Symbiosis

www.symbiosisonlinepublishing.com
ISSN Online : 2374-6904

Research Article Journal of Exercise, Sports & Orthopedics Open Access

Kinematic Strength Predictors at the Shoulder in Youth Baseball Pitchers

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Received: December 28 2018; Accepted: January 28,2019; Published: February 06,2019

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Abstract

The number of throwing-related arm injuries in youth baseball pitchers is increasing. Many variables correlate with increased injury rates, but the role of shoulder strength in pitching mechanics and resulting injuries is not well understood. Thus, the purpose of this study was [1] determine if shoulder strength is associated with youth pitchers' throwing kinematics, [2] investigate how Biodex can be used as a training modality for improving strength and performance while preventing throwing-related injuries. Kinematic data was collected from seventeen youth pitchers ages 9-14 years old. Isometric and isokinetic strength data was collected using the Biodex. Spearman correlations were used to investigate associations between Biodex measurements and kinematic data at the shoulder for maximum external rotation (MER), maximum internal rotation (MIR), maximal internal acceleration (MIA), and maximal internal velocity (MIV) during the pitching cycle. There was a significant correlation between MER and isokinetic external rotation strength at 60 and 180°/sec and isometric external and internal rotation at 45°. MIA was significantly correlated with isokinetic external and internal rotation strength at 60°/sec, and isometric internal rotation strength at 0, 45, and 105°. MIV was significantly correlated with isokinetic external and internal rotation strength at 60°/sec. Age, BMI, and years of experience were investigated as confounding variables; none were significant. There are significant correlations between kinematic measurements during the pitching cycle and shoulder strength. We feel training at strength parameters best correlated with each kinematic phase could improve pitching mechanics while preventing injuries in youth pitchers.

Keywords: Gait; Biodex; Vicon; Throwing; Injury

Abbreviations

MER: Maximum External Rotation; MIR: Maximum Internal Rotation; MIA: Maximum Internal Acceleration; MIV: Maximum Internal Velocity

Introduction

In the United States, the competitive nature of baseball continues to rise, with athletes playing in multiple leagues year-round [1, 2]. As a result, there has been an increase in the number of throwing-related shoulder and elbow injuries, which are more prevalent in positions with repetitive throwing [1-7]. Youth players often experience increased numbers of injuries due to joint laxity, underdeveloped musculature, and unclosed epiphyseal plates [8-11]. In a season, 18-22% of these athletes will have elbow pain and 26.5-29% will experience shoulder pain [12]. There has been significant research on throwing-related injuries with regards to pitch count and poor throwing mechanics, with both being associated with increased rates of injury, but less is known about how arm strength correlates with injuries [7, 13-15]. The purpose of this study was to determine if shoulder strength (relative) relates to a pitcher's throwing kinematics, possibly contributing to the injuries seen in youth baseball pitchers and to investigate how Biodex measurements could be used as a training modality for improving performance and preventing throwing related injuries.

Methods

Subject Recruitment

IRB approval was obtained prior to recruiting participants. Written assent and consent to participate were obtained from the subjects and subjects' legal guardian before data was collected. Subjects without a history of arm pain or surgery on their throwing arm were eligible for inclusion in the study. Fifteen participants were right-handed, and two were left-handed. Each subject was given a survey about his medical history, pitching history, and history of injury or pain of his throwing arm.

Physical Examination

A physical therapist performed a physical examination on each participant prior to data collection. Upper and lower extremity anthropometric measurements, as well as full body measurements were made for the identification of joint centers and for computer model input. These measurements included the trunk, lower extremity, arm and forearm lengths, inter-ASIS distance, knee and ankle joint diameters, hand size and thickness, wrist and elbow diameter, and shoulder offset. Passive shoulder rotation and Beighton Hypermobility Scores were also recorded to help quantify joint laxity.

Testing Protocol

Prior to data collection, pitchers spent a few minutes stretching and throwing practice trials until they felt comfortable with the testing protocols. All pitchers threw with an overhand pitching motion. They pitched from a custom-made, portable pitching mound into a net located 12 feet away from the pitching rubber with a strike zone taped onto the net to allow for better accuracy. Afterwards, the pitchers threw 10 trials, and 3 properly performed trials were chosen and averaged for data analysis.

