CLINICAL AND BIOMECHANICAL COMPARISONS BETWEEN YOUTH PITCHERS WITH AND WITHOUT A HISTORY OF THROWING ARM PAIN OR INJURY

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This study aimed to determine if there are clinical and kinematic differences in youth pitchers with a self-reported history of throwing arm pain or injury (PI) to those without (NPI). Forty male baseball pitchers ages 9 to 14 years old were divided into a PI group (n=20) and a NPI group (n=20). Injury history, pitching exposure, subject demographics, range of motion, and strength measurements were collected, along with throwing arm kinematics via a motion capture system. When comparing PI and NPI, significant physical differences were observed, with a greater presence of axillary hair, increased forearm length and decreased shoulder internal rotation strength in PI. No significant differences of upper limb motion during pitching were reported. When considering youth pitchers, evidence of physical maturity, arm length, and strength could be important factors in developing pain or injury.

Keywords: Pitching, kinematics, pediatrics, injury, biomechanics

INTRODUCTION: The Sports and Fitness Industry Association estimated that 4.1 million athletes between the ages of 6 and 12 played baseball in 2017-18, a 3.3% increase from the prior year (Aspen Institute Project Play, 2019). Sports medicine physicians are concerned over the increasing number of overuse injuries in youth sports, and baseball is at the forefront (DiFiori et al., 2014). Many of these overuse injuries occur at the shoulder and elbow, including labral tears and ulnar collateral ligament (UCL) tears which can require surgical intervention (Saper et al., 2018). Youth baseball pitchers are a vulnerable population with over half of pitchers between the ages of 9- and 14-years old reporting shoulder or elbow pain in a season (Lyman et al., 2001).
The prevention of throwing arm injuries in youth baseball pitchers has often focused on limiting the number of innings and pitches. Initially, inning counts were followed until the 1990s when pitch counts and rest periods became popularized based on expert opinion (Feeley et al., 2018). Evidence then followed establishing high pitch counts as a risk factor for shoulder and elbow pain as well as injury in youth pitchers (Lyman et al., 2002). Other variables such as age, height, pitching over 100 innings per year, pitching for multiple teams, pitch velocity, training more than 16 hours per week, a history of elbow pain, and arm fatigue have been identified as risk factors for youth and adolescent throwing arm injuries and pain (Agresta et al., 2019, Norton et al., 2019, Yang et al., 2014). Adolescent throwers can suffer various injuries depending on their skeletal maturity from stress on the medial, lateral, and posterior aspects of the skeleton caused by tension failure, compression, and shear-stress during extension (Looney et al., 2021). Okoroha et al. (2018) reported that as pitchers mature – indicated by increased height, arm length and elbow circumference, they experience less torque across the medial elbow when throwing, which they hypothesized was protective against elbow injuries. Links between clinical measures, including maturity, and biomechanical risk factors for pain or injury need to be further explored in youth pitchers. Therefore, the goal of this study was to determine clinical and kinematic differences in youth pitchers with a history of throwing arm pain or injury compared to youth pitchers without a history of throwing arm pain or injury.

METHODS: Forty male baseball pitchers (12.2 ± 1.4 years, 161.0 ± 12.9 cm, 49.7 ± 12.9 kg) participated in this study. Subjects with a history of prior surgery on their throwing arm or current throwing arm pain or injury were excluded. Written informed consent and assent were obtained from each subject and their parental guardian. A questionnaire was completed with parental supervision. Two questions were used to define subject groups. The first question asked the subject if they had a throwing injury or arm pain related to throwing in the last year. If the subject answered yes, and in the subsequent question indicated they missed at least one game or less, they were assigned to a history of pain or injury group (PI), otherwise they were assigned to the no history of pain or injury group (NPI). The questionnaire also addressed lifetime and current exposure to pitching and maturation based on the presence or absence of axillary hair.

Physical characteristics including height, weight, BMI, hand size, lower extremity length, trunk length, upper arm length, and forearm length were measured. Passive external and internal rotation of the throwing shoulder were measured by a single physical therapist using standard supine measurement techniques (Fleisig et al., 2011). Joint mobility was assessed using the Beighton hypermobility scale (Smits-Engelsman et al., 2011). Grip strength was measured using a Jamar dynamometer, with a middle grip position (Li et al., 2019). Three trials were performed for each hand and the average of the three trials was recorded. Isokinetic and isometric analysis was conducted using a Biodex dynamometer (Biodex Corporation, Shirley, NY) to assess throwing shoulder muscle strength. The Biodex was set to 50 degrees from the vertical axis and then rotated 20 degrees to keep the humerus in the scapular plane for a standard testing procedure (Greenfield et al., 1990). Isokinetic analysis consisted of two tests: 60 degrees per second for five repetitions and 180 degrees per second for ten repetitions. Isometric analysis was conducted at 0, 45, and 105 degrees of external rotation. Three repetitions at each angle were conducted and the mean force was recorded. All strength measures were normalized to body mass.

Subjects underwent pitching analysis with a 12-camera motion capture system (Vicon System, Oxford, UK). Thirty-eight reflective markers (14mm diameter) were attached using double sided tape to each subject at specific bony landmarks (Nissen et al., 2007). A static trial was taken prior to warming up. The subjects performed a whole body warm up for five minutes. Subjects then threw ten full-effort fastball pitches from a portable indoor pitching mound into a backstop with a strike zone. The backstop was placed 5.36 m from the mound. Subjects were asked to throw their most accurate fastball with maximal effort. For each subject, the three best pitching trials thrown to the center of the net were selected for further processing. Vicon Nexus software was used to calculate throwing arm joint kinematics using the Vicon plug-in upper limb model, including shoulder horizontal adduction/abduction, shoulder abduction/adduction, internal/external rotation, and elbow flexion. Three key events of the pitching cycle were analyzed: foot contact (FC), shoulder maximum external rotation (MER), and ball release (BR).

