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The effects of restricted glenohumeral horizontal adduction motion on shoulder and elbow forces in collegiate baseball pitchers

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Background: Decreased glenohumeral (GH) horizontal adduction range of motion (ROM) among baseball pitchers has been associated with the development of various shoulder and elbow pathologies. No research has examined how this tightness may affect the forces placed on the shoulder and elbow during the pitching motion.
Methods: Fifty-five asymptomatic National Collegiate Athletic Association Division I baseball pitchers participated. Twenty-five participants had –10° or less horizontal adduction ROM in their throwing shoulder. The remaining 30 participants had greater than –10° of horizontal adduction. A digital inclinometer was used to measure GH horizontal adduction, internal rotation, and external rotation ROM while in 90° of shoulder abduction. Forces produced in the throwing shoulder and elbow were assessed with a 3-dimension, high-speed video capture system and based on the sum of angular momenta of the kinetic chain segments around the center of gravity. Separate 2-tailed *t* tests were run to determine significant differences between groups ($P < .05$).
Results: Both groups presented with significant bilateral differences in their total arcs of motion ($P < .04$). This suggests that the loss of horizontal adduction in these groups was at least partially due to soft tissue tightness. There were no significant between-group differences for shoulder external rotation torque or shoulder and elbow distraction ($P > .10$). The restricted ROM group had significantly more shoulder abduction torque ($P = .04$), shoulder horizontal abduction torque ($P = .004$), elbow flexion torque ($P = .002$), and elbow valgus torque ($P = .02$) compared with the control group.
Conclusions: These results demonstrate that collegiate pitchers with –10° or less of horizontal adduction ROM in their throwing shoulder create significantly more shoulder abduction and horizontal abduction torque, as well as more elbow flexion and valgus torque, during the pitching motion than those with more ROM.
Level of evidence: Basic Science Study; Kinesiology

Keywords: Baseball; biomechanics; elbow; flexibility; shoulder; throwing

This study was approved by the Illinois State University Institutional Review Board prior to all data collection (IRB no. 2012-0006).

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As a result of large forces placed on the shoulder during the throwing motion, baseball pitchers often experience bony and soft tissue adaptations. When these forces are experienced by youth pitchers, whose bones are still structurally immature, the result is often an increase in glenohumeral (GH) external rotation range of motion

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(ROM) with a concomitant decrease in internal rotation, thereby leaving the total arc of motion relatively unchanged compared with the nonthrowing arm.[23] Decreased GH internal rotation may also be caused by soft tissue adaptations such as tightness of the posterior capsule,[30] as well as the posterior deltoid and posterior rotator cuff, which work together to eccentrically control the arm during the deceleration phase of the throwing motion.[21]

This posterior shoulder tightness, from soft tissue restrictions, can result in both lost GH internal rotation[30] and horizontal adduction ROM.[2,12] Excessive tightness can lead to shoulder pathology,[28,36] such as internal impingement[18] and subacromial impingement.[5,14,17,32] These previous authors have hypothesized that as tightness develops and ROM restrictions appear, there is increased stress placed on the upper extremity during the throwing motion, leading to an increased risk of injury. However, no research has examined what amount of GH horizontal adduction ROM is related to increased shoulder and elbow forces during the pitching motion.

The primary objective of this study was to determine how restricted GH horizontal adduction ROM affects upper extremity forces during the throwing motion in collegiate baseball pitchers. The secondary objective was to quantify what level of horizontal adduction ROM restriction would result in larger kinetic forces during the throwing motion. We hypothesized that pitchers with –10° or less horizontal adduction ROM would have greater shoulder and elbow pitching forces than pitchers with greater ROM.

Materials and methods

Subjects

A convenient sample of 55 asymptomatic National Collegiate Athletic Association Division I baseball pitchers volunteered to participate. Pitchers with –10° or less horizontal adduction ROM were assigned to the restricted ROM group and pitchers with more than –10° of horizontal adduction ROM were assigned to the control group. Twenty-five participants had –10° or less horizontal adduction ROM in their throwing shoulder (restricted ROM group: age = 19.4 ± 1.4 years; height = 186.8 ± 5.0 cm; mass = 88.1 ± 6.5 kg). The remaining 30 participants had greater than –10° of horizontal adduction (control group: age = 19.4 ± 1.1 years, height = 186.8 ± 5.5 cm; mass = 89.1 ± 8.3 kg). All participants had no recent history of upper or lower extremity injury (past 3 months) and no history of upper or lower extremity surgery.

Procedures

A blinded, cross-sectional research design was used for this study. Each participant attended 1 testing session in a biomechanics laboratory and provided informed consent as approved by the university's ethics review committee prior to any data collection. The examiners who conducted the pitching analysis were blinded to the group of each participant.

