College Pitchers Demonstrate Directional Differences in Shoulder Joint Position Sense Compared With Controls

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Context: The relationship between overhead throwing and its effect on proprioception is not well understood. It is important to gain a better understanding of how these are related, to protect overhead athletes from an increased risk of injury. Objective: To investigate proprioceptive alterations in the overhead thrower’s shoulder. Design: Cross-sectional study. Independent variables are limb (dominant and nondominant), group (thrower or control), and target angle. Dependent variables are joint position sense accuracy between throwers and nonthrowers, although both groups display increased accuracy closer to their end range of external rotation. The throwing shoulder demonstrates a different repositioning pattern, overshooting the desired target angle, while all other shoulders undershoot.

Keywords: proprioception, biomechanics, motor control, orthopedics

Baseball pitching is one of the most dynamic biomechanical tasks performed by athletes. At the college and professional level, the shoulder can experience velocities in excess of 7000°/s in internal rotation. Given the repetitive nature of this loading, it is perhaps not surprising that injuries to the upper-extremity represent between 45% and 58% of all injuries to baseball players. In fact, shoulder irregularities are so common in throwing athletes that, even when asymptomatic, they often present with abnormal magnetic resonance images. Although the exact etiology of these injuries is not completely understood, there are many distinct physical characteristics of the throwing shoulder that have been studied in relation to injury, such as range of motion (ROM), laxity, osseous adaptations, muscle strength, and scapular position. However, less is known about the sensorimotor adaptations in these athletes.

Compared with other joints in the human body, the shoulder relies more heavily on dynamic stability from muscular forces, rather than bony and ligamentous constraints. To accurately guide and protect the shoulder through overhead motions, the associated musculature should fire synchronously. In order to perform precise coordinated motions, such as pitching a baseball, accurate afferent feedback from the limb is essential. The sensorimotor system integrates afferent information from the limbs to help form a model of limb motion, which in turn, helps to generate an efferent response of the surrounding musculature, activating dynamic restraints, and maintaining functional joint stability throughout movement. Any compromise of this afferent feedback may lead to decreased muscle coordination, increased shoulder instability, and an increased risk of injury. In fact, a recent meta-analysis demonstrated a link between proprioception deficits and several shoulder injuries, such as glenohumeral instability and shoulder impingement syndrome.

Many studies have investigated proprioception in a variety of overhead athletes. However, few studies have focused on a comparison between pitching and nonpitching shoulders in baseball players. Compared with nonthrowing arms in a passive protocol, deficits were found in the throwing shoulder during a threshold detection task, and a joint position sense (JPS) task. Although active protocols are more representative of actual motion patterns, only one study has investigated this population with an active protocol, and no differences were observed. Due to the lack of research focusing on this population, and the variety of testing protocols used, further research is needed to better understand possible proprioceptive alterations in throwers.

The aim of this study is to examine active JPS in Division I intercollege baseball pitchers. Specifically, we compared side-to-side differences within these subjects, as well as differences with subjects who are not overhead athletes. We hypothesized that baseball pitchers would have greater errors in their dominant (throwing) shoulder as compared with their nondominant shoulder, as well as a nonthrowing control group.

Methods

Design

This study represents a cross-sectional study design, with 2 groups (throwers and nonthrowers) and 2 sides (dominant and nondominant). The dependent variables are JPS and ROM.

Participants

Twelve Division I baseball pitchers and 13 nonthrowing control subjects.

Intervention

Shoulder proprioception was assessed using an active joint repositioning task administered with an iPod Touch.

Main Outcome Measure

Root mean square error and constant error of repositioning angles were used to assess accuracy and directional patterns, respectively.

Results

There were no differences in accuracy between groups. Constant error revealed differing repositioning patterns between limbs for the pitchers and also between groups for the dominant side. Although the throwing shoulder overshoot the target angles by 0.4°, all nonthrowing shoulders undershot by an average of 2.7°.

Conclusions

There is no difference in shoulder joint position sense accuracy between throwers and nonthrowers, although both groups display increased accuracy closer to their end range of external rotation. The throwing shoulder demonstrates a different repositioning pattern, overshooting the desired target angle, while all other shoulders undershoot.
Participants

Two groups of healthy individuals were recruited for this study. One group consisted of 13 NCAA Division I baseball pitchers from the University of Oregon baseball team (age = 20.1 [1.0] y, height = 188 [5] cm, weight = 93.2 [8.5] kg; 8 right hand dominant, 5 left hand dominant). Exclusion criteria for the pitchers were: (1) prior shoulder surgery and (2) previous history of shoulder dislocation. The second group was a nonthrowing control group matched for sex and arm dominance and recruited from a college-aged population (age = 20.1 [1.8] y, height = 176 [7] cm, weight = 74.2 [10.1] kg; 8 right hand dominant, 5 left hand dominant). Exclusion criteria for the control group were the same as the pitching group, with the additional exclusion condition of competing in overhead or throwing sports, such as baseball, swimming, and so forth. The institutional review board at the University of Oregon approved the study, and all subjects signed a consent form.

