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A Comparison of Throwing Kinematics between Youth Baseball Players with and without a History of Medial Elbow Pain

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Abstract

Risk factors in throwing factors associated to little league elbow have not been adequately explored. Whether these factors also affect the players' performance is also important to elucidate while modifying throwing pattern to reduce injury. The purpose of this study was to compare the differences in throwing kinematics between youth baseball players with or without a history of medial elbow pain (MEP) and to determine the relationship between their throwing kinematics and ball speed. Fifteen players with previous MEP were matched with 15 healthy players by age, height and weight. Throwing kinematics was recorded by an electromagnetic motion analysis system. A foot switch was used for determining foot off and foot contact. Ball speed was recorded with a sports radar gun. The group with a history of MEP demonstrated less elbow flexion angle at maximum shoulder external rotation and had more lateral trunk tilt at ball release compared to the healthy group. The group with a history of MEP also had faster maximum upper torso rotation velocities, maximum pelvis rotation velocities and ball speeds. Maximum shoulder external rotation angle (r = 0.458, *P* = 0.011), elbow flexion angle at maximum shoulder external rotation (r = -0.637, *P* = 0.0003), and maximum upper torso rotation velocity (r = 0.562, *P* = 0.002) had significant correlation with ball speed. Findings of this study can be treated as elbow injury-related factors that clinicians and coaches can attend to when taking care of youth players.

Key Words: baseball, injury, youth player

Introduction

Little league elbow is a common injury in youth baseball players (6, 7, 11). The reported incidences of elbow injury have been variable and may be trending upward since Gugenheim *et al*. reported 17% of youth baseball pitchers experienced elbow problems (6), Lyman *et al*. found that 26% of 298 youth baseball pitchers complained about elbow pain (11), and Hang *et al*. indicated that 52% of the 343 youth players examined had elbow problems during a baseball season (7).

Youth baseball players are still growing and have immature musculoskeletal systems. Repetitive stress directed to the growth plate, cartilage and ligaments around the elbow during throwing may

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Table 1. Characteristics of the participants with and without previous medial elbow pain (MEP)

	MEP (n = 15) Mean (SD)	Healthy (n = 15) Mean (SD)	*P*-value
Age (years)	11.3 (0.6)	11.1 (1.0)	0.41
Height (cm)	148.8 (8.6)	147.2 (8.5)	0.18
Mass (kg)	44.0 (10.3)	41.4 (10.3)	0.052
Practice and play (hours/week)	21.7 (3.7)	21.6 (3.8)	0.92

result in a series of micro-traumas ultimately leading to injury. If these injuries are not treated carefully, they may become chronic with permanent implications (1, 9, 16). Common elbow injuries in these players include osteochondritis dissecans, avulsion fractures of the medial epicondyle, medial epicondylitis and ulnar collateral ligament sprains. It has been reported that 68% of elbow injuries in youth baseball players are on the medial side (9).

High valgus stress, produced during the late cocking phase of throwing, may result in medial elbow injuries (4, 5). Several studies investigated the relationships between throwing kinematics and valgus stress of the elbow (12, 17, 19). Sabick *et al*. indicated that repetitive valgus stress to the elbow may distract soft tissues around the elbow joint leading to injury (17). A multiple linear regression analysis for professional baseball players found that when shoulder abduction angle at lead foot contact was increased, valgus stress to the elbow was also increased. Peak valgus stress was decreased as elbow flexion angle increased at the moment of peak valgus stress. During the arm acceleration phase, when the maximum angular velocity of shoulder horizontal adduction was increased, elbow valgus stress was also increased (19). Matsuo *et al*. found that trunk lateral tilt and shoulder abduction angle at ball release may affect peak elbow valgus stress during overhead throwing (12). In their computer simulations, the minimum peak elbow valgus stress was produced when the trunk lateral tilt angle and the shoulder abduction angle at ball release were 10° and 100° respectively. The greatest value of peak elbow valgus stress was produced when the trunk lateral tilt angle and the shoulder abduction angle at ball release were 40° and 120°, respectively. In youth baseball players, Sabick *et al*. reported that when the maximum shoulder external rotation angle (MER) was increased, elbow valgus stress increased (17). Nissen *et al*. suggested that trunk and pelvic transverse-plane rotations correlated with elbow valgus stress (13). Keeley *et al*. indicated that the combination of increased medial force and valgus stress being placed on the elbow could lead to little league elbow or medial compartment instability (8).

