A COMPARISON OF YOUTH PITCHING KINEMATICS ACROSS PREPUBESCENT AND PUBESCENT PITCHERS

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To reduce injuries in youth baseball pitchers coaches teach proper mechanics at a young age. Unfortunately, the mechanics taught to beginning pitchers are based on data from adolescent pitchers and may result in techniques that could injure younger pitchers. Thus, the purpose of this study was to identify differences between the pitching mechanics of prepubescent and pubescent baseball pitchers. Of the 20 parameters analyzed in the study, 7 were observed to be different between the two groups. The findings of this study indicate that the mechanics currently being taught to youth pitchers may not be appropriate for all ages and that furthur study is needed to help identify what mechanics are correct for all ages of pitchers. The data produced in this study may help clinicians appreciate the mechanical differences between pitchers of various ages and better understand the etiology of pitching injuries as they relate to age.

KEY WORDS: pitching, kinematics, pubescent, prepubescent.

INTRODUCTION: Youth baseball pitchers suffer injury at extremely high rates, with most of the injuries thought to be the result of overuse (Sabick et al., 2004). The underlying cause of these injuries is often attributed to the use of improper mechanics during pitching which result in repeated, unnecessary stresses being placed on the throwing arm. Because of this it is currently thought that the best practice for reducing these stresses is to teach proper pitching mechanics at an early age (Fleisig et al., 1999). Although skill development for young pitchers may be most critical at the beginning of their career, the mechanics currently being taught to these pitchers are often based on the results of biomechanical analyses of the pubescent pitching motion. Previously, biomechanical studies incorporating subjects over the age of ten (Fleisig et al., 1999; Sabick et al., 2004; Nissen et al., 2007) did not take into account the age related differences between pubescent and prepubescent pitchers. Thus, the purpose of this study was to quantify pitching kinematics in both prepubescent and pubescent pitchers in an attempt to identify differences between the various age groups. It was hypothesized that prepubescent pitchers would exhibit mechanics that were significantly different than those observed in pubescent pitchers.

METHODS: Data Collection: Eighteen right hand-dominant baseball pitchers assigned to two separate groups participated in the study (9 prepubescent and 9 pubescent). Data collection sessions were conducted in the Human Motion Research Lab, Texas A&M University-Commerce. Testing protocols were approved by that institution's ethics board, and prior to testing each pitcher and their parent(s)/guardian(s) all provided consent.

Prior to testing, a 3.38 m^3 calibration cube with 18 calibration points was suspended above the pitching mound using techniques described by Escamilla et al. (1998) and the three-dimensional space was calibrated. Following calibration the root mean square error in calculating the three-dimensional location of markers within the calibrated space was determined to be less than 10 mm. Reflective markers were attached bilaterally to each subject on the greater trochanter of the hips and the lateral-superior tip of the acromions, the medial and lateral epicondyles of the throwing elbow, and the radial and ulnar styloid process of the throwing wrist. Each subject then performed their own specified warm-up routine before throwing three maximal effort fastballs for strikes toward a catcher located 13.4 m from the pitching mound. To be considered a successful trial, a pitch was required to pass through a strike zone ribbon suspended 0.4 m above home plate and encompassing an area of 0.2 m^2. In addition, the velocity of all successful trials was required to be within 3 mph of the velocity of the fastest strike thrown for each subject. Each pitch was digitally recorded by three synchronized high speed digital video cameras (Basler Vision Technologies, Germany) recording at 120 Hz and that were arranged to capture the movement from the dominant side. Between trials each subject was allowed a 40-60 s rest period.