Motion Data Collection

Pitching motion was captured using a full body Plug-in-Gait model through Vicon Motion System (Plug-In Gait Marker Set, Vicon Motion System, Lake Forest, CA) integrated with the Vicon Nexus Workstation (Vicon Motion System, Oxford, UK). This model measured joint kinematics similar to the methods used from the model from Davis et al [16]. 12 synchronized circumferentially placed cameras at a frequency of 250 Hz were used to locate 39 reflective markers measuring 14 mm in diameter. Markers were placed on anatomical landmarks, including the head band (1-4), C7 (5), T10 (8), right scapular (9), right clavicle (6), sternum (7) bilateral shoulder (10,17), bilateral humerus (11,18), bilateral elbow (12,19), bilateral forearm (13,20), bilateral hands (14-16, 21-23), bilateral ASIS (26,27), bilateral PSIS (24,25), bilateral thigh (28,34), bilateral knees (29,35), bilateral tibia (30,36), bilateral ankle and foot (31-33, 37-39) (Figure 1). Markers were secured using double sided tape. After marker attachment, a static calibration trial was performed to calibrate marker placement with the anthropometric data input into the system, and to calculate the joint centers and alignment of the axis.

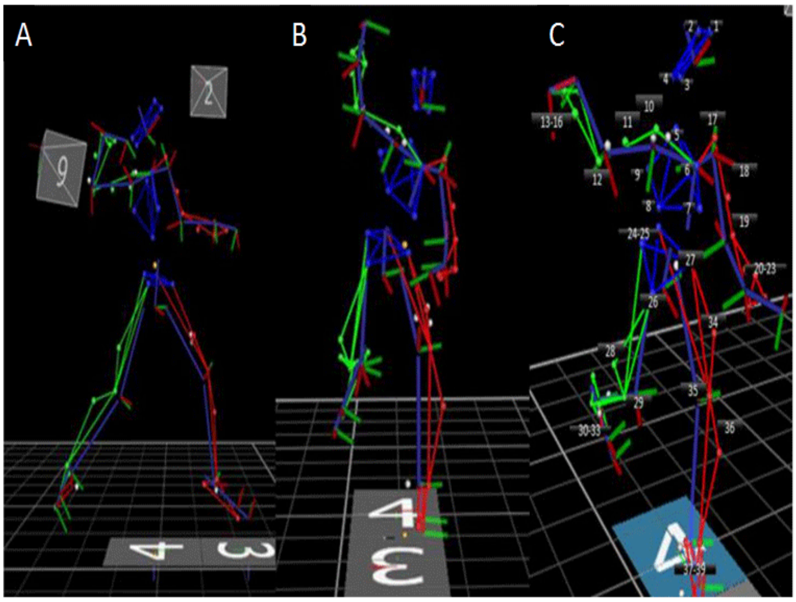

Figure 1: (A, B)A Model With Marker Placement And (C) Marker Placement Numbered

The orientations for the Vicon system were calculated by the relative orientation of proximal and distal segments, while Euler's equation of motion was used to calculate upper extremity angle measurements in coronal, sagittal, and transverse planes. The kinematic measurements made during the pitching cycle included motion of the wrist, forearm, elbow, and the glenohumeral joints. We used the standard angle and orientation methods to define our measurements, which are further defined by the International Society of Biomechanics [17]. The wrist angles were measured between the hand and the forearm. Forearm motion was measured as the supination/pronation of the radius and ulna. Elbow angle was measured between the humerus and forearm. Finally, the glenohumeral joint angle was measured between the scapula and the humerus.

Workstation (Vicon Motion Systems) was used for data processing, which includes marker labeling, gap filling, stage labeling, and data filtering. The data signals from the marker trajectories during motion used a fourth-order Butterworth low-pass filter in order to filter low frequencies from the data with a 15 Hz cut off frequency. Pitching data was then interpolated to the percent of the pitching cycle with a customized Matlab code.

