SB^{3}C2017
Summer Biomechanics, Bioengineering and Biotransport Conference
June 21 – 24, Tucson, AZ, USA

ELBOW AND SHOULDER JOINT TORQUES ARE CORRELATED WITH BODY MASS INDEX BUT NOT GAME PITCH COUNT IN YOUTH BASEBALL PITCHERS

Jim D. Darke (1), Eshan M. Dandekar (3), Arnel Aguinaldo (4), Scott Hazelwood (1,2), Stephen M. Klisch (1,2)

(1) Biomedical Engineering Department
California Polytechnic State University
San Luis Obispo, CA, USA

(2) Mechanical Engineering Department
California Polytechnic State University
San Luis Obispo, CA, USA

(3) Kinesiology Department
California Polytechnic State University
San Luis Obispo, CA, USA

(4) Kinesiology Department
Point Loma Nazarene University
San Diego, CA, USA

INTRODUCTION

The number of ulnar collateral ligament (UCL) reconstructive (i.e. "Tommy John") surgeries performed on youth baseball pitchers have more than doubled since 2000 [1]. Routinely pitching while fatigued is considered a leading factor associated with UCL injuries; adolescent pitchers who had elbow or shoulder surgery were 36 times more likely to have routinely pitched with arm fatigue [1]. MLB/USA Baseball Pitch Smart guidelines limit 9-10 yr. old pitchers to a maximum 75 pitches per game, a figure based on long-term studies related to injury prevention [2]. Several studies have shown that pitching kinematics (e.g. elbow flexion/extension and pronation/supination, scapulothoracic internal-external rotation) may change as adult pitchers reach muscular fatigue [3], and such kinematic changes could result in higher elbow and shoulder rotational torques that may increase injury risk [4]. Several biomechanical studies have been done on ~12 yr. old youth pitchers [5,6] but none have been reported at the 9-10 yr. old level. This study aims to predict elbow and shoulder joint torques throughout a simulated game of 75 pitches for 9-10 yr. old youth pitchers and investigate joint torque correlations with pitch count, pitch speed, and body mass index (BMI; kg/m^2).

METHODS

Experiments

Protocols were approved by Cal Poly's Human Subjects Committee to minimize risks to human subjects. We conducted motion analysis experiments on 9 experienced baseball pitchers whose ages qualified them as 9-10 year olds during the 2016 season at Cal Poly's Human Motion Biomechanics (HMB) Lab. The HMB Lab includes a motion analysis system (Motion Analysis Corp., Santa Rosa, CA, USA) with 8 digital cameras used to track retroreflective markers and characterize motion kinematics. Height and weight measurements were recorded for BMI calculations. Subjects completed a pre-game warm-up including stretching, jogging, and 20-25 non-pitching throws. Then, subjects changed into compression clothing and retroreflective markers were placed on anatomical landmarks based on the UETrak (Motion Analysis Corp.) pitching marker set [5]. Subjects pitched a simulated game of 75 fastball pitches consisting of 2 innings. The pitchers threw 38 and 37 pitches in the 1st and 2nd innings, respectively. Each inning was separated by a 15-minute break to simulate the team on offense.

Subjects pitched off of a mound in the room's center and into a net 23 feet away with a scaled strike zone (Fig. 1). Every 5 pitches the pitcher was asked to take a 30 second break to simulate a change in batters and every 10 pitches was asked if any soreness or pain was felt (all pitchers were able to throw 75 fastballs with no pain). Marker trajectory was recorded in Cortex analysis software (Motion Analysis Corp.) at 200 Hz and filtered using a 4th order Butterworth filter with a cutoff frequency of 13.4Hz. A radar gun was

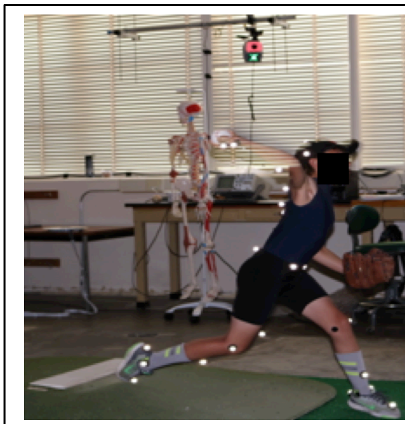

Fig. 1: Youth pitcher with retroreflective markers.

used to track ball speed, which was not disclosed in order to prevent any mechanical changes based on having that information available.

Analysis

Biomechanical outputs were processed using UETrak software. Marker and pitch speed data were collected for 3 "pitch periods" defined by pitches 1-5, 34-38, and 71-75. For each subject, 3 pitches were selected from each pitch period for analysis. Maximum values of elbow varus torque and shoulder internal rotation torque between foot contact and ball release were averaged to obtain one value at each pitch period for each subject. Also, pitch speeds were averaged to obtain one value at each pitch period.

Statistics

Repeated measures ANOVAs were performed to determine significant differences in joint torque and pitch speed between pitch periods at a significance level of 0.05. Both absolute and normalized (by body weight times height) torques were analyzed. Also, regression analyses were performed to determine significant correlations between joint torque and pitch speed or BMI at each pitch period ($p<0.05$ significant).

