging from $r = 0.73$ to 0.86. It appears so long as the set-up, sensor attachment, and digitization protocols remain consistent across data collection sessions, ETD's are a reliable tool in analyzing throwing movements in younger subjects.

KEY WORDS: biomechanics, baseball pitching, motion capture.

INTRODUCTION: Electromagnetic tracking devices (ETDs) allow for the three-dimensional measurement of both position and orientation of multiple sensors. Although these systems are susceptible to experiencing magnetic distortion from nearby metal (Milne et al., 1996), this limitation can be addressed through metal mapping and experimental design (Day et al., 2000). Proper utilization of these techniques allows for reported data reported from ETD systems to be compared with those data reported from passive optical systems (Richards, 1999). Unfortunately, although the establishment of general reliability measures for ETDs is vital, it is also necessary to establish reliability data for specific joints and movements when incorporating the system into new avenues of study.

While ETDs have been widely used in upper extremity analyses (Meskers et al., 1998; Myers, et al., 2005), these studies have often incorporated less dynamic movements than the baseball pitching motion. Because baseball pitching is such a dynamic movement, the reliability of ETD measurements established in the aforementioned studies can not be inferred to analyses of baseball pitchers. Therefore, it is necessary to establish the reliability of ETD measurements describing the pitching motion. Consequently, the purpose of this study was to establish the inter-day reliability for an ETD in measuring upper extremity kinematics of baseball pitching.

METHODS: Eleven healthy youth baseball pitchers (mean age: 11.3 ± 0.9 years, height: 138.2 ± 6.1 cm, mass: 52.4 ± 5.9 kg) participated in the current study. Prior to subject testing, a series of wooden platforms (121.92 cm in length, 121.92 cm in width, and 42 cm tall) were positioned so that a portable wooden pitching mound could be placed on them. Also, a wooden tower measuring 243.84 cm in height, 45.72 cm in width, and 45.72 cm was positioned a distance of 10.16 cm away from the edge of the platforms. The tower was constructed of only wood, glue, and wooden pegs (as were the platforms and mound) and used to support the extended range transmitting (ERT) device responsible for generating the magnetic field. The complete set-up of the throwing area is shown in Figure 1. Subsequent to the set-up of the testing area, a series of four calibration points were digitized to establish a reference axes system. Following calibration of the system, the root mean square error (RMSE) of sensors positioned randomly within the calibrated space was determined to be less than 1 cm.

To collect data describing the reliability of the ETD used in the current study, two data collection sessions were conducted. Four days were allowed between testing sessions to allow pitchers adequate recovery. All testing protocols were held constant across the two testing sessions. Kinematic data were collected using a series of 10 electromagnetic sensors. The 10 sensors were attached at the medial aspect of the torso (at C7) and pelvis (at S1) (Myers, et al., 2005), the distal/lateral aspect of both the throwing and non-throwing humerus and forearm, and the distal/lateral aspect of both the right and left thigh and shank. Following sensor attachment during the first testing session, the position of the electromagnetic sensors was marked using a waterproof permanent marker so that sensors would be placed in the same location during subsequent data collection sessions. After the sensor locations had been marked, one additional sensor was attached to a wooden stylus to digitize the palpated position of the bony landmarks (Myers, et al., 2005; Wu, et al., 2005).

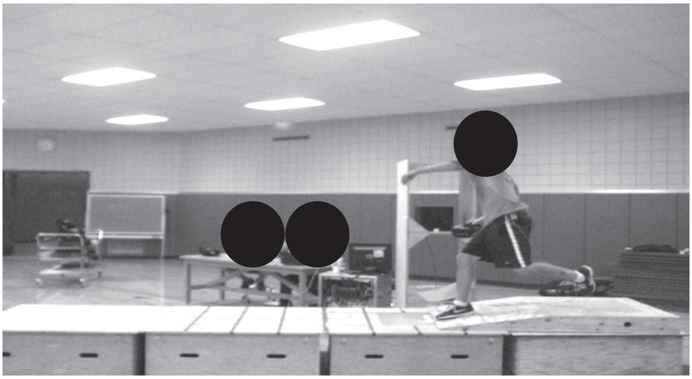

Figure 1: Example set-up of interlocking platforms, pitching mound, and ERT tower.

Following landmark digitization, pitchers were allowed to complete a warm-up period before throwing a series of maximal effort fastball pitches toward a catcher located the regulation distance (18.44m) from an indoor pitching mound. For all test trials, pitches were delivered from the stretch position. To analyze ETD inter-day reliability, those data from the five fastest pitches passing through the strike-zone on each day were selected for detailed analysis

Data describing the position and orientation of electromagnetic sensors were collected at 140 Hz. Raw data were independently filtered along each global axis using a 4th order Butterworth filter with a cutoff frequency of 13.4 Hz (Fleisig, et al., 1999). Throwing kinematics were calculated using the Euler angle decomposition sequences recommended by the International Shoulder Group of the International Society of Biomechanics (ISB; Wu, et al., 2005).

