Estimation Of Optimal Shoulder Orientation During The Acceleration Phase In Baseball Pitching From Minimal Shoulder Joint Load Viewpoint

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Introduction: Baseball pitchers are prone to shoulder injury as a result of the extreme joint reaction forces and torques placed on the shoulder particularly during the late cocking to the deceleration phase in baseball pitching, especially tremendous joint forces apply to the shoulder near ball release (Fleisig GS, AJSM, 1995). Little information or analysis is available about relationship between shoulder orientation and shoulder joint load during the acceleration phase.

It is believed that the glenohumeral joint incurs large shoulder distraction and shear force as humeral head moves anterior to posterior during acceleration and follow-through. Relationship between shoulder distraction force and kinematic parameters of pitching mechanics has been evaluated (Werner SL, JSES, 2007). Little information is known about shoulder shear force as shoulder anterior/posterior and superior/inferior forces during the acceleration phase. Thus, the purpose of this study was to evaluate relationship between shoulder orientation and shoulder force at ball release and to estimate optimal shoulder orientation at ball release, which is minimized shoulder shear force as shoulder anterior/posterior and superior/inferior force.

Methods: Three hundred and four Japanese baseball pitchers in various competition levels without pathologic lesions by on radiographs and MRI were measured with a high-speed motion capture automatic digitizing system during 2002 to 2013 years. Subject demographic characteristics appearances as age, height and body mass were 16.7 ± 4.87 years (range: 8 to 34 years old), 169.7 ± 11.48 cm, 62.6 ± 13.66 kg.

For measurement of the pitching, a full-body marker set was used to bilaterally define the upper- and lower-body, as the head, upper arm, forearm, hand, trunk, pelvis, thigh, shank and foot, segments. Thirty six spherical reflective plastic markers were attached to subject’s skin directly on the anatomical locations determined. Subsequently, a motion capture three-dimensional automatic digitizing system was used to collect 500-Hz from 7 CCD synchronized cameras was set up around the regulation soil pitching mound in an indoor laboratory. Moreover, 2 high-speed video cameras synchronized at 250-Hz recorded the pitching motion to determine the point of ball release. Ball release was defined as the point when the ball was clearly separate from the pitcher’s hand in 2 high-speed camera views and was in accord with the procedure of previous literature (Pappas, AJSM, 1985). At the same time, ball speed was measured by a radar gun. After performing a preparation routine of stretching and warm-up pitching, each subject pitch to 5 fastball pitches off the pitching mound to a catcher at the regulation
distance of 18.44 m. The best ball fastballs thrown for strikes (in terms of speed, location and outcome) were chosen for the examination.

Six local coordinate systems were set on each segment of the upper extremity with references to previous (Wu G, J Biomecha, 2005). The shoulder joint was modeled ball-and-socket joint. To describe the shoulder joint motion relative to the trunk, an Eulerian angle sequence was used by Z-Y′-X″. The standard Newton-Euler sequence was used for estimating shoulder force. Then shoulder force was expressed as percent body weight (%BW) to normalize data between subjects. To estimate optimal shoulder orientation at ball release, Rz0 was defined a shoulder horizontal adduction/abduction angle, which indicated zero value of shoulder anterior/posterior force at ball release by linear regression analysis. Similarly-defined Ry0 was a shoulder adduction/abduction angle, which indicated zero value of shoulder superior/inferior force at ball release by linear regression analysis. Afterward, each 2 group with consideration of shoulder orientation at ball release was created: {A- < Rz0 - 5, Rz0 - 5 ≤ A ≤ Rz0 + 5, Rz0 + 5 < A+}, {B- < Ry0 - 5, Ry0 - 5 ≤ B ≤ Ry0 + 5, Ry0 + 5 < B+}. Because shoulder passive and active ranges of motions are measured 5 degrees intervals in the orthopaedic field. Finally, 9 combinations as composition of anterior/posterior and superior/inferior forces were created: {AB, AB-, AB+, A-B, A-B-, A-B+, A+B, A+B-, A+B+}.

Statistical analysis was performed with a standard statistical software package. We employed MANOVA to investigate significant differences of averages of anterior/posterior and inferior/superior forces applied to the shoulder at ball release among {A-, A, A+} and {B-, B, B+} groups. Finally, MANOVA was performed among 9 combinations.

Results: Anterior/posterior shoulder joint force significant correlated with shoulder horizontal abduction/adduction (r=-.83, P<.001) and superior/inferior shoulder joint force significant correlated with shoulder abduction/adduction (r=-.74, P<.001) equally (Table 1). As a result of these, Rz0 was shown a horizontal adduction of 6.17 degrees and Ry0 was an abduction of 88.19 degrees. Average of shoulder posterior force at A+ and average of shoulder anterior force at A- were significant increases in comparison with A respectively (P<.001). Average of shoulder superior force at B+ and average of shoulder inferior force at B- were significant increases in comparison with B respectively (Table 2). Finally, A+B-, A-B, A-B-, A-B+ were shown statistically significant differences in AB, which was minimal resultant force consisting of anterior/posterior and superior/inferior forces (Figure 1).

Table 1. Correlation between shoulder joint force and shoulder orientation at ball release

<table>
<thead>
<tr>
<th>Shoulder orientation (deg)</th>
<th>External rotation (+)</th>
<th>Abduction (+)</th>
<th>Horizontal Adduction (+)/Abduction (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior (+)/Posterior (-) force</td>
<td>r=-.513 (P&lt;.001)</td>
<td>r=-.109 (P=.057)</td>
<td>r=-.830 (P&lt;.001)</td>
</tr>
<tr>
<td>Distraction force</td>
<td>r=.055 (P=.343)</td>
<td>r=.194 (P=.001)</td>
<td>r=.014 (P=.814)</td>
</tr>
<tr>
<td>Superior (+)/Inferior (-) force</td>
<td>r=.311 (P&lt;.001)</td>
<td>r=-.741 (P&lt;.001)</td>
<td>r=-.235 (P&lt;.001)</td>
</tr>
</tbody>
</table>
Discussion: The results from this study demonstrated that shoulder orientation at ball release was strongly correlated with shoulder force at ball release. Additionally, optimal shoulder orientation at ball release from minimal shoulder force viewpoint was estimated the combination of horizontal adduction of 6.17 degrees and abduction of 88.19 degrees. The commonly theory concerning pitching-related shoulder joint injury during the late cocking phase to the acceleration phase has been established that horizontal abduction of the humerus beyond the plane of scapula, or hyperangulation, which can lead to tensile stressing of the anterior aspect of the capsule, SLAP lesion (Snyder SJ, Arthroscopy, 1990), internal impingement (Mihata T, AJSM, 2010), rotator interval lesion (Nobuara K, Clin Orthod, 1990) and any more pitching-related shoulder joint injuries. The results of this study demonstrated that shoulder shear force at 3 groups regarding excessive horizontal abduction significant increased in comparison with a minimal shoulder shear force group. Thus, the data of this study support these statements. The current study suggested that excessive shoulder horizontal abduction at ball release is one cause of incorrect throwing mechanics from shoulder shear force viewpoint and may cause several pitching-related injuries.

Significance: These data provide a scientific basis for clinicians, athletes, and coaches to establish methods to reduce shear force at the shoulder joint to prevent pitching-related injuries.

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