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SHOULDER KINETICS DURING PITCHING AND THEIR RELATION TO REPORTED SHOULDER PAIN

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The purpose of this study was to identify those variables associated with shoulder pain in young baseball pitchers and develop a logistic regression model capable of predicting shoulder pain. Subjects (n=19) completed shoulder pain documentation before throwing fastball pitches recorded for analysis. At the shoulder, anterior force during cocking and proximal force and internal rotation torque during acceleration were related to shoulder pain ($p \leq 0.01$). Kinetic variables could be used independently to develop a significant logistic regression model. However, when combined, interaction between kinetic variables prevented individual logistic regression coefficients from accounting for a significant magnitude of variability in shoulder pain. Further study is necessary to determine how these variables interact with regard to shoulder pain during pitching.

KEY WORDS: injury, prediction, baseball, youth.

INTRODUCTION: The Minor League Division of little league baseball is where young pitchers begin to participate in what are known as player pitch divisions. In the Minor League Division, the primary focus is on developing the fundamentals of the game of baseball. For baseball pitchers, it is pitching mechanics (Steve Barr, Personal Communication, May, 2010). The development of proper pitching mechanics at this stage is vital since the most appropriate time to prevent injuries in pitchers is at the beginning of their careers (Fleisig, et al., 1999; Nissen, et al., 2007). Unfortunately, due to the complex nature of the pitching motion, the attempts of coaches to instill proper mechanics at the onset of pitchers' careers has not resulted in decreasing injury rates in youth pitchers. Within the available literature, kinetics within the shoulder have often been discussed as the underlying factors resulting in shoulder pain (Aguinaldo et al., 2007; Fleisig et al., 1995; Keeley et al., 2008). The two kinetic parameters most often discussed are anterior force which peaks near the time of maximum shoulder external rotation and proximal force which peaks near ball release (Fleisig et al., 1995; Fleisig et al., 1999; Keeley et al., 2008). Thus, the purpose of the current study was to associate peak shoulder kinetics throughout the various phases of the pitching motion with reported shoulder pain in youth baseball pitchers. An additional purpose was to identify how these forces regressed on the incidence of shoulder pain by modeling those parameters as predictors of shoulder pain in young baseball pitchers. It was hypothesized that shoulder pain would be associated with both peak shoulder anterior force during arm cocking and peak shoulder proximal force during arm acceleration as these variables had previously been associated with shoulder injury (Fleisig et al., 1995). It was also hypothesized that these variables would logistically regress on shoulder pain in young baseball pitchers, allowing a predictive model for shoulder pain to be developed.

METHODS: Nineteen healthy youth baseball pitchers (11.2 ± 1.7 years, height: 142.6 ± 9 cm, mass: 41.1 ± 6.3 kg) participated in the current study. Upon the provision of consent, participants were prepared so that kinematic data could be collected to identify the various phases of the pitching motion. Ten electromagnetic sensors were attached to the medial aspect of the torso (at C7) and pelvis (at S1), 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 (Myers, et al., 2005).
Following sensor attachment, pitchers were allowed to complete a warm-up period in preparation for data collection. Test trails consisting of maximal effort fastball pitches toward

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a catcher located 18.44 m from an indoor pitching mound were conducted. For all test trials, pitches were delivered from the stretch position, using only the slide step delivery method. Those data from the three fastest pitches passing through the strike-zone for each delivery method were selected for detailed analysis.
Throwing kinetics were calculated by modeling the torso and arm as four rigid links in series and connected by ball-and-socket joints (Feltner & Dapena, 1986; Fleisig et al., 1999; Keeley, et al., 2008; Sabick, 2004a). Body segment masses and inertial parameters were obtained from previous literature (Clauser, et al., 1969) and scaled to participant height and mass (Hinrichs, 1990). Shoulder anterior force was defined as the anterior component of the resultant force acting along the anterior/posterior axis of the shoulder, while shoulder proximal force was defined as the component of the resultant force acting along the longitudinal axis of the shoulder (Keeley, et al., 2008; Sabick, et al., 2004a; Sabick, et al., 2004b). Each of these forces was modeled using a convention that calculated the force applied by the torso to the proximal humerus and were normalized to percent bodyweight.
To collect data describing shoulder pain, a medical history questionnaire was utilized. This questionnaire, completed by both the participants and their parents collected information describing the following: 1) shoulder pain following throwing outing during the current competitive season; 2) shoulder pain frequency following a throwing outing; 3) level of relative shoulder pain on a scale of one thru 10; and 4) loss of practice time or performance time due to shoulder pain. Each of these variables was assessed for the most current competitive season.
The data in the current study were analyzed using the Statistical Package for Social Sciences 15.0 (SPSS Inc, Chicago, IL). To identify the relationship between shoulder kinetics and shoulder pain, point-by-serial correlation coefficients were calculated. Additionally, the Pearson product moment correlation coefficient was calculated between peak shoulder anterior force, peak shoulder proximal force, and peak shoulder internal rotation torque to identify the strength of the relationship between these parameters. Finally, logistic regression techniques were used to define a predictive model identifying the probability a baseball pitcher experiencing shoulder pain. In the current study, the three shoulder kinetics were the independent variables and shoulder pain was the dependent variable.