Procedures

We assessed JPS with an active joint repositioning task, using a fifth generation iPod Touch (Apple.com) and a previously developed and validated JPS app.24 The app uses the internal sensors of the device (accelerometers and gyroscopes) to record the orientation of a body segment with respect to gravity,25 and enables an evaluation protocol similar to that previously described using an electromagnetic tracking device.26,27 However, instead of visual directions, it provides auditory commands to the subjects through Bluetooth wireless speakers. The use of the app is described in detail previously,24,28 and is briefly summarized here.

With the subject in a neutral position (described below), the app prompted the subject to move to a target angle with the use of 2 tones—a low tone when the angle was too low and a high tone when the angle was too high. The tones ceased when the subject was within 2° of the target angle. After holding the position for 2 seconds, the subject was instructed to return to the starting position. Following a 1-second pause, the subject was instructed to move to the target position, with no audio or verbal feedback. Once motionless for 2 seconds (angular velocity <0.25°/s), the subject was instructed to return to the neutral position. After a 1-second pause, the next trial began.

The protocol was modified to allow for testing of shoulder internal/external rotation. The iPod Touch was attached to the distal forearm of the participant. The subject was assessed in the supine position on a treatment table, with the hips and knees flexed at approximately 45° and 90°, respectively. The scapula and hip were fully supported by the table, with the shoulder abducted to 90° and the elbow flexed to 90° with a closed fist. The neutral position for the present study was with the forearm vertical (Figure 1). The elbow of the shoulder being tested was supported but allowed to rotate, using a tripod attached to a device consisting of a splint formed to the elbow and a rotating axle. This device provided support for the subject and ensured all movement was due to shoulder rotation. Also, an adjustable stopping device on the axle could be engaged and disengaged as needed to ensure a consistent neutral position. The same examiner positioned all subjects to ensure they were in a consistent position. Practice consisted of 2 trials at 50° shoulder external rotation. Testing consisted of 3 trials each at 40°, 60°, and 80° shoulder external rotation in randomized order. Testing trials were then repeated on the opposite shoulder. The order of testing (dominant or nondominant side) was randomly determined for each subject.

Active internal and external ROM measurements were also made on each side. These measurements were also performed with the elbow supported in the rotating splint to ensure motion was due to shoulder rotation. The subjects were instructed to keep their backs flat on the testing table, but were otherwise free to rotate as far as possible in either direction within the constraints of the supporting device. Measurements were recorded using the iPod touch.

Statistical Analysis

Paired t tests were used to compare ROM between sides for the pitchers. A correlation was run between all target angles, errors, maximum internal rotation, maximum external rotation, and total ROM. There were 2 dependent variables for JPS errors: root mean square (RMS) error and constant error.29 Although RMS errors are an assessment of overall error, constant errors reflect directionality of errors. For each dependent variable, a 3-way analysis of variance was run, with 1 between-subject comparison, group (pitchers and controls), and 2 within-subjects comparisons, side (dominant and nondominant), and angle (40°, 60°, and 80°). The alpha level for all analyses was set at .05.

Results

One baseball pitcher was excluded from data analysis due to pain in to his nonthrowing arm that impeded data collection, leaving 12 subjects in the pitching group and 13 subjects in the control group. The dominant shoulder of the pitching group had significantly more external rotation (P = .02) and less internal rotation (P < .001) when compared with their nondominant shoulder. However, there were no differences in total ROM between sides (P = .20) (Figure 2). No significant correlations were found between target angles, average constant error, or ROM measurements (P > .05).

For RMS errors, there were no significant 3-way (P = .43) or 2-way interactions (P = .67). There was no significant effect of side (P = .99) or group (P = .16) (Figure 3). However, there was a significant effect of angle (P = .04). Follow-up simple effects demonstrated that subjects had significantly higher error scores at 60° of external rotation when compared with 80° of external rotation (P = .01), but there were no differences for 40° (P = .14).
For constant error, there was no 3-way interaction ($P = .35$) and no 2-way interaction between angle and group ($P = .12$) or between angle and side ($P = .18$). There was also no main effect of angle ($P = .37$). However, there was a significant interaction between side and group ($P = .01$). When considering side-to-side differences, the pitchers demonstrated a significant difference between their dominant and nondominant shoulders ($P = .01$). There was no difference between sides for the control group ($P = .24$). For group comparisons, the dominant shoulder of the pitching group differed significantly from the dominant shoulder of the control group ($P = .03$), but there were no significant differences between groups for the nondominant side ($P = .99$) (Figure 4). On average, although the pitchers’ dominant sides demonstrated a slight overshoot pattern, the pitchers’ nondominant sides and both sides for the control group demonstrated an undershoot pattern.