Three phases of the pitching cycle were analyzed, including late cocking, acceleration, and deceleration. Late cocking phase was defined as stride foot contact to MER. Acceleration phase was defined MER until ball release. Ball release was observed when the wrist markers passed the elbow markers for four frames [16]. Finally, deceleration was defined as ball release until MIR [18]. These phases were analyzed because maximum external glenohumeral rotation (MER), maximum internal glenohumeral rotation (MIR), maximal internal acceleration (MIA), and maximal internal velocity (MIV) are produced during these phases. In addition, the late cocking and acceleration phases are when the shoulder and elbow forces are greatest and are the phases when the pitcher is most prone to injuries [18].

Active Shoulder Strength

Strength was assessed using both isokinetic and isometric testing. The Biodex was set to 50° in the scapular plane for optimal scapular angle. Isokinetic testing consisted of two tests: 60°/sec for five repetitions and 180°/sec for 10 repetitions. Isometric testing was conducted at 0°, 45°, and 105° for three repetitions for each angle. For the purpose of Biodex testing, 0° was defined when the participant was internally rotated to where his hand touched his abdomen. The subjects then externally rotated to 45 and 105°. Three reps at each angle were conducted

Statistical Analysis

Spearman Correlations were used to investigate associations between Biodex measurements of strength and kinematic data recorded at the shoulder for MER, MIR, MIA, and MIV during the pitching cycle. Collinearity between potentially predictive variables was investigated. Stepwise selection was used to find the best-fit linear model for each of the kinematic outcomes. All significant Biodex predictors were considered for inclusion into the models. Due to small sample size and collinearity, only one predictor remained in each model. Potential confounders of interest (BMI, experience, age) were also considered for inclusion in the model, but none remained. Statistical analysis was done using SAS (SAS Version 9.2, Cary, NC).

Results

Data was collected and analyzed for seventeen healthy youth male pitchers ages 9-14 years old (mean age, 11.4 years; height, 154.9 cm; mass, 44.6 kg) There was a significant correlation between MER during the late cocking phase and isokinetic external rotation strength at both 60 and 180°/sec as well as isometric external and internal rotation strength at 45°. MIA was significantly correlated with isokinetic external and internal rotation strength at 60°/sec, as well as isometric internal rotation strength at 0, 45, and 105°. Finally, MIV was significantly correlated with isokinetic external and internal rotation strength at 60°/sec. When age, BMI, and years of experience were investigated as confounding variables, none were found to be significant. There were many significant collinearities found among the significant strength variables. When the collinearities were accounted for in the statistical model, only isokinetic external rotation strength at 180°/sec remained significantly associated with MER. For MIA, only isometric internal rotation strength at 105° remained significant. Finally, for MIV, only isokinetic internal rotation strength at 60°/sec remained significant (Table 1).

Table 1: Significant correlations between shoulder muscle strength and kinematics (r, P<0.05)

Biodex	Maximum External Rotation	Maximum Internal Acceleration	Max Internal Velocity
Isokinetic external rotation 60°/sec	r = 0.508 p-value = 0.037	r = 0.588 p-value = 0.013	r = 0.510 p-value = 0.036
Isokinetic internal rotation 60°/sec	---	r = 0.576 p-value = 0.016	r = 0.538 p-value = 0.026
Isokinetic external rotation 180°/sec	r = 0.618 p-value = 0.008	---	---
Isometric internal rotation 0°	---	r = 0.628 p-value = 0.007	---
Isometric external rotation 45°	r = 0.519 p-value = 0.033	---	---
Isometric internal rotation 45°	r = 0.551 p-value = 0.022	r = 0.610 p-value = 0.009	---
Isometric internal rotation 105°	---	r = 0.698 p-value = 0.002	---

Discussion

When it comes to using the Biodex as a training modality for improving performance and preventing throwing-related injuries, beyond simple strength assessment, there is a paucity of data. Studies have shown that isokinetic training is effective because it loads the musculature throughout the range of motion helping develop motor learning, decrease compressive joint forces, and effectively increase strength [19,20]. As in all rehabilitation and performance training programs, isometric strengthening also plays an essential role and can also effectively strengthen the muscles of the shoulder [21]. We suggest that the Biodex could be an effective way for isokinetic and isometric training to increase performance and prevent shoulder throwing related injuries. Our findings help layout the initial parameters for an effective rehabilitation and training program using the Biodex.