Studies have investigated relationships between throwing kinematics and elbow valgus stress during throwing in youth baseball players (5, 8, 13, 17). Few studies have compared the differences in throwing kinematics between youth baseball players with or without a history of medial elbow injury. In addition, throwing guidelines for youth baseball players mainly focus on overuse injury prevention. Learning proper throwing kinematics as early as possible may assist in injury prevention for youth players. Thus, it would be worthwhile to understand if there are differences in throwing kinematics between youth baseball players with or without a history of medial elbow problems for future injury prevention and rehabilitation strategies. The purpose of this study was to examine kinematic variables of throwing between little league players with or without a history of medial elbow pain (MEP) to determine if differences could be identified. Based on the findings of previous studies (12, 17, 19), we hypothesized that youth baseball players with previous MEP may show greater shoulder abduction angles at lead foot contact, greater MER angles, less elbow flexion angles at MER, greater maximum angular velocities of shoulder horizontal adduction during acceleration phase, and greater trunk lateral tilt and shoulder abduction angles at ball release that could increase elbow valgus stress when compared to their healthy counterparts.

Materials and Methods

Participants

Thirty youth baseball players with 1-2 years of organized baseball experience participated in this study. Fifteen players with a history of MEP within the past year were age, height and weight were matched to fifteen players with no history of MEP. Players with a history of MEP that required conservative treatments were included. Players with existing neuromuscular or musculoskeletal problems or had elbow pain at the time of testing were excluded to avoid potential compensations in throwing mechanics due to pain and injury rather than the participants' natural mechanics. All players used overhead throwing.

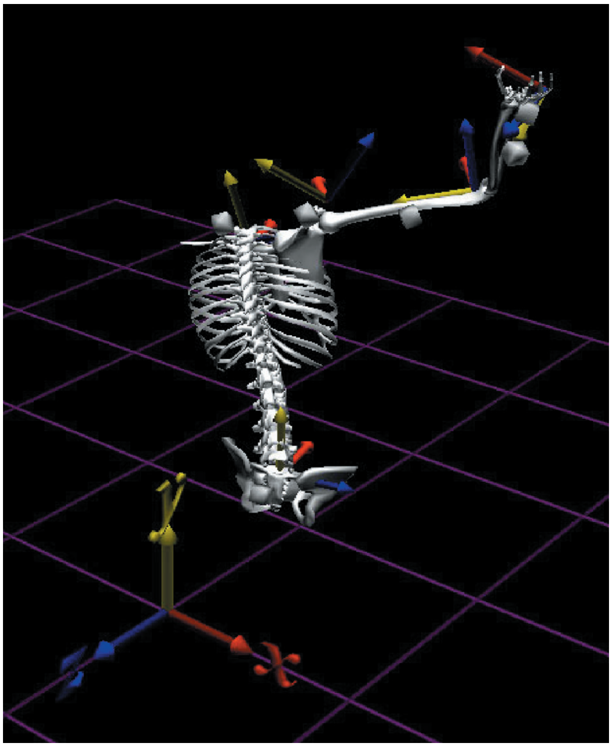

Fig. 1. Locations of electromagnetic receivers.

Demographic data of all participants are presented in Table 1.

Motion Analysis

Throwing motion was recorded using the Motion Monitor software (Innovative Sports Training, Inc., Chicago, IL, USA) integrated with the Polhemus LIBERTY electromagnetic motion tracking system (Polhemus, Colchester, VT, USA) at 120 Hz, a commonly used frequency for pitching analysis (4, 8, 17, 19). Four receivers were attached to the subject's skin using double-sided tape, surgical tape, and non-elastic cuffs at the following locations of the throwing arm: the posterior acromial angle of the scapula, the distal lateral humerus, the posterior aspect of the distal radius, and the dorsal aspect of the 3rd metacarpal bone. Two additional receivers were attached to the first segments of the thoracic and sacral spine for measuring upper torso and pelvic motion (Fig. 1). The position and orientation of each receiver were computed relative to the transmitter which was placed behind the subject. The coordinate systems and Euler rotation sequences for the upper extremity and trunk motions were defined based on the protocols recommended by the International Society of Biomechanics (20). We used the rotation method to define the shoulder joint center (18). The rotation method relies on rotation of the humerus relative to the scapula to locate the center of rotation. Each participant's upper arm was held in 10 positions of a small circle to collect multiple readings for locating the shoulder joint center. The accepted variation that occurred in the center of rotation readings needed to have a root mean square (RMS) error small than 0.0025 m. A RMS of 0.001 m and 1.3° was obtained by our motion analysis system for determining the accuracy of the receivers in measuring the position and orientation. A foot switch was attached under the sports shoe of the lead foot for determining time of foot raise and foot contact. Time of ball release was defined as the instant when wrist acceleration phase was becoming deceleration phase (15). Ball speed was measured with a sports radar gun (Decatur Electronics, Inc., Tualatin, Oregon, USA).