RESULTS

Subjects' age, height, weight, and BMI values (mean ± 1 S.D.) were 10.2 ± 0.4 yrs., 143.4 ± 8.2 cm, 35.7 ± 5.8 kg, and 17.3 ± 1.6 kg/ m^2, respectively. Absolute (Fig. 2) and normalized elbow varus and internal rotation torques did not change by pitch period. While most studies reported peak torque values occurring during the late cocking

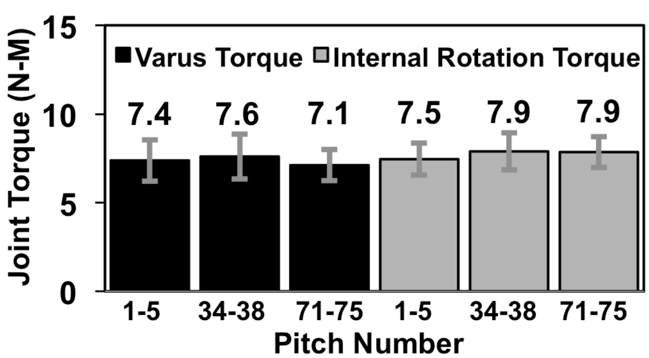

Fig. 2: Absolute elbow varus and shoulder internal rotation torques at each pitch period. Mean ±1 S.D. values shown.

phase, at or before when the shoulder is at maximum external rotation (MER) [5,6], peak values in this study continually occurred just after MER during the acceleration phase. Pitch speed did not change throughout the simulated game. Pitchers averaged 37.0±4.2 mph for pitches 1-5, 38.3±4.1 mph for pitches 34-38, and 35.8±2.2 mph for pitches 71-75. While absolute joint torques were not correlated to pitch period or speed, significant positive correlations existed between joint torques and BMI at each pitch period ($p<0.05$) (Fig. 3), with the exception of varus torque at pitches 71-75 ($p=0.07$).

DISCUSSION

While no significant changes in joint torques were found throughout the simulated game, there were some notable discoveries for an age group that has not been included in previous biomechanical studies. A pitching study with 12 yr. olds revealed that a maximum elbow varus torque of ~ 18 N-m occurs just before MER [6]. A different pitching study with 12 yr. olds revealed that a maximum shoulder internal rotation torque of ~ 33 N-m also occurs just before MER [5]. Our study revealed that for 9-10 yr. old pitchers, these peak values don't

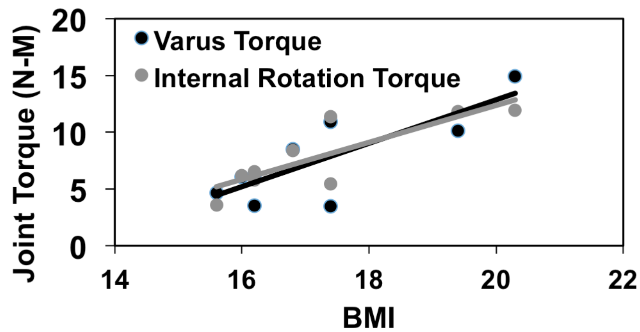

Fig. 3: Correlations between absolute joint torques (pitches 34-38) and BMI. R^2 values were 0.64 and 0.70 for elbow and shoulder torques.

occur until just after MER, right before ball release, with the exception of one pitcher whose elbow varus torques occurred just before MER for 67% of his pitches. This could be the result of less experience and development of pitching mechanics for this age group. The significantly smaller peak values are most likely the result of the smaller mass and pitch speed of 9-10 yr. olds as compared to older youths of previous studies [5,6]. Also, this study revealed positive correlations between joint torques and BMI; that finding is similar to previous results linking joint torque and body mass with older (12-16 yr. old) pitchers [9].

Limitations include the use of an adult anthropometric model in the UETrak calculations. A study on anthropometric properties in children [7] showed that 10 yr. olds have a larger mass % in their hand, lower arm, and upper arm of 50%, 3%, and 7% when compared to adults [8]. Also, the ball mass used (145 g) is less than the MLB ball mass (170 g) assumed in UETrak. Although these mass errors should only slightly over-estimate joint torques, a future study should correct these errors. Another limitation is that the size of the lab did not allow for the regulation pitching distance to be achieved.

Although elbow and shoulder torques did not change throughout the simulated game, it is important to note that muscle groups around the elbow provide dynamic valgus stability [10] and if they become fatigued, a player may be putting higher loads on their UCL. Major findings of this study include the positive correlations between joint torques and BMI, suggesting that pitch limits may be altered based on weight and height as young overweight pitchers may be at higher risk for overuse injuries. These novel findings suggest that ongoing studies should aim to produce a more comprehensive, biomechanical understanding of injury risk factors in youth baseball pitchers.

ACKNOWLEDGEMENTS

This work was supported by the W.M. Keck Foundation (JDD, EMD) and the Donald E. Bently Center (SK).

REFERENCES

[1] Fleisig, GS and Andrews JR. *Sports Health,* 4.5: 419-24, 2012.
[2] Lyman, S et al. *Med Sci Sports Exerc*, 33(11):1803-10, 2001.
[3] Escamilla, RF. *AM J Sports Med*, 23-33, 2016.
[4] Fleisig, GS et al. *Am J Sports Med,* 23.2: 233-39, 1995.
[5] Aguinaldo, AL et al. *J Appl Biomech*,23: 42-51, 2007.
[6] Sabick, MB et al. *J Shoulder and Elbow Surg,* 13.3: 349-55, 2004.
[7] Jensen, Robert K. et al. *J Biomech,* 19.5: 359-68, 1986.
[8] Winter, DA. New York: Wiley, 1990.
[9] Garner, JC et al. Ped Exer Sci, 23: 379-87, 2011.
[10] Lin, Fang et al. *J Shoulder and Elbow Surg,*16.6: 795-802, 2007.