A digital inclinometer (SPI-Tronic; Garden Grove, CA, USA) was used to measure GH horizontal adduction, internal rotation, and external rotation ROM. One trial was used for each measurement. Horizontal adduction ROM of the throwing arm was measured with each subject in a supine position resting on a standard treatment table. One examiner stabilized the test arm scapula by applying a posteriorly directed force to the anterior-lateral border of the scapula. This examiner then used their other hand to passively move the test arm into horizontal adduction while maintaining the GH joint in neutral rotation. At the end range of motion, a second examiner aligned the digital inclinometer with the humeral shaft to determine the angle between the humerus and a vertical reference created by the inclinometer (Fig. 1). If the humerus failed to move beyond 0° (perpendicular to table), then this angle was referred to as a negative value. If the humerus was able to be passively moved past 0° (closer toward the trunk), then this angle was referred to as a positive value.

For bilateral GH rotational ROM measurements, subjects were positioned in a supine position with the test shoulder in 90° of abduction. From this position, 1 examiner stabilized the scapula by applying a posteriorly directed force to the anterior acromion. This examiner then used his other hand to passively move the test shoulder into end-range internal rotation and external rotation. At the end range of each motion, a second examiner aligned the digital inclinometer with the shaft of the forearm to determine the angle of GH rotation. Bilateral total arc of motion was calculated as the sum of internal rotation and external rotation. A prior testing conducted by the investigators of this study showed strong intrarater reliability for assessment of horizontal adduction (r = 0.93, standard error of the mean [SEM] = 1.6°), external rotation (r = 0.95, SEM = 3.1°), and internal rotation (r = 0.98, SEM = 2.0°).

Prior to pitching data collection, all participants completed their preferred warmup routine (eg, stretching, strengthening exercises, warmup pitches). After completing the warmup, 26 reflective makers (Motion Analysis Corp, Rohnert Park, CA, USA) were placed on various anatomic landmarks.[33-35] Participants wore spandex shorts and no shirt to minimize accessory movement of the markers.

For analysis of the pitching motion, a regulation size (2.7 m [length] × 2.5 m [width] × 0.3 m [height]) collegiate indoor pitching mound (ProModel, ProMounds, Brockton, MA, USA) was used. Participants threw off the mound to a strike zone target positioned 18.4 m away. Each participant threw 5 fastball trials at maximum effort. Pitches out of the strike zone were excluded and repeated. All pitches were monitored for location from behind the pitcher, and pitch velocity was determined using a radar gun (Stalker Sport, Plano, TX, USA) from behind the strike zone. The average of 3 fastball, thrown for strikes, with the highest ball velocities were used for analysis.

These pitch trials were recorded using 8 electronically synchronized high-speed (240-Hz) Eagle digital cameras (Motion Analysis Corp) that surrounded the pitching mound. ExpertVision software (Eva 6.0; Motion Analysis Corp) was used to track the reflective markers, and kinetics were determined using methods previously described by Feltner and Dapena[6] that are based on the sum of angular momenta of the kinetic chain segments around the center of gravity. All forces were normalized to each individual pitcher's body weight for distraction forces and to their respective body weight × height for torques.

Figure 1 Glenohumeral horizontal adduction range of motion measurement using digital inclinometer.

Statistical analysis

Dependent variables included maximum shoulder and elbow distraction forces measured as a percentage of a participant's body weight (%BW), as well as shoulder abduction, shoulder horizontal abduction, shoulder external rotation, elbow flexion, and elbow valgus torques as a percentage of a participant's body weight × height (%BW×H). Separate 2-tailed *t* tests were used to determine significant differences between groups ($P < .05$) (SPSS Statistics Software, version 26; IBM, Armonk, NY, USA).

Results

All ROM measurements can be viewed in Table I, while pitching kinetics can be viewed in Table II. There were no between-group differences for age ($P = .9$), height ($P = .9$), mass ($P = .6$), or ball velocity ($P = .6$). Both groups presented with significant bilateral differences in their total arcs of motion (restricted: $P = .01$; control: $P = .04$). The restricted ROM group had significantly less GH horizontal adduction compared to the control group ($P = .001$). There were no significant between-group differences for shoulder external rotation torque ($P = .2$), shoulder distraction ($P = .4$), or elbow distraction ($P = .1$). The restricted ROM group sustained significantly more shoulder abduction torque ($P = .04$), shoulder horizontal abduction torque ($P = .004$), elbow flexion torque ($P = .002$), and elbow valgus torque ($P = .02$) compared with the control group.

Table I Descriptive glenohumeral range of motion characteristics by group (°)

Measurement	Restricted ROM group	Control group
Horizontal adduction ROM		
Throwing arm	−15 ± 5	0 ± 8
Internal rotation ROM		
Throwing arm	43 ± 8	49 ± 8
Nonthrowing arm	55 ± 8	61 ± 10
External rotation ROM		
Throwing arm	104 ± 10	107 ± 11
Nonthrowing arm	98 ± 9	101 ± 9
Total arc of motion ROM		
Throwing arm	148 ± 11	157 ± 14
Nonthrowing arm	155 ± 11	162 ± 15

ROM, range of motion.

Discussion

Although posterior shoulder tightness has been associated with shoulder pathologies, such as internal impingement[18] and subacromial impingement[17] in baseball pitchers, no previous research has shown how this tightness may alter forces accumulated during the pitching motion. The results of this study are the first to suggest that pitchers with −10° or less of horizontal adduction ROM produce more shoulder abduction torque, shoulder horizontal abduction torque, elbow flexion torque, and elbow valgus torque during the pitching motion, compared to those with greater ROM.