A dual pass fourth-order Butterworth filter was used to filter the kinematic data with a cut-off frequency of 10 Hz. Kinematic variables during pitching were calculated as those described by Escamilla *et al*. (3). Data analysis was limited to the arm cocking phase (lead foot contact to MER) and arm acceleration phase (MER to ball release) (Fig. 2). These variables included shoulder abduction angle at the instant of lead foot contact, MER angle, elbow flexion angle at MER, trunk lateral tilt at MER, shoulder abduction angle at MER, maximum angular velocity of shoulder adduction, trunk lateral tilt angle at ball release, shoulder abduction angle at ball release, and maximum angular velocities of shoulder internal rotation, upper torso rotation, pelvis rotation and elbow extension.

Participants performed a self-directed warm-up consisting of stretches and throws prior to data collection to familiarize with the testing protocol. Five fastballs that hit the strike zone placed 14.63 m away (the regulation pitching distance of Bronco league) were recorded. The fastest 3 throws were selected for data analysis.

Statistical Analysis

Paired *t*-tests were performed to determine significance between group differences in all variables investigated in this study. Additional statistical analysis regarding the relationships between throwing kinematics and ball speed was performed using the Pearson product-moment correlation coefficients. SPSS 12.0 (SPSS, Inc, Chicago, IL, USA) was used for data analysis. Statistical significance was set at $P < 0.05$.

Results

Kinematic measurements during throwing and ball speed of the two groups are shown in Table 2. An example of shoulder external rotation angle, elbow

Table 2. Throwing kinematics of youth players with and without previous medial elbow pain (MEP)

	MEP (n = 15) Mean (SD)	Healthy (n = 15) Mean (SD)	*P*-value
Lead foot contact			
Shoulder abduction (°)	99.2 (16.3)	101.7 (15.8)	0.37
Arm cocking phase			
Max. shoulder External Rotation (MER) (°)	151.6 (22.4)	142.2 (32.6)	0.17
Elbow flexion at MER (°)	91.2 (17.0)	101.3 (10.4)	0.004*
Trunk lateral tilt at MER (°)	19.1 (11.7)	13.7 (9.1)	0.16
Shoulder abduction at MER (°)	102.3 (12.6)	100.9 (13.4)	0.92
Max. upper torso rotation velocity (°/s)	1065.8 (66.8)	931.1 (104.2)	0.0002*
Max. pelvis rotation velocity (°/s)	727.7 (88.2)	622.1 (84.2)	0.001*
Arm acceleration phase			
Max. shoulder horizontal adduction velocity	561.6 (129.5)	509.8 (140.8)	0.36
Max. shoulder internal rotation velocity (°/s)	4905.3 (750.0)	4826.1 (379.7)	0.30
Max. elbow extension velocity (°/s)	1677.6 (312.8)	1756.9 (238.4)	0.20
Instant of ball release			
Trunk lateral tilt (°)	29.3 (9.9)	23.4 (9.0)	0.035*
Shoulder abduction (°)	88.3 (10.1)	90.2 (10.7)	0.26
Ball speed (m/sec)	24.8 (2.7)	23.0 (2.7)	0.006*

