STERNOCLAVICULAR JOINT MOVEMENT DURING BACKSWING IN BASEBALL PITCHING MAY BE A GOOD INDICATOR OF SHOULDER INJURY

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The purpose of this study was to demonstrate the characteristics of joint movements performed by the pitchers who suffered from throwing shoulder injuries. Fourteen semi-professional baseball pitchers participated in our longitudinal study. We captured their pitching using an optical motion capture system. We investigated their disease history once a year, for 5 years, in order to investigate the relationship between baseball-related throwing injuries and pitching mechanics. Two of the players suffered from shoulder pain and had to take a “no throw” rest for several weeks during the season. Both pitchers had a reduced range of motions for retraction at the sternoclavicular joint during backswing. However, they presented the same range of motions for shoulder horizontal abduction, as the other healthy pitchers.

KEY WORDS: shoulder complex, hyperangulation, glenohumeral joint.

