Relationship between upper limb injuries and hip range of motion and strength in high school baseball pitchers

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Abstract
We aimed to examine the relationship between hip range of motion (ROM) and abduction strength and throwing-related shoulder/elbow injuries in high school baseball pitchers. The study included 135 baseball pitchers. We asked them to fill out a questionnaire at the checkups, that included the dominant arm and the years of baseball experience. To avoid a confirmation bias, the examiners were blinded to the participants’ hand dominance. All players underwent physical function measurements, such as height, weight, shoulder and hip strength, and shoulder and hip ROM. Shoulder and elbow injury was defined as shoulder and elbow pain that the patient had been aware of in the past 3 years. The results of injured and non-injured pitchers were compared. Eighty-five pitchers had experienced a shoulder or elbow injury in the past 3 years. The shoulder ROM and strength in the injured and non-injured groups did not differ to a statistically significant extent. The hip external rotation ROM on the dominant side, the hip abduction strength on the non-dominant side, and the hip abduction strength on the dominant side were significantly lower in the injured group than in the non-injured group. The results may contribute to reducing the incidence of these injuries.

Keywords
baseball, elbow and shoulder, high school, sports

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Introduction
Shoulder and elbow injuries in baseball players represent a major problem. Previous studies have reported that a high pitch velocity, shoulder external rotation insufficiency, and prone external rotation strength were risk factors for shoulder and elbow injuries. As previously described, the evidence to support risk factors, such as the upper limb range of motion (ROM) and upper limb strength measured in the preseason, has been relatively sufficient. However, the throwing motion can be understood as a kinetic chain that passes energy from the lower extremity, via the pelvis and trunk, and subsequently releases it through the upper extremity. The lower extremity generates a tremendous amount of energy during an overhead throw, which is transferred, via the kinetic chain, superiorly through the core, shoulder, elbow, and eventually the hand before ball release. As such, the strength and

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direction of the leg drive may be critical to proper performance during the throwing motion. Although the numbers of studies investigating dysfunction of the trunk and lower extremities as risk factors for shoulder and elbow injury have been relatively small in number in comparison to those investigating risk factors related to the upper extremities, significant associations have been demonstrated between throwing-related shoulder and elbow injuries and trunk and lower limb dysfunction, abnormal foot posture and hip ROM deficits in elementary school baseball players. However, evidence related to lower limb risk factors has been limited. Furthermore, no studies have related the relationship between hip muscle strength and shoulder and elbow injury in high school baseball players, or specifically high school baseball pitchers. Thus, the purpose of this study was to investigate the relationship between hip ROM and the strength and incidence of shoulder and elbow injuries with a focus on high school baseball pitchers.

Materials and methods

Participants

The present study enrolled 135 male high school baseball pitchers (mean age 16.5 ± 0.7, 15–17 years) who participated in medical checkups held by our hospital in February 2015. This medical checkup is an annual event performed since 2003 by our hospital for the early detection and treatment of various injuries. Before enrolment in the study, all pitchers and their parents provided their written informed consent. The study was approved by the Institutional Review Board of Gunma University Hospital on January 28, 2015 (Identification number 1003 2015-01-28). All methods were carried out in accordance with relevant guidelines and regulations. The eligibility criteria included being able to collect a questionnaire to be filled in at the time of participation in the medical checkups and the provision of informed consent by both the player and their parents. All players were eligible for inclusion in the present study.

Medical checkups

We asked the players to fill out a questionnaire at the checkups; the questionnaire included the dominant arm and years of baseball experience. All pitchers underwent measurements of their physical function, such as height, weight, shoulder strength and ROM, and hip ROM and strength. The questionnaire and physical examination were conducted by different doctors. To avoid a confirmation bias, the examiners were blinded to the participants’ hand dominance while performing the physical examination.

Shoulder ROM

The method of ROM measurement by a digital protractor was established in a previous study. According to method of previous studies, certified orthopedic surgeons measured the bilateral passive shoulder ROM of horizontal adduction, and 90° abducted external and internal rotation using a digital protractor (iGaging, CA, USA). The ROMs were measured in the supine position. When measuring passive horizontal adduction, the examiner stabilized the axillary border of the scapula and another certified orthopedic surgeon placed a digital protractor on the humerus. When measuring the passive external rotation and internal rotation, the examiner stabilized the scapula by applying a posterior force to the coracoid process and another certified orthopedic surgeon placed a digital protractor on the forearm.