Data describing throwing kinematics were analyzed using the Statistical Package for Social Sciences 15.0 (SPSS Inc, Chicago, IL). Prior to investigating the relationship between pitching kinematics, distributional analyses were conducted to determine normality. Once the data were deemed to be normally distributed, mean and standard deviation were calculated so that mean difference analyses could be conducted to ensure that no differences were observed across the single pitch and three pitch average data pools. Once it was determined that there were no mean differences, interclass correlation coefficients (ICCs) were calculated in the form of Pearson product moment correlation coefficients.

RESULTS: Distributional analysis of data describing the average of the five fastest pitches for each day indicated that all model assumptions were met prior to testing for ETD reliability. Following distributional analyses, tests for mean differences were conducted to ensure no inter-day differences were observed between the variable means. These results showed that no differences were present across the testing days with significance levels ranging from a minimum of $p = 0.09$ for axial torso rotation at maximum shoulder external rotation to p = 0.98 for stride angle at foot contact. Correlation analyses examining inter-day reliability of the ETD showed that the system was within acceptable limits (r > 0.73). The results of all correlation analyses are displayed in Table 1.

Table 1
Results of ICC testing for reliability at foot contact (FC), maximum shoulder external rotation (MER), and ball release (REL)

	FC		MER		REL	
	r	95% CI	r	95% C.I.	r	95% C.I.
Stride Variables						
Length (% height)	.80	.39 – .95	---	--------	---	--------
Angle (°)	.83	.46 – .95	---	--------	---	--------
Pelvis Variables						
Lateral Flexion (°)	.83	.46 – .95	.77	.32 – .94	.82	.43 – .95
Axial Rotation (°/s)	.81	.41 – .94	.74	.25 – .93	.79	.36 – .94
Torso Variables						
Flexion (°)	.84	.49 – .96	.75	.27 – .93	.73	.23 – .92
Lateral Flexion (°)	.86	.54 – .96	.79	.36 – .94	.81	.41 – .95
Axial Rotation (°/s)	.78	.34 – .94	.77	.32 – .94	.79	.36 – .94
Shoulder Variables						
Elevation (°)	.79	.36 – .94	.77	.32 – .94	.82	.43 – .95
Plane of Elevation (°)	.76	.30 – .93	.79	.36 – .94	.79	.36 – .94
Axial Rotation (°/s)	.85	.51 – .96	.73	.23 – .92	.75	.27 – .93
Elbow Variables						
Flexion (°)	.79	.36 – .94	.79	.36 – .94	.76	.30 – .93

DISCUSSION: This study was designed to determine the reliability of an electromagnetic tracking device (ETD) in analyzing the throwing motion of high school baseball pitchers. This was necessary to ensure that the use of electromagnetic tracking is a viable method for describing the three-dimensional movements of the high school pitching motion. By demonstrating that an ETD can be effectively utilized to describe the high velocity throwing motion, this study demonstrates that ETDs can be utilized as a lower cost tool for analyzing highly dynamic movements in human samples.

Throughout the selected instances of the pitch cycle, the ETD used in the current study was shown to be reliable across multiple data collection session with ICCs ranging from r = 0.73 to r = 0.86. The ICCs are well within the acceptable limits with regard to motion capture system reliability. Thus, it appears so long as the set-up, sensor attachment, and digitization protocols remain consistent across data collection sessions, ETD's are a reliable tool in analyzing throwing movements in younger subjects.

Although the ETD used in this study was shown to be reliable across multiple collection session, there are some concerns that must be addressed. The most pressing concern that should be noted is that previous literature has indicated younger pitchers are significantly more variable with regard to pitching kinematics than are their older counterparts (Fleisig et al., 2009). This indicates that it cannot be determined whether the inter-day variability observed in the current investigation is a product of the individual pitchers or the ETD utilized throughout data collection. Thus, further study regarding this subject is warranted. A second concern regarding the use of this system is its applicability for use in analyzing older pitching populations. This concern arises from the fact that, in the current study, as the movement progressed from the less dynamic stride phase to the more dynamic arm cocking and arm acceleration phases, the reliability of the system decreased slightly. This is important as it has been shown that as the age of baseball pitchers increases, the speed with which the movement is carried out also increases (Fleisig et al., 1999). Thus, it is necessary to conduct similar reliability studies with samples varying in age to ensure that ETDs remain reliable across various age groups.

CONCLUSION: An ETD can be utilized as a low cost tool for describing the biomechanics of young baseball pitchers. So long as all known system limitations are addressed in the design of the testing protocol, ETD's provide an effective and reliable biomechanical description of pitching mechanics across multiple data collection sessions. However, the reliability of using such equipment has yet to be investigated in older baseball pitchers. Therefore, further study is required in order to determine the reliability of such systems in pitchers over the age of 12 years.

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