RESULTS: Peak anterior force during the arm cocking phase averaged 31.3 ± 13.6 N (7.7 ± 3.4% bodyweight), peak proximal force during the arm acceleration phase averaged 201.6 ± 48.7 N (50.1 ± 12.1% bodyweight), and peak shoulder internal rotation torque during the arm acceleration phase averaged -2.41 ± 1.14 Nm (-0.85 ± 0.40% bodyweight*height). The results of the point-by-serial correlation analyses are shown in Table 1. Each of the kinetic variables was significantly related to pitcher shoulder pain. Further analysis of the relationship between the two independent variables indicated a significant positive relationship was present ($r = 0.456$, $p = 0.05$). Because of this relationship and its potential for introducing mutlicollinearity into the logistic regression model, the kinetic variables were centered prior to conducting the logistic regression analyses. All further analyses incorporating peak shoulder anterior force and peak shoulder proximal force were conducted using the centered forms of the variables.
Three logistic regression models were developed in an attempt to identify the predictive capabilities of peak anterior force during arm cocking, peak proximal force during arm acceleration, and peak shoulder internal rotation torque during arm acceleration with regard to shoulder pain. The first model was developed using peak anterior force to predict the probability of shoulder pain in young pitchers. This model demonstrated and overall accuracy of 84.2% and correctly predicted 66.7% of the injury cases (Chi-square$_{(1)}$ = 13.02; $p < 0.001$).The second model used peak shoulder proximal force to predict the probability of shoulder pain in young pitchers. This model was also identified as being a significant model when predicting shoulder pain (Chi-square$_{(1)}$ = 7.159; $p = 0.006$). The third model used peak shoulder internal rotation torque to predict the probability of shoulder pain in young pitchers. This model was also identified as being a significant when predicting shoulder pain (Chi-square$_{(1)}$ = 6.471; $p = 0.01$).

Following these analyses, a multiple logistic regression model was developed to determine the effectiveness of the combination of these three shoulder kinetics in predicting shoulder pain. The overall model test identified that the combination of shoulder kinetics was significant in predicting pitchers who experienced shoulder pain (Chi-square$_{(3)}$ = 23.699; $p < 0.001$). However, further analysis of individual regression coefficients indicated that, in combination, none of the three shoulder kinetic variables accounted for a significant magnitude of variability in shoulder pain. These results are shown in Table 2. Interestingly though, as shown in Table 3, the model classification data indicate that the multiple variable model accurately predicted approximately 100% of all cases included in the study

Table 1
Results of Point-by-Serial Correlation Analyses

Parameter	Peak Shoulder Anterior Force	Peak Shoulder Proximal Force	Peak Shoulder Internal Rotation Torque
Shoulder Pain			
Point-by-Serial Correlation	0.745	0.603	-0.562
Sig. (2 tailed)	< 0.001	0.006	0.01
N	19	19	19

Table 2
Regression Coefficients for the Three Variable Model

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Peak Anterior Force	2.919	476.27	0.000	1	0.995	18.516
Peak Proximal Force	0.746	1307.86	0.000	1	1.000	2.108
Peak Internal Rotation Torque	-41.58	106847.6	0.000	1	1.000	0.000
Constant	-377.99	146939.8	0.000	1	0.998	0.000

Table 3
Classification Table Displaying Predicted Values for Shoulder Pain Using the Three Variable Model

		Predicted		
Observed	Value	0	1	Percentage Correct
Non-symptomatic	0	13	0	100
Symptomatic	1	0	6	100
Overall Percentage				100

DISCUSSION: The ability to accurately predict a pitcher's likelihood of experiencing shoulder pain is of great benefit to the baseball community and the results of this study indicate that three variables (peak shoulder anterior force during arm cocking, peak shoulder proximal force during arm acceleration, and peak shoulder internal rotation torque during arm acceleration) are significantly related to shoulder pain. Currently however, the combination of these variables cannot be effectively utilized to build a model identifying the probability of young pitchers to experience shoulder pain. When combined into a single model, it appears that these variables may interact in such a way that mutlicollinearity issues arise. Thus, it is difficult to ascertain each variable’s unique contribution to the multivariable model making further study necessary. Additionally, because pain can be described as a multifactorial sensation that may include neurological, psychological, physiological, in addition to the biomechanical components described here, additional study should include analysis of pain components other than biomechanical parameters. By continuing to investigate the interaction between biomechanical components associated with pain, as well as initiating examination of the possible neurological, psychological, and physiological parameters associated with pain a better understanding of the multivariate nature of pain may be developed. This improved understanding may function to allow the development of a multi-variable model that accurately predicts the likelihood of young pitchers experiencing shoulder pain.

CONCLUSION: Although the current study showed that specific shoulder kinetics were related to shoulder pain in young pitchers, further study is necessary. Research should focus not only on the interaction between the biomechanical variables included in the current model, but also on parameters outside the realm of biomechanics in an attempt to build a more accurate pain model. Through the achievement of such a model, coaches, researchers, and sports medicine practitioners may be able to better identify those pitchers at increased risk of reporting shoulder pain. Following the accurate identification of those pitchers at risk for pain, individualized training programs may be developed to address the specific issues presented by each pitcher. Thus, it is ultimately through better understand all parameters associate with shoulder pain that we may eventually be successful in decreasing its incidence in young baseball pitchers

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