$^*P < 0.05$

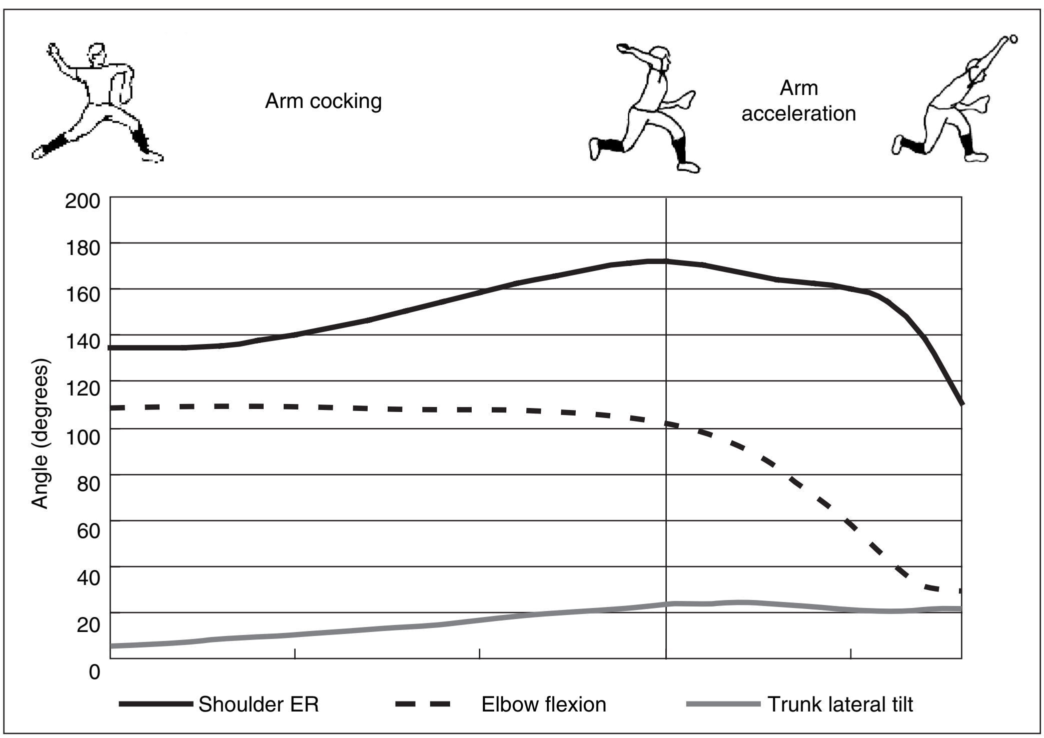

Fig. 2. Shoulder external rotation angle, elbow flexion angle and trunk lateral tilt angle from lead foot contact to ball release of a player.

flexion angle, and trunk lateral tilt angle from lead foot contact to ball release of a participant is shown in Fig. 2. Youth players with a history of MEP demonstrated significantly faster ball speed compared to the healthy group (P = 0.006). The group with a history of MEP also demonstrated significantly less elbow flexion angle at MER (P = 0.004) and had significantly greater trunk lateral tilt at ball release

Table 3. Relationships between throwing kinematics and ball speed in youth baseball players

	Correlation coefficients	*P*-value
Lead foot contact		
Shoulder abduction (°)	-0.070	0.714
Arm cocking phase		
Max. shoulder External Rotation (MER) (°)	0.458	0.011*
Elbow flexion at MER (°)	-0.637	0.0003*
Trunk lateral tilt at MER (°)	0.142	0.462
Shoulder abduction at MER (°)	0.056	0.774
Max. upper torso rotation velocity (°/s)	0.562	0.002*
Max. pelvis rotation velocity (°/s)	0.124	0.514
Arm acceleration phase		
Max. shoulder horizontal adduction velocity	0.156	0.409
Max. shoulder internal rotation velocity (°/s)	0.037	0.849
Max. elbow extension velocity (°/s)	-0.264	0.158
Instant of ball release		
Trunk lateral tilt (o)	-0.011	0.956
Shoulder abduction (°)	0.121	0.540

* $P < 0.05$

($P = 0.035$). Furthermore, the group with a history of MEP demonstrated significantly greater maximum upper torso rotation velocity ($P = 0.0002$) and maximum pelvis rotation velocity ($P = 0.001$) compared to the healthy group. All other kinematic variables were not significantly different between the two groups.

The relationships between throwing kinematics and ball speed of all players is shown in Table 3. There was a positive mild relationship between the MER angle and ball speed (r = 0.458, $P = 0.011$). When the MER angle was increased, ball speed was increased. There was a negative moderate relationship between elbow flexion angle at MER and ball speed (r = -0.637, $P = 0.0003$). As elbow flexion angle at MER was decreased, ball speed was increased. Furthermore, there was a positive moderate relationship between maximum upper torso rotation velocity and ball speed (r = 0.562, $P = 0.002$). As the maximum upper torso rotation velocity was increased, ball speed was increased.