In our study isokinetic external rotation strength at 60 and 180°/sec was significantly correlated with MER. Previous studies show that the external rotators of the shoulder are essential in producing MER and that MER is significantly correlated with ball velocity [22,23]. It has also been found that the external rotators are essential in deceleration of the arm in order to prevent anterior joint impingement and labral tears that are caused by unopposed torque produced by the internal rotator muscles at the shoulder [24]. Thus, we suggest an effective way to obtain maximal performance and prevent injury in youth baseball pitchers would be to train at these isokinetic parameters.

We found that MIA and MIV at the shoulder was significantly correlated with isokinetic internal rotation and isokinetic external rotation strength at 60 °/sec. These findings are consistent with Hermassia et al. [25] who previously showed that training at heavier resistance increases peak power, velocity and dynamic strength compared to training at lighter loads. We suggest that high resistance training would improve strength and velocity and help pitchers reach maximal performance.

Our study also revealed that isometric strength has important implications for both MER and MIA. In the past, isometric training was thought to be less beneficial because it does not mimic the dynamic motion of pitching. However, it has been found that isometric contraction at the shoulder, in both external and internal rotation, mimics isokinetic contraction in that torque is produced by the rotator cuff, which is responsible for supporting the pitching motion [21]. Our findings show a significant correlation between MER and isometric external and internal rotation strength at 45° and between MIA and isometric internal rotation strength at 0, 45, and 105°. Because of these findings we suggest not only training at isokinetic parameters but also isometric in order to reach peak performance and prevent throwing-related injuries.

Finally, this study has several limitations. The first is that we did not record ball velocity, with only MIV and MIA recorded at the shoulder. We assumed that MIV and MIA are correlated to ball velocity as was found by Hermassi et al. [25]. The second limitation is the small sample size of our study. With only seventeen participants, we were not able to achieve a high level of power. In the future this study should be repeated with a larger number of participants to corroborate the findings.

Conclusion

This study provides useful data for youth baseball pitchers and coaches in how to achieve optimal performance and prevent serious injury through use of the Biodex. We suggest isokinetic training at 60 and 180°/sec to improve performance and help prevent injury in youth pitchers. We also recommend that isometric training not be overlooked as it has been in the past because it too can improve performance and injury prevention.

Acknowledgement

Statement of Grant Support

Departmental support provided to medical students for conducting research but no external funding nor grant support was acquired for this study.

