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Original Article

Throwing kinematics and elbow varus torque relative to ball size in junior baseball players

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Abstract. [Purpose] The purpose of this study was to investigate changes in the shoulder and elbow joint angles, upper limb angular velocities, and elbow varus torque when throwing balls of two different sizes. [Participants and Methods] The pitching motion of 26 junior baseball players was analyzed using an optical motion capture system. The balls used were a standard baseball and a small ball of equal weight. Shoulder external rotation/abduction and elbow flexion were measured. The maximum values of shoulder joint internal rotation, elbow joint extension, wrist flexion angular velocity, and elbow joint varus torque were also evaluated. The ball velocity was determined as an index of pitching performance. [Results] The shoulder external rotation and elbow flexion angles were higher when pitching with a small ball. The joint angular velocity was also significantly higher when pitching with a small ball for all items examined. The ball speed was significantly higher with the small ball. The maximum varus torque of the elbow joint divided by the ball velocity was significantly lower for the small ball. [Conclusion] For a junior baseball player with a small hand length, using a small ball enables pitching with low stress on the elbow joint.
Key words: Junior baseball, Elbow injuries, Ball size

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INTRODUCTION

Baseball players often acquire injuries in the upper limbs on the dominant hand side, and medial elbow joint injuries are common in junior baseball players[1, 2)]. Medial elbow joint injury is caused by forced valgus stress at the elbow joint during the acceleration phase of the pitching motion[3, 4)]. The number of pitches, shoulder range of motion, muscle strength, and technical factors have been reported as the causes of elbow joint injuries in junior baseball players[5–7)]. According to the results of kinetic research, a load of 64 Nm for professional baseball players and 28 Nm for junior baseball players is applied to the elbow when pitching[8)]. Three-dimensional motion analysis equipment is often used to investigate the biomechanics of pitching, but there are few studies targeting junior baseball players. In addition, the same ball has been used in adults and juniors, and so far, changes in pitching movements due to ball weight differences have been reported[9–11)]. However, because the ratio of the ball size to hand size is different, the effect of the diameter of the ball on the pitch should also be considered. In this study, two types of balls with the same weight but different diameters were used and the pitching motion and elbow joint torque were analyzed under these two conditions. The hypothesis of this study was that the junior baseball player could improve the mobility of the shoulder and elbow joints by using a small ball, which could reduce the torque applied to the elbow joints. The purpose of this study was to clarify whether changes in ball size help improve the performance of junior baseball players and prevent elbow joint injuries.

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PARTICIPANTS AND METHODS

There were 26 junior baseball players (25 males and 1 female) who participated in the study. The participants had an average age of 9.7 ± 1.0 years, height of 136.5 ± 7.4 cm, weight of 33.2 ± 7.4 kg, hand length of 14.6 ± 0.9 cm, and baseball experience of 38.4 ± 19.7 months (Table 1). The participants and their parents were informed in advance of the purpose of this study, in accordance with the Declaration of Helsinki. Prior to the experiment, verbal and written informed consent was obtained from all participants. The resulting data were securely stored under an encrypted name to protect the participants' privacy. Ethical approval for this study was obtained from the ethics review committee of Teikyo Heisei University (approval code: R01-093-01). Throwing motions were measured using an optical motion capture system (VICON Motion Systems, Oxford Metrics Inc., plug-in-pitch models, Oxford, UK) with 10 infrared cameras. The sampling frequency was 500 Hz, and the data were processed using a Butterworth low-pass filter. The balls used were a standard hardball (diameter 74 mm, 141 g: normal ball) and a small ball (diameter 65 mm, 141 g: small ball), both of which weighed the same. The pitching surface was a flat floor, and the target was a net installed 5 m away from the pivoting foot. The target point was positioned at the participant's eye-level. Infrared reflection markers were attached to a total of 16 points according to the report of Wu et al.[12] (7th cervical spine, 8th thoracic spine, sternum notch, xiphoid process, anterior acromion, posterior acromion, acromion angle, medial sternal superior condyle, radial pedicle, lateral sternal superior condyle, ulnar stalk, distal 3rd metacarpal, distal 3rd finger, and 3 points of the ball). Before the evaluation, the participants jogged, stretched, and then practiced throwing around 20 pitches until they got used to each ball. The analysis of the pitching motion conformed to the method described by Fleisig et al[8]. The pitching attempts involved five standard and small balls each, and the participants were instructed to throw at maximum speed. The items measured were joint angle (shoulder external rotation, shoulder abduction, elbow flexion), joint angle velocity (shoulder internal rotation, elbow extension, and wrist flexion), and elbow varus torque. The ball speed was measured as an index of performance. The average joint angle in the maximum external rotation phase (MER) during the pitching of five balls was measured. The maximum values for shoulder joint internal rotation, elbow joint extension, wrist flexion angle velocity, and elbow joint varus torque were applied from the MER to the release phase. For the ball velocity, the maximum velocity at the center of the three markers attached to the ball was calculated, and the maximum varus torque of the elbow joint was divided by the ball speed. Regarding the analysis method, the Euler angles were obtained using the right-hand Cartesian coordinate system for the shoulder and elbow joint angles. The joint angular velocity was calculated as the shoulder joint angular velocity for the upper arm with respect to the thorax, elbow joint angular velocity for the forearm with respect to the upper arm, and the wrist joint angular velocity with respect to the forearm. The varus torque of the elbow joint was calculated by solving the equation of motion from the distal side according to the method of Andrews[13]. Statistical software R for Windows (version 2.13.0) was used for statistical analysis, and each index was compared using a paired t-test with the significance level set to 5%.