Discussion

Age, height and weight are reported risk factors associated with little league elbow (11, 14). Lyman *et al*. found that the risk of elbow injury increased if a player was older, heavier and shorter in the age range between 9 and 12 years (11). Olsen *et al*. found that players with elbow injuries were 4 cm taller and 5 kg heavier than their counterpart players in the age range between 14 and 20 years (14). These authors thought that taller and heavier players have the ability to throw a ball harder that may lead to elbow injury after repetitive throwing (14). In addition to the potential effect of age, height and weight, we would also like to learn if there are other risk factors related to throwing kinematics that may lead to medial elbow injury in youth players. Therefore, age, height and weight were matched for the two groups in this study. The results of this study reveal that there are differences in throwing kinematics between the two groups.

The results of this study showed that players with a history of MEP demonstrated less elbow flexion angle at MER. It has not been ascertained whether or not this difference is associated with greater valgus stress as discussed in previous studies (17, 19). However, increasing elbow flexion angle during late cocking phase may detrimentally affect ball speed. Alternative strategies to accommodate these conditions may be to improve upper torso rotation velocity and perhaps physical characteristics such as strength of the shoulder and core muscles to improve ball speed.

Among studies investigating youth baseball players, elbow flexion angle at MER in the current study was more than that in the studies of Sabick *et al*. (57 ± 22°) and Keeley *et al*. (57 ± 21.8°) (8, 17). Our results, on the other hand, were close to the studies of Fleisig *et al*. (95 ± 12°) and Dun *et al*. (100.8 ± 9.3°) although they reported maximum elbow flexion angle during the arm cocking phase (2, 5). In the study of Nissen *et al*., elbow flexion angle at MER was observed to be 81 ± 11° (13). These differences among studies may be due to variable experience levels of the youth players playing baseball and may also reflect differences in coaching techniques. Thus, it is hard to suggest proper elbow flexion angle at MER for individual players.

We found that players with a history of MEP demonstrated more trunk lateral tilt angle at ball release but their shoulder abduction angle was similar, approximately 90° which was similar to that of the healthy group at that point in time. Other kinematic variables including shoulder abduction angle at foot contact, MER during the cocking phase, maximum velocity of shoulder horizontal adduction during the acceleration phase, and shoulder abduction angle at ball release were not significantly different between the two groups. These variables were considered to be risk factors for MEP (17, 19). Whether the different throwing patterns we observed contribute to increased elbow valgus stress and whether the similar throwing pattern observed in this study were due to modifications of players with a history of MEP to prevent recurrent elbow injury need further investigation.

In this study, players with a history of MEP demonstrated faster ball speed than the healthy group. Greater MER, less elbow flexion at MER and greater maximum upper torso rotation velocity were found to be associated with ball speed. Among these variables, players with a history of MEP demonstrated less elbow flexion at MER and greater maximum upper torso rotation velocity than the healthy group. Whether these players were assigned to play more often due to their better performance resulting in their overuse injury will need further exploration.

Lyman *et al*. and Olsen *et al*. have reported that elbow injuries in youth baseball players are more commonly related to overuse, such as the number of pitches per inning, games participated and the number of pitches per season, months of playing per year, the number of warm up pitches before a game, frequency of playing as a starter, pitching with higher velocity, and pitching with arm pain or fatigue (10, 14). We inquired about pitch counts over a period of time but found that accurate pitch counts for practice and play were not available; therefore, time of practice and play was substituted in Table 1. It is the limitation of this study to elucidate if medial elbow injuries in the group with a history of MEP were caused by overuse, or by their throwing pattern. Meanwhile, elbow valgus stress may be affected by both throwing kinematics and shoulder torques (12, 17, 19). Further study is needed to discuss the relationship between elbow valgus stress, throwing kinematics and shoulder torques in youth payers with a history of medial elbow problems to identify potential risk factors of elbow injury. This study is the first step to compare differences in throwing patterns between youth players with or without a history of MEP. Despite this, findings of this study can be treated as elbow injury-related factors that clinicians and coaches can attend to when taking care of youth players.

Differences in throwing kinematics were observed between youth baseball players with or without a history of MEP. Although we are not able to conclude with certainty that the findings of this study are the causes or results of elbow injury in youth baseball players, these factors can be considered while adjusting throwing posture for these players. Developing excellent athletes requires care of both their sports performance and health.

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