**Discussion**

The principal aim of this study was to describe proprioceptive alterations in the throwing shoulder of Division I intercollegiate baseball pitchers. Based upon previous studies describing a loss of proprioceptive abilities following injury, we hypothesized that the throwing shoulder would demonstrate greater JPS errors compared with the contralateral side and the nonthrowing control shoulders. $^{10,12,30}$ Although the throwing shoulder was trending toward being more accurate, this was not shown to be significant when looking at RMS error. We then examined constant error and found that the pattern of errors differed significantly by shoulder, with the throwing shoulder overshooting the target angle and the nonthrowing shoulders undershooting the target angle.

The fact that we observed differences in joint position errors between the throwing and nonthrowing shoulders is not surprising. However, to our knowledge, no previous studies have reported different directional patterns of error in the throwing shoulder. Whether this is an adaptation by the shoulder to protect itself during the throwing motion, or a deleterious result of cumulative trauma to the joint, is unclear. On average, the throwing arm was found to have larger external rotation ROM and a larger external rotation motion during JPS testing. It is possible that the ROM in the throwing shoulder allows for pitchers to move past the target angle more easily than less mobile shoulders. However, we found no correlation between ROM and error measurements. Future studies should examine directional differences in shoulder JPS to determine what may cause these differences.

We found a difference for RMS error across target angles, with $60^\circ$ of external rotation showing significantly more error than the $80^\circ$ target angle. This is in agreement with previous research showing increased JPS acuity closer to end ranges of motion in both throwers and nonthrowers.$^{20,31}$ This could be due to increased tension in the surrounding musculature, ligaments, and joint capsule. Some studies attempted to control for this by...
individualizing the target angle to select percentages of each subject’s specific ROM.15,32 Baseball players have a differing arc of motion in their throwing shoulder compared with nonthrowing shoulders, which is characterized by a shift toward increased external rotation and deceased internal rotation.13–35 This was confirmed in the present study. Therefore, our target angles of 40°, 60°, and 80° of shoulder external rotation varied in location in regard to the total arc of motion of the subject being tested. However, this lack of individualization did not prevent us from seeing proprioceptive differences between target angles.

Our findings are in agreement with previous research in that there were observable JPS differences between the throwing and nonthrowing shoulder of overhead athletes.14–16,20,22,36,37 However, we were unable to detect side-to-side differences in shoulder accuracy. Previous studies have used absolute error to determine accuracy and have found contrasting results regarding the throwing shoulder.15,16 We used RMS error, which is a combination of absolute and variable error and has been shown to produce similar findings to absolute error.29 Few studies have focused on a comparison between pitching and nonpitching shoulders in baseball players. Compared with nonthrowing arms in a passive protocol, deficits were found in the throwing shoulder during a threshold detection task,20 a JPS task,32 and a latent muscle reaction test.21 Only one study has investigated this population with an active protocol, and no differences were observed.23 An active repositioning task is more realistic in that it requires muscular involvement and is, therefore, a better indicator of shoulder JPS during movement. This changes the task for the research participant. Our methods required the subject to actively externally rotate their shoulder from the supine position. This requires an eccentric contraction of the internal rotators of the shoulder as the subject lowers their forearm toward a horizontal position. This level of muscular involvement differs from previous studies and most likely contributed to our conflicting results.

Our study is not without its limitations. Working with a smaller sample size consisting of only the baseball pitchers available on campus left us underpowered and unable to make any conclusions regarding JPS between the groups. A sensitivity power analysis revealed that a 1.7° difference would have been detected with the given sample size.38 Although this is higher than what was found for the within-subject analysis, it is lower than what was observed for the between-subject analysis. Finally, although we did our best to limit tactile feedback, it is possible that the subjects gained some position sense through scapular contact with the table.

Conclusions

Although there were no differences in RMS errors, we did find a significant directional difference in the repositioning errors in pitching shoulders. The throwing shoulder of the pitcher overshoots the target angle, while their nondominant shoulder and both control shoulders undershoot the target angle. These repositioning errors did not correlate with the increased external rotation ROM observed in the throwing shoulder. Future research should include directional differences in their JPS analysis and should investigate a possible mechanism for these different repositioning patterns.

References