Binary variables from the questionnaire were statistically analyzed using Chi-Square tests. A Fisher's exact test was performed when cell counts in two-way cross tabulations were small. Exact Wilcoxon rank-sum tests were performed to compare distributions of ordered categorical variables between two groups. Student's t-tests were used to analyze physical measurements, strength measurements, and kinematic parameters between PI and NPI. Level of significance was $p < 0.05$. All statistical analysis were performed using SAS version 9.4 (SAS Institute).

RESULTS: Forty male baseball pitchers completed the study, with 20 in each group (PI: 12.5 ± 1.5 years, 164.6 ± 13.9 cm, 52.4 ± 14.4 kg; NPI: 11.9 ± 1.3 years, 157.4 ± 10.7 cm, 47.0 ± 10.6 kg). There were no significant differences between groups for age, height, mass, BMI, hand size, arm length, trunk length, or lower extremity length. Only forearm length was significantly different, with PI (26.3 ± 2.7 cm) having longer forearms than NPI (23.8 ± 1.9 cm) group (p = 0.002). For the strength measures, only internal rotation at 180 deg/sec was significantly different, with PI having slightly lower relative isokinetic torque (0.04 ± 0.01 Nm/kg) compared to NPI (0.05 ± 0.01 Nm/kg) (p = 0.011). There were no other statistically significant differences on clinical examination. The only significant difference in questionnaire results between the groups was that PI had a higher report of axillary hair as compared to NPI ($p = 0.020$). The groups showed no significant difference in years of participation in baseball or pitching, number of months participating in baseball each year, pitching for multiple teams, inning and pitch counts, time allowed for pitching warm up, education in proper throwing mechanics, throwing breaking pitches, participating in strength and conditioning programs, and use of arm orthotics. There were also no significant differences in throwing arm shoulder or elbow kinematics between the groups (Table 1).

Table1. Comparison of kinematics between PI and NPI

	PI (n=20)			NPI (n=20)			p-value
Foot Contact							
Shoulder Horizontal Abduction (-)	-19.4	±	11.7	-20.9	±	15.0	0.753
Shoulder Abduction (+)	87.7	±	17.0	92.3	±	10.9	0.373
Shoulder External Rotation (-)	-52.6	±	29.3	-67.2	±	22.3	0.145
Elbow Flexion (+)	81.2	±	18.5	85.7	±	22.7	0.547
Max External Rotation							
Shoulder Horizontal Adduction (+)	6.1	±	15.5	10.0	±	9.7	0.427
Shoulder Abduction (+)	94.0	±	7.7	96.1	±	7.9	0.487
Shoulder /External Rotation (-)	-141.1	±	20.6	-144.7	±	13.3	0.587
Elbow Flexion (+)	81.2	±	17.4	78.6	±	14.0	0.669
Ball Release							
Shoulder Horizontal Adduction (+)	12.5	±	24.5	13.3	±	9.9	0.900
Shoulder Abduction (+)	80.9	±	56.8	95.0	±	8.3	0.341
Shoulder External Rotation (-)	-80.8	±	43.8	-106.8	±	24.7	0.057
Elbow Flexion (+)	38.4	±	24.1	37.2	±	7.3	0.859

DISCUSSION: Prior studies performed on youth baseball pitchers identified possible risk factors for injury including pitch and inning counts, pitching for multiple teams, proper throwing mechanics, and physical maturity (Lyman et al., 2001, Lyman et al., 2002). These risk factors were explored in a questionnaire, but no significant difference was found except in the presence of axillary hair. Although there was no significant difference in our study between PI and NPI in their adherence to pitch counts, it is worth noting that only 55% of PI subjects always adhered to pitch count as compared to 75% in NPI. There were no reported differences in throwing arm kinematics. While focusing on different body parts, Fava et al. (2023) also did not find biomechanical differences in trunk or pelvis kinematics in youth pitchers with and without upper-extremity pain.

The only significant differences between PI and NPI were increased presence of axillary hair, longer forearm length, and decreased internal rotation strength in PI. The increased presence of axillary hair would indicate a greater sexual maturity rating (SMR) in PI. Growth of the limbs would also occur during this time of rapid growth velocity and would explain why forearms were longer in PI. Despite the difference in SMR between the groups, the only strength difference shown was decreased isokinetic internal rotation strength in PI. This counters typical maturation, as significant gains in strength are seen when axillary hair appears. While significant, the difference between groups was very small and may not be clinically relevant. Although they did not examine the presence of axillary hair, Okoroha et al. (2018) reported that increased forearm length and physical maturity in youth pitchers were independent protectors against elbow torque. The current study did not examine pitching kinetics. More studies are needed regarding the impact of maturation on pitching mechanics independent of chronological age.

This study had several limitations. The sample size was relatively small from one geographic region. As with all self-reported questionnaire data, response bias may have led to misreporting. It was conducted in a controlled indoor setting at a shortened throwing distance, without a catcher or batter present, which could affect how pitches were thrown.

CONCLUSION: The pitchers in PI and NPI were similar in their results. We identified clinical differences in these pitchers that should be further explored with a prospective study, prior to pain or injury, to better decipher if poor mechanics lead to pain or injury or pain or injury leads to modifying mechanics. We recommend further studies on physical maturity factors that can vary greatly during adolescence.

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