RESULTS

The external rotation angle of the shoulder joint in MER was significantly higher with the small ball compared to the standard ball with 83.0 ± 9.2° and 77.3 ± 8.6°, respectively. Shoulder abduction angles were not significantly different between the two groups. The elbow joint angle was also significantly larger for the small ball (94.0 ± 15.3°) than for the normal ball (88.5 ± 16.8°). Regarding the joint angular velocity, shoulder internal rotation with the standard and small balls were 1,563.2 ± 318.8°/s and 1,776.3 ± 337.3°/s, respectively. Moreover, the values for wrist flexion were 696.4 ± 241.1°/s with the standard ball and 920.2 ± 321.1°/s with the small ball. These results showed significantly higher angular velocities with the small ball. Additionally, ball speed was also significantly increased with the small ball compared to the normal ball, with 17.1 ± 2.2 m/s and 15.2 ± 1.8 m/s, respectively. The maximum varus torque of the elbow joint divided by the ball velocity was significantly lower for the small ball (Table 2).

Table 1. Characteristics of the study

Characteristic	N=26
Age (years)	9.7 ± 1.0
Gender (n)	Male: 25 Female: 1
Height (cm)	136.5 ± 7.4
Body weight (kg)	33.2 ± 7.4
Hand length (cm)	14.6 ± 0.9
Baseball experience (months)	38.4 ± 19.7

Mean ± Standard Deviation.

Table 2. Comparison of data with two types of balls

	Normal (φ74 mm 141 g)	Small (φ65 mm 141 g)	
Joint angle at MER (deg)			
Shoulder external rotation	77.3 ± 8.6	83.0 ± 9.2	**
Shoulder abduction	97.4 ± 12.5	97.3 ± 13.3	
Elbow flexion	88.5 ± 16.8	94.0 ± 15.3	*
Maximum angular velocity (deg/s)			
Shoulder internal rotation	1,769.8 ± 504.5	2,181.1 ± 669.3	**
Elbow extension	1,563.2 ± 318.8	1,776.3 ± 337.3	**
Wrist flexion	696.4 ± 241.1	920.2 ± 321.1	**
Ball speed (m/s)	15.2 ± 1.8	17.1 ± 2.2	**
Maximum elbow varus torque			
(Nm)	15.4 ± 5.7	15.8 ± 5.8	
(Nm / ball speed)	1.0 ± 0.3	0.9 ± 0.2	*

*$p<0.05$, **$p<0.01$.
φ: diameter.
Mean ± Standard Deviation.
MER: maximum external rotation phase.