Shoulder strength

The intra-rater validity and reliability of shoulder strength measurements by hand-held dynamometers have been established in a previous study. According to the methods of previous studies, certified orthopedic surgeons measured the seated supraspinatus, prone internal and prone external rotation strength in both shoulders using a Power-Track II Commander hand-held dynamometer (J-Tech Medical, Salt Lake City, UT, USA). When measuring the seated supraspinatus strength, the participant was asked to sit on an examination table with his back against the wall and to abduct the humerus to 90° in the coronal plane and then horizontally adduct to 45° with the forearm neutral. The dynamometer was placed 5 cm proximal to the proximal wrist extension crease as the pitcher raised the arm perpendicular to the floor with maximum effort. Internal and external rotation were measured in the prone position with abduction of the humerus to 90° and 90° of elbow flexion. Then, the examiner stabilized the humerus and the arm was set in a neutral position. The participant was asked to rotate their arm externally or internally with maximum power against the dynamometer. When measuring internal rotation, the dynamometer was placed on the volar side of the forearm, 5-cm proximal to the proximal wrist flexion crease. When measuring external rotation, the dynamometer was placed on the dorsal side of the forearm, 5-cm proximal to the proximal wrist extension crease.

Hip ROM

The ROMs were assessed using a reliable and previously validated technique. The ROMs were measured in the prone position. All hip ROM data were collected by two orthopedic surgeons using a digital protractor (iGaging, CA, USA). With one of the measurers holding the athlete’s pelvis stationary, the other measurer bent the knee on the measurement side 90° and rotated the hip joint internally.
and externally with 0° of flexion. The other leg was kept straight on the ground. The angles between the perpendicular plane and the lower leg were defined as internal rotation and external rotation, respectively.

**Hip strength**
A previous study reported that good peak hip abduction strength may contribute to proper throwing mechanics and a reduced risk of injury. thus, we considered this item. According to previous studies, muscle strength was measured in the lateral position on the non-tested side. The non-tested leg was positioned with slight hip and knee flexion and the pelvis was stabilized by the examiner, to prevent it from rotating anteriorly or posteriorly. The test leg was then positioned in slight hip abduction, extension, and external rotation. The Power Track II Commander handheld dynamometer (J-Tech Medical, Salt Lake City, UT, USA) was positioned over the distal portion of the shank, just proximal to the ankle. The examiner applied downward adduction against the effort of the pitcher, as they raised their leg perpendicular to the floor with maximum effort. The reliability of this method of measuring hip abduction strength has been previously demonstrated in several studies (ICC = 0.84–0.98).

**Statistical analyses**
In the questionnaire, “shoulder or elbow injury” was defined as shoulder and elbow pain that the patient had been aware of in the past 3 years during the pitching motion. Pitchers with injuries that occurred via other injury mechanisms, such as trauma from falls, collisions with other players, sprains while running, or being hit by a pitch, were excluded from the statistical analyses. The pitchers were divided into injured and non-injured groups. The results were analyzed using an independent t-test. Thereafter, to identify the associated factors for shoulder and elbow injuries and to calculate odds ratios (ORs) and 95% CIs, a logistic regression analysis was performed after adjusting for significant variables that were identified in the univariate analyses. Variables that showed a P value of <0.05 in a univariate analysis were included in the model. All statistical analyses were performed using the IBM SPSS Statistics software program (version 26, IBM Japan, Tokyo). P values of <0.05 were considered to indicate statistical significance.

**Results**
Out of the 135 pitchers who completed the questionnaire, 85 pitchers had experienced a shoulder or elbow injury in the past 3 years (Table 1).

**Univariate analyses**
The age, height, weight and years of baseball experience of the injured and non-injured groups did not differ to a statistically significant extent. Furthermore, the shoulder ROM and strength in the injured and non-injured groups did not differ to a statistically significant extent. The hip external rotation on the dominant side (injured vs. non-injured: 49.0 ± 11.6 vs. 43.8 ± 10.8, P = 0.01), the hip ABD strength on the non-dominant side (injured vs. non-injured: 15.8 ± 3.6 vs. 14.5 ± 3.3, P = 0.04), and on the dominant side (injured vs. non-injured: 16.8 ± 4.5 vs. 15.3 ± 3.5, P = 0.04) were significantly lower in the injured group in comparison to the non-injured group (Table 1).

**Multivariate analyses**
A logistic regression analysis showed that hip external rotation on the dominant side was a significant associated factor for the shoulder and elbow injury (P = 0.04, Odds ratio 0.959) (Table 2). This means that a 5.2° increase in hip external rotation in the dominant side reduced the incidence of injury by 20% (calculated Odds ratio 0.804).

**Post-hoc power analyses**
A post-hoc power analysis demonstrated that the statistical power between the injured and non-injured groups was 0.99.