Data Analysis: Reflective marker locations were digitized in each frame from maximum knee lift through maximum internal rotation. Following digitization, the three-dimensional location of each marker was calculated using Direct Linear Transformation (Abdel-Aziz & Karara, 1971), and then filtered independently in the X, Y, and Z axis using a 2nd order Butterworth filter set at a cut-off frequency of 13 Hz (Sabick et al., 2004). Previously established techniques were then used to calculate the torso and throwing arm kinematics defined in Figure 1 (Dillman et al., 1993; Fleisig et al., 1999). For each subject, mean and standard deviation was calculated for: 1) shoulder abduction, 2) shoulder horizontal abduction, 3) shoulder internal rotation, anc 4) elbow flexion. In addition to these parameters, the rate of axial torso rotation was calculated as the cross-product of the upper torso vector and its first derivative (Feltner and Dapena, 1989).

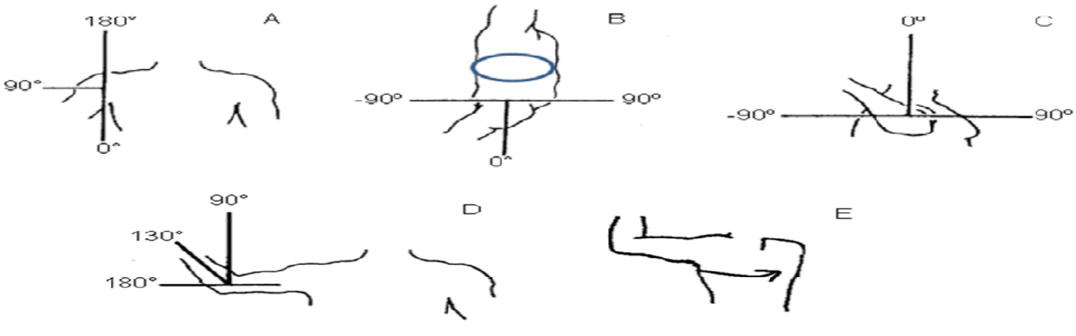

Figure 1: Definition of joint angles: A) shoulder abduction, B) shoulder horizontal abduction, C) shoulder external rotation, D) elbow flexion, and E) axial torso rotation. Adapted from Flesig et al., 1996.

Statistics: For each subject, mean and standard deviation were calculated for each kinematic parameter. Prior to testing for mean differences the nature of the distribution was analyzed, and after the data were deemed to be normally distributed paired independent sample *t*-test were used to compare mean values between the prepubescent and pubescent groups at the following intervals: 1) stride foot contact; 2) maximum shoulder external rotation; 3) ball release; and 4) maximum shoulder internal rotation. For each of the analyses, age was the independent variable and the kinematic parameter being analyzed was the dependent variable. Because the data were analyzed at four independent intervals, the level of significance for kinematic data was adjusted and set at alpha = 0.01. In addition, to discuss any differences identified between the groups in terms of standard deviation units, the effect size (d) was calculated for all parameters at all intervals.

RESULTS: The results of kinematic analyses are shown in Table 1 and of the 20 position parameters analyzed, 7 were different between groups. Previous reports indicate that pitching mechanics do not vary greatly with age and support the notion that proper pitching mechanics can be taught at an early age (Fleisig et al., 1999). The results of these studies must be interpreted with caution as they do not incorporate the youngest of pitchers. This study, by including younger subjects, identified several mechanical

Table 1 Kinematic differences between prepubescent and pubescent pitchers

	Prepubescent (n=9)	Pubescent (n=9)	Sig.	d
Stride foot contact				
Horizontal adduction (°)	-22 ± 7	-17± 9	*	0.08
Elbow extension (°)	101 ± 41	90 ± 43	*	0.19
Maximum shoulder external rotation				
Torso rotational velocity (°/s)	701 ± 440	1120 ± 414	*	1.60
Ball release				
Torso rotational velocity (°/s)	450 ± 312	772 ± 464	*	1.64
Maximum shoulder internal rotation				
Torso rotational velocity (°/s)	265 ± 272	676 ± 379	*	2.33
Horizontal adduction (°)	7 ± 9	34 ± 18	*	0.59
Elbow extension (°)	169 ± 8	148 ± 12	*	0.47

Note: * significant difference between groups ($p < 0.01$).

differences between prepubescent and pubescent baseball pitchers. Thus the experimental hypothesis of the study was retained. Of the 20 kinematic variables analyzed at various instances throughout the pitching motion, 7 differed significantly between groups. Although differences in the magnitude of various parameters were identified, the movement patterns observed were generally similar between the groups. Thus, to better compare the differences observed between the two independent groups, the effect size (d) was caluculated so that those differences might be discussed in terms of standard deviation units.