DISCUSSION

The results of this study showed that, during the pitching motion of junior baseball players, there were differences in joint angle, joint angular velocity, elbow varus torque, and ball speed when balls of different sizes but equal weight were used. Of all the phases of the throwing motion, the maximum valgus stress is applied to the elbow joint during the acceleration period from the MER to the release phase[14, 15], and the valgus stress of the elbow joint is buffered with respect to the throwing direction. It is thought that there is extension of the thoracic spine, posterior tilt of the scapula, external rotation of the shoulder joint, and flexion of the elbow joint during this phase. Aguinaldo[16] reported that an increase in the external rotation angle of the shoulder joint and the flexion angle of the elbow joint at the MER is associated with a decrease in the valgus torque of the elbow joint. Fleisig et al.[8] and Sabick et al.[14] reported that the elbow joint angle of junior baseball players in MER was 57° to 95°, respectively. The results of this study showed that the shoulder joint external rotation angle and elbow joint flexion angle were significantly higher with the small ball; therefore, it would be better for junior baseball players to use a ball with a smaller diameter than one of the same size as an adult. This suggests that the risk of injury can be reduced. The maximum angular velocity of shoulder joint internal rotation, elbow joint extension, and wrist joint flexion during the acceleration period of throwing were all significantly higher with the small ball than with the normal ball. During the acceleration period, movements in the upper limbs occur in the order of internal rotation of the shoulder joint, extension of the elbow joint, and flexion of the wrist joint. According to the joint angle data, the increase in the elbow flexion angle with the small ball reduced the radius of gyration of the upper arm; this probably increased the internal rotation speed of the shoulder joint, and consequently, the elbow extension and wrist flexion speeds, as well. Additionally, for junior baseball players, a large ball may suppress the activity of intrinsic muscles of the hand, such as the lumbricals, which are essential in gripping the ball; furthermore, it may increase the activity of muscles that may hinder the movement of the wrist joint, such as the flexor digitorum superficialis and flexor digitorum profundus. In this study, the maximum varus torque of the elbow joint divided by the ball speed was low, even though the angular velocities of shoulder internal rotation and elbow joint extension as well as the ball velocity increased with a small ball. It has been reported that elbow joint torque increases as the pitching speed increases[17]; however, in this study, the elbow joint turned toward the throwing direction during the acceleration period due to the improvement of the shoulder joint external rotation angle with the small ball. This was probably because the valgus stress was buffered. For junior baseball players with a hand length of 15 cm or less, using a ball smaller than the commonly used hardball may improve pitching efficiency and reduce the risk of medial elbow joint injury. The limitation of this study was that, despite the use of different ball sizes, detailed analysis of the fingers and the relationship between the fingers and the ball during the release period could not be done.

Funding and Conflict of interest
There are no conflicts of interest.

REFERENCES

1) Lyman S, Fleisig GS, Andrews JR, et al.: 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: 463–468. [Medline] [CrossRef]
2) Adams JE: Injury to the throwing arm. A study of traumatic changes in the elbow joints of boy baseball players. Calif Med, 1965, 102: 127–132. [Medline]
3) Fleisig GS, Andrews JR, Dillman CJ, et al.: Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med, 1995, 23: 233–239. [Medline] [CrossRef]
4) Fleisig GS, Andrews JR: Prevention of elbow injuries in youth baseball pitchers. Sports Health, 2012, 4: 419–424. [Medline] [CrossRef]
5) 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: 1803–1810. [Medline] [CrossRef]
6) Gugenheim JJ Jr, Stanley RF, Woods GW, et al.: Little league survey: the Houston study. Am J Sports Med, 1976, 4: 189–200. [Medline] [CrossRef]
7) Fleisig G, Chu Y, Weber A, et al.: Variability in baseball pitching biomechanics among various levels of competition. Sports Biomech, 2009, 8: 10–21. [Medline] [CrossRef]
8) Fleisig GS, Barrentine SW, Zheng N, et al.: Kinematic and kinetic comparison of baseball pitching among various levels of development. J Biomech, 1999, 32: 1371–1375. [Medline] [CrossRef]
9) Reinold MM, Macrina LC, Fleisig GS, et al.: Effect of a 6-week weighted baseball throwing program on pitch velocity, pitching arm biomechanics, passive range of motion, and injury rates. Sports Health, 2018, 10: 327–333. [Medline] [CrossRef]
10) Yang WW, Liu YC, Lu LC, et al.: Performance enhancement among adolescent players after 10 weeks of pitching training with appropriate baseball weights. J Strength Cond Res, 2013, 27: 3245–3251. [Medline] [CrossRef]
11) Fleisig GS, Phillips R, Shatley A, et al.: Kinematics and kinetics of youth baseball pitching with standard and lightweight balls. Sports Eng, 2006, 9: 155–163. [CrossRef]
12) Wu G, van der Helm FC, Veeger HE, et al. International Society of Biomechanics: ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—part II: shoulder, elbow, wrist and hand. J Biomech, 2005, 38: 981–992. [Medline] [CrossRef]
13) Andrews JG: Biomechanical analysis of human motion. In: Kinesiology, IV, American Association for Health, Physical Education and Recreation, 1974, pp 32–42.
14) Sabick MB, Torry MR, Lawton RL, et al.: Valgus torque in youth baseball pitchers: a biomechanical study. J Shoulder Elbow Surg, 2004, 13: 349–355. [Medline] [CrossRef]
15) Werner SL, Fleisig GS, Dillman CJ, et al.: Biomechanics of the elbow during baseball pitching. J Orthop Sports Phys Ther, 1993, 17: 274–278. [Medline] [CrossRef]
16) Aguinaldo AL, Chambers H: Correlation of throwing mechanics with elbow valgus load in adult baseball pitchers. Am J Sports Med, 2009, 37: 2043–2048. [Medline] [CrossRef]
17) Slowik JS, Aune KT, Diffendaffer AZ, et al.: Fastball velocity and elbow—varus torque in professional baseball pitchers. J Athl Train, 2019, 54: 296–301. [Medline] [CrossRef]