| Demographic data | Non-injured (N = 50) | Injured (N = 85) | P value |
|------------------|----------------------|------------------|---------|
| Age (years)      | 16.6 0.6             | 16.4 0.7         | 0.06    |
| Height (cm)      | 172.2 6.1            | 172.9 5.4        | 0.45    |
| Weight (kg)      | 65.1 7.8             | 66.3 7.6         | 0.38    |
| Baseball experience (years) | 8.1 2.3          | 8.2 1.9         | 0.73    |
| Shoulder on the dominant side |             |                 |         |
| Shoulder ER Strength (lb) | 35.0 6.7          | 34.3 6.7        | 0.53    |
| Shoulder IR Strength (lb) | 38.5 8.5         | 37.5 8.1        | 0.50    |
| Shoulder ABD Strength (lb) | 35.5 7.0        | 36.3 6.6        | 0.46    |
| Shoulder ER ROM (°) | 107.4 8.1       | 108.8 8.8       | 0.35    |
| Shoulder IR ROM (°) | 40.4 11.5        | 41.0 10.4       | 0.75    |
| Shoulder HA ROM (°) | 9.1 6.3          | 9.9 8.3         | 0.60    |
| Hip on the non-dominant side |             |                 |         |
| ABD Strength (lb) | 15.8 3.6          | 14.5 3.3        | 0.04*   |
| IR ROM (°) | 27.5 8.8              | 25.8 8.1        | 0.25    |
| ER ROM (°) | 47.3 11.0             | 43.8 10.6       | 0.07    |
| Hip on the dominant side |             |                 |         |
| ABD Strength | 16.8 4.5              | 15.3 3.5        | 0.03*   |
| IR ROM (°) | 29.5 9.7              | 27.2 8.5        | 0.16    |
| ER ROM (°) | 49.0 11.6             | 43.8 10.8       | 0.01*   |

*P < 0.05.
SD: Standard deviation.
IR: Internal rotation.
ER: External rotation.
HA: Horizontal adduction.
ABD: Abduction.
Table 2. Results of the multivariate analysis.

|                      | Odds ratio | 95% CI       | P value |
|----------------------|------------|--------------|---------|
| Age                  | 0.55       | 0.303–0.999  | 0.05    |
| Hip ABD Strength (Dom) | 0.908     | 0.828–0.996  | 0.75    |
| Hip ABD Strength (Non-dom) | 0.898    | 0.808–0.999  | 0.64    |
| Hip ER ROM (Dom)     | 0.959      | 0.928–0.991  | 0.04*   |

*P < 0.05.

CI: Confidence interval.
ABD: Abduction.
ER: External rotation.
Dom: Dominant.

Discussion

In this study, we found that a decreased hip ROM in external rotation on the dominant side and bilateral hip abduction strength were associated with the experience of shoulder and elbow injury in the past 3 years. The evidence suggests that a program to improve hip ROM and strength may be used to prevent shoulder and elbow injuries.

Hip abduction strength weakness

Failure to smoothly perform the kinetic chain generated from the lower limb is one of the causes of pitching-related shoulder disorders. Since hip motion is also a part of the kinetic chain, it is possible that hip dysfunction may disrupt the kinetic chain. Burkhart et al. reported that inflexibility of the non-dominant hip or of trunk rotation, or weakness of the hip abductors breaks the kinetic chain. This breakage increases lumbar lordosis in acceleration, which places the arm behind the body. Thus, it is presumed that the load on the shoulder and elbow joints generated during the pitching motion was affected by lower limb movement. However, this study only indirectly speculated on the association between hip abduction strength weakness and shoulder and elbow injury, it was not confirmed. Laudner et al. compared hip abduction strength in professional baseball players between pitchers and fielders and found that pitchers had lower hip abduction strength in comparison to fielders. In addition, they did not focus on pitchers. Garrison et al. reported that hip ROM did not differ between high school and college baseball players with an elbow UCL tear and a group of healthy controls. In a study of 29 professional baseball pitchers, Scher et al. reported that dominant hip internal rotation and non-dominant hip internal rotation did not differ between pitchers with and without a history of shoulder injury. This evidence is very important for protecting baseball players from preventable shoulder and elbow injuries. However, those studies were associated with some limitations. The study by Garrison et al. did not divide the players according to position. Among high school-aged players, it has been reported that pitchers experience more upper limb injuries during the season in comparison to fielders. Thus, when considering shoulder and elbow injury, pitchers and fielders need to be considered separately. The study by Scher et al. did not evaluate the external rotation of the hip range of motion, and the relatively small sample size was a limiting factor.

Limitations

The present study was associated with some limitations. First, other external load factors, such as the total number of pitches and the number of innings pitched, were not evaluated in this study. This should be examined in future studies. Second, we did not perform imaging tests, including radiography, CT, or MRI to detect pathological aspects in the participants’ hip joints. However, our study was based on medical checkups because we wanted to avoid unnecessary radiation exposure. Third, we did not take into account the effects of the trunk function, such as lumbar lordosis and dynamic balance. Finally, this was a cross-sectional study. Thus, it is not known whether the decrease in ROM of the hip joint was a cause or a result of shoulder and elbow injuries.

Conclusion

In the injured group, the hip external rotation on the dominant side and the hip abduction strength on the non-dominant and dominant sides were significantly lower in comparison to the non-injured group. The results may contribute to reducing the incidence of these injuries.
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Data availability
The datasets generated during this study and/or the data analyzed during the current study are not publicly available based on a decision by the ethics committee disapproval; however, they are available from the corresponding author on reasonable request.

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