The results of the current study support the findings of previous studies (Aguinaldo et al., 2007) that indicate young pitchers have difficulty in controlling the rate of axial torso rotation thoughout the pitch cycle. However, it is often thought that more skilled pitchers are able to better control their torso rotation throughout the pitching cycle. Our results contradict this as we show that pubescent pitchers increase the velocity of their torso rotation early in the pitch cycle ("opening up early") with their rate of axial torso rotation consistenlty being 1.5 to 2 standard deviation units higher than the prepubescent group. Opening up early in the pitch cycle often means that the torso is rotating prior to proper positioning of the scapula and humerus, which could ultimately result in excessive horizontal abduction, or hyperangulation. It has also been speculated that slight changes in timing could result in reduced output and potentially harmful joint loads at the throwing shoulder (Fleisig et al., 1996). It may ultimately be the increased rate of torso rotation observed in pubescent pitchers that contributes to the high rate of shoulder soft tissue injuries in this younger group.

Unlike torso rotation, the magnitude of the observed differences between groups for the other paramters were quite small in terms of the effect size. Of interest however was that 3 of the 7 differences between prepubescent and pubescent pitchers were observed during the deceleration phase of the motion. The deceleration phase acts primarily as a mechanism for injury prevention by slowing the tremendous velocities generated during arm acceleration. Thus, it is important to understand how the differences observed in deceleration kinematics relate to number of injuries often experienced by pubescent pitchers. Pubescent pitchers often experience inflammation of the rotator cuff at a higher rate than prepubescent pitchers. During deceleration, the rotator cuff works to control internal rotation of the humerus as well as horizontal adduction of the arm across the torso (Fleisig et al., 1996). The large range of horizontal adduction observed in pubescent pitchers may result in increased activity of the rotator cuff musculature, ultimately placing pubescent pitchers at an increased risk for rotator cuff injury. This problem may compound as a youth pitchers become less capable of controlling internal rotation through activation of the rotator cuff. If damage to the rotator cuff results in a decreased ability to control internal rotation during deceleration, pubescent pitchers may be forced to compensate by increasing the already large range of horizontal adduction of the arm across the torso in order to decelerate the throwing arm.

CONCLUSION: Although previous reports have indicated that pitching mechanics do not vary greatly with age and have supported the notion that proper pitching mechanics can be taught at an early age, the results of the current study indicate that pitching mechanics may vary based on age. By including younger subjects, this study identified several mechanical differences between prepubescent and pubescent baseball pitchers, with the most dramatic differences being observed for axial torso rotation. The findings of this study indicate that the mechanics currently being taught to youth pitchers may not be appropriate for all ages and that furthur study is needed to help identify what mechanics are correct for all ages of pitchers. The data produced in this study may help clinicians appreciate the mechanical differences between pitchers of various ages and better understand the etiology of pitching injuries as they relate to age. For instance, one finding of the current study which may relate to overuse tendonopathy at the subscapularis in prepubescent pitchers was a brief period of shoulder abduction prior to maximum external rotation. As the arm is both abducted and externally rotated during late cocking, anterior shoulder stresses also increase. This increase may typically be reduced through an increase in the activity of the subscapularis. (Glousman et al., 1988). If a lack of muscular strength in prepubescent pitchers renders them unable to compensate for these increased stresses, a scenario becomes possible where the subscapularis is required to repeatedly work beyond its capacity, resulting in overuse tendonopathy and/or a loss of muscular integrity.

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