Model Predicting Shoulder Distraction Force during Baseball Pitching

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INTRODUCTION

Baseball pitching is often considered the most dynamic overhand movement in sports and repeatedly subjects the shoulder to high magnitudes of distraction force. There is evidence that this distraction force, peaking near ball release, contributes to an increased incidence of shoulder injury (Fleisig, 1995).

From a biomechanical perspective, the segmental interaction during pitching is commonly described using the kinetic chain theory. Alterations in this chain during pitching may place the shoulder at increased risk. Unfortunately, there is limited research investigating the impact of lower body and/or pelvis kinematics on shoulder kinetics. Therefore the purpose of this study was to identify pitching kinematics, including stride and pelvis parameters significantly related to shoulder distraction force at the instant of ball release and then use multiple regression techniques to develop a model explaining the variability in shoulder distraction force at release through using those parameters.

METHODS

Thirty-four healthy high school baseball pitchers (mean age: 16.8 ± 1.4 years, height: 174.9 ± 8.3 cm, mass: 79.3 ± 8.1 kg) participated in this study. To collect kinematic data, a series of six electromagnetic sensors attached to subjects as shown in Figure 1. Subsequent to electromagnetic sensor attachment, an additional sensor was attached to a wooden stylus and used to digitize the palpated position of various bony landmarks.

Throwing kinematics were calculated using standards and conventions recommended by the International Shoulder Group (Wu, 2005). Raw sensor orientation and position data were collected at a rate of 1000 Hz before being transformed to locally based coordinate systems for each body segment. Euler angle decomposition sequences were used to describe the position and orientation of the pelvis, torso, humerus, and forearm. Throwing kinematics for left handed subjects were calculated using the same conventions, but mirroring the world z axis so that the segments could be analyzed and described from a right hand point of view.

Throwing kinetics were calculated using previously described inverse dynamics techniques with the torso and throwing arm being modeled as four rigid links in series and connected by ball-and-socket joints (Keeley, 2008). Shoulder distraction force was normalized (% bodyweight) with the internal force acting along the longitudinal axis of the shoulder.

Initially, Pearson product moment correlation coefficients were calculated to identify those stride and pelvis parameters that were significantly related to shoulder distraction force throughout the pitching motion. Following the correlation analysis, multiple regression techniques were used to identify the model that best predicted shoulder distraction force. In all models developed during the current study, shoulder distraction force at release was the dependent variable and those variables identified as significantly related to shoulder distraction force at release were the independent variables.

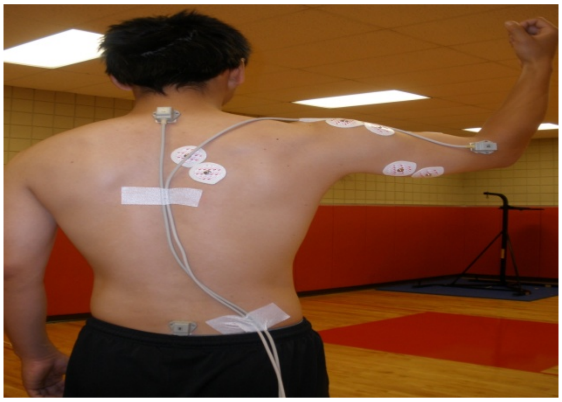

Figure 1. Example of electromagnetic sensor attachment.

RESULTS and DISCUSSION

Forty-seven parameters were analyzed from foot contact thru release in the current study. Shoulder distraction force at release averaged -1.72 %BW (-1334.98 N) across all pitchers. The results of correlational analyses indicated that five parameters were significantly related to shoulder distraction force at release ($p < 0.01$, $\alpha = 0.05$).

For the regression analysis, overall model testing indicated the model containing all predictors accounted for a significant magnitude of variance in shoulder distraction force at release. However, coefficient analysis within this model indicated that two of the parameters (stride angle and lateral pelvis flexion at foot contact) did not significantly contribute to the explained variance and were therefore removed from the model. The final model results are shown in Table 1 and explained 78.5% of the variance in shoulder distraction force at release.

The variance explained by the final model indicated that the lower body plays a key role in the magnitude of shoulder distraction force at the instant of release. Because the torso is directly linked to the pelvis, the inclusion of pelvis kinematics in the final model is not surprising. Previous reports have indicated that rate and timing of torso rotation play a key role in the development of increased shoulder kinetics (Aguinaldo, 2007). Thus, in keeping with the kinetic chain theory, increased velocity of pelvis axial rotation may translate to an increase in the velocity of torso axial rotation resulting in the humerus externally rotating to greater angles. As these angles increase, distraction force within the shoulder may increase resulting in decreased stability within the joint.

Table 1. Results of Overall Model Testing for final regression analysis[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	577374	1	577374	12.11	.001[a]
	Residual	1526141	32	47691		
	Total	2103515	33			
2	Regression	1526186	1	763093	40.98	.000[b]
	Residual	577328	31	18624		
	Total	2103515	33			
3	Regression	1650749	1	550250	36.46	0.000[c]
	Residual	452766	30	15092		
	Total	2103515	33			

a. Predictors: (Constant), Stride Length
b. Predictors: (Constant), Stride Length,, Pelvis Lateral Tilt @ MER
c. Predictors: (Constant), Stride Length,, Pelvis Lateral Tilt @ MER, Pelvis Axial Rotation Velocity @ REL
d. Dependent Variable: Distraction Force @ REL

REFERENCES

Aguinaldo, A.L., et al. (2007). *J Applied Biomechanics*, **23**, 42-51.

Fleisig, G.S., et al. (1995). *American J Sports Medicine*, **23**, 233-239.

Keeley, D.W., et al. (2008) *J Pediatric Orthopedics*, **28**, 452-459.

Wu, G., et al. (2005). *J Biomechanics*, **38**, 981-992.