References

1. Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. Am J Sports Med. 2002;30(4):463-468. Doi: 10.1177/03635465020300040201
2. Tisano BK, Estes AR. Overuse Injuries of the Pediatric and Adolescent Throwing Athlete. Med Sci Sports Exerc. 2016;48(10):1898-1905. Doi: 10.1249/MSS.0000000000000998
3. Cain EL Jr, Dugas JR, Wolf RS, Andrews JR. Elbow injuries in throwing athletes: a current concepts review. Am J Sports Med. 2003;31(4):621-635. Doi: 10.1177/03635465030310042601
4. Fleisig GS, Andrews JR. Prevention of elbow injuries in youth baseball pitchers. Sports Health. 2012;4(5):419-424. Doi: 10.1177/1941738112454828
5. Fleisig GS, Andrews JR, Cutter GR, et al. Risk of serious injury for young baseball pitchers: a 10-year prospective study. Am J Sports Med. 2011;39(2):253-257. Doi: 10.1177/0363546510384224
6. Keeley DW, Hackett T, Keirns M, Sabick MB, Torry MR. A biomechanical analysis of youth pitching mechanics. J Pediatr Orthop. 2008;28(4):452-459. Doi: 10.1097/BPO.0b013e31816d7258
7. Lyman S, Fleisig GS, Waterbor JW, et al. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. Med Sci Sports Exerc. 2001;33(11):1803-1810.
8. Leonard J, Hutchinson MR. Shoulder injuries in skeletally immature throwers: review and current thoughts. Br J Sports Med. 2010;44(5):306-310. Doi: 10.1136/bjsm.2009.062588
9. Mersmann F, Bohm S, Schroll A, Boeth H, Duda G, Arampatzis A. Evidence of imbalanced adaptation between muscle and tendon in adolescent athletes. Scand J Med Sci Sports. 2014;24(4):e283-289. Doi: 10.1111/sms.12166
10. Sabick MB, Kim YK, Torry MR, Keirns MA, Hawkins RJ. Biomechanics of the shoulder in youth baseball pitchers: implications for the development of proximal humeral epiphysiolysis and humeral retrotorsion. Am J Sports Med. 2005;33(11):1716-1722. Doi: 10.1177/0363546505275347
11. Walton J, Paxinos A, Tzannes A, Callanan M, Hayes K, Murrell GA. The unstable shoulder in the adolescent athlete. Am J Sports Med. 2002;30(5):758-767. Doi: 10.1177/03635465020300052401
12. Lyman S, Fleisig GS. Baseball injuries. Med Sport Sci. 2005;49:9-30. Doi: 10.1159/000085340
13. Davis JT, Limpisvasti O, Fluhme D, Mohr KJ, Yocum LA, Elattrache NS, et al. The effect of pitching biomechanics on the upper extremity in youth and adolescent baseball pitchers. Am J Sports Med. 2009;37(8):1484-1491. Doi: 10.1177/0363546509340226
14. Dillman CJ, Fleisig GS, Andrews JR. Biomechanics of pitching with emphasis upon shoulder kinematics. J Orthop Sports Phys Ther. 1993;18(2):402-408. Doi: 10.2519/jospt.1993.18.2.402
15. Nissen CW, Westwell M, Ounpuu S, et al. Adolescent baseball pitching technique: a detailed three-dimensional biomechanical analysis. Med Sci Sports Exerc. 2007;39(8):1347-1357. Doi: 10.1249/mss.0b013e318064c88e
16. Davis III RB, Õunpuu S, Tyburski D, Gage JR. A gait analysis data collection and reduction technique. Human Movement Science. 1991;10(5):575-587.
17. Wu G, Siegler S, Allard P, Kirtley C, Leardini A, Rosenbaum D, et al. ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion--part I: ankle, hip, and spine. International Society of Biomechanics. J Biomech. 2002;35(4):543-548.

18. Chen FS, Diaz VA, Loebenberg M, Rosen JE. Shoulder and elbow injuries in the skeletally immature athlete. J Am Acad Orthop Surg. 2005;13(3):172-185.
19. Ellenbecker TS, Davies GJ. The Application of Isokinetics in Testing and Rehabilitation of the Shoulder Complex. J Athl Train. 2000;35(3):338-350.
20. Malliou P, Giannakopoulos K, Beneka A, Gioftsidou A, Godolias G. Effective ways of restoring muscular imbalances of the rotator cuff muscle group: a comparative study of various training methods. Br J Sports Med. 2004;38:766-772.
21. Boettcher CE, Cathers I, Ginn KA. The role of shoulder muscles is task specific. J Sci Med Sport. 2010;13:651-656.
22. Fortenbaugh D, Fleisig GS, Andrews JR. Baseball Pitching Biomechanics in Relation to Injury Risk and Performance. Sports Health. 2009;1:314-320.
23. Ouellette H, Labis J, Bredella M, Palmer WE, Sheah K, Torriani M. Spectrum of shoulder injuries in the baseball pitcher. Skeletal Radiol. 2008;37:491-498.
24. Greiwe RM, Ahmad CS. Management of the throwing shoulder: cuff, labrum and internal impingement. Orthop Clin North Am. 2010;41:309-323.
25. Hermassi S, Chelly MS, Fathloun M, Shephard RJ. The effect of heavy- vs. moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. J Strength Cond Res. 2010;24:2408-2418.