Previous research has shown that posterior shoulder tightness is associated with increased forward scapular posture[10] and scapular internal rotation.[15] This could result in the shoulder leading during the acceleration phase while the arm lags behind, resulting in the increased shoulder horizontal abduction torque. This larger amount of shoulder horizontal abduction torque, in the restricted ROM group, could also explain the larger amount of elbow valgus torque as Sabick et al[26] described this positive relationship. Previous research has also identified a moderate-to-strong relationship, during the pitching motion, between this elbow valgus torque and elbow flexion torque.[13] This association may help explain why the restricted ROM group also presented with more elbow flexion torque than the control group. However, future research is needed to investigate these hypotheses.

Although GH horizontal adduction ROM has been correlated with injury,[3] much of the previous research has focused on glenohumeral internal rotation deficit (GIRD).[1,29,36] Chou et al[4] reported that collegiate pitchers with GIRD produced greater shoulder loads during the pitching motion than those without GIRD. This is valuable information as clinicians comprehend the potential causes of shoulder and elbow pathology in baseball pitchers; however, the specific cause of GIRD can be a source of confusion and can be mistakenly associated with the disabled throwing shoulder.[7,31] Lost internal rotation ROM may stem from soft tissue adaptations[2,25] and/or bony adaptations.[20,23] Soft tissue adaptations, such as tightening of the posterior capsule and contracture of the posterior deltoid and posterior cuff muscles, are often the focus of clinical treatments. These treatments may include, but are not limited to, static stretching,[11,14,24,27] muscle energy techniques,[16] and soft tissue mobilizations,[8] which have

Table II Descriptive pitching kinetics characteristics by group

Measurement	Restricted ROM group	Control group	*P* value
Shoulder distraction, %BW	114 ± 14	110 ± 23	.400
Shoulder ABD torque, %BW×H	7 ± 3	5.0 ± 3	.040
Shoulder horiz ADD torque, %BW×H	6 ± 1	5 ± 2	.004
Shoulder ER torque, %BW×H	4 ± 2	4 ± 2	.200
Elbow distraction, %BW	98 ± 14	89 ± 20	.100
Elbow flexion torque, %BW×H	5 ± 2	4 ± 1	.002
Elbow valgus torque, %BW×H	6 ± 1	5 ± 1	.020

%BW, percentage of body weight; %BW×H, percentage of bodyweight x height; ABD, abduction; horiz ADD, horizontal adduction; ER, external rotation; ROM, range of motion.

been shown to improve this ROM. Bony adaptations leading to GIRD stem primarily from increased humeral retroversion.[20,23] Not only can GIRD caused by increased retroversion be corrected clinically, previous research has suggested that this bony adaptation may actually decrease the risk of shoulder injury; nevertheless, there is still controversy surrounding this topic.[19,22]

Because of the association between humeral retroversion and GIRD,[23] this study examined the pitchers' bilateral total arc of motion. This assessment provides subsequent information into what specific adaptations may be causing the lost ROM. Both the restricted ROM and the control groups presented with bilateral differences in their total arcs of motion ($P < .04$). Because of these differences in their bilateral arcs of motion, this demonstrates that their loss of internal rotation did not have a concomitant increase in external rotation that typically accompanies bony adaptation.[23] This suggests that at least some posterior soft tissue tightness was present in both groups. As such, with the demonstrated increase in upper extremity forces sustained by the restricted ROM group, therapeutic interventions aimed at improving GH horizontal adduction ROM, may assist in reducing some of these unwanted forces that accumulate during the throwing motion. However, subsequent research is necessary to prove this hypothesis.

There are a few limitations to this study worth noting. The results of this study provide insight into how posterior shoulder tightness is associated with increased upper extremity forces during pitching. However, further research is necessary to examine how these increased forces may lead to tissue trauma and subsequent pathology. Second, although the bilateral differences in the total arcs of motion among both groups suggest that soft tissue tightness was present in the available amount of horizontal adduction ROM, the authors of this study cannot specifically state how much was from soft tissue adaptations as opposed to bony adaptations. Lastly, –10° of horizontal adduction ROM was chosen as the cutoff between the restricted and control groups. There have been no previous research identifying a specific amount of horizontal adduction that is considered pathologic. The authors of this study empirically chose –10° based on clinical experience and previous studies which have shown that greater restrictions in this ROM can lead to unwanted changes in shoulder position,[10,15] soft tissue restraints,[9] and subsequent shoulder pathology.[17,18,32]

Conclusion

The results of this study demonstrate that collegiate pitchers with –10° or less of horizontal adduction ROM in their throwing shoulder create significantly more shoulder abduction and horizontal abduction torque, as well as more elbow flexion and valgus torque, during the pitching motion than those with more ROM. These findings should be considered in the therapeutic interventions used both prior to and following pathologies associated with this tightness.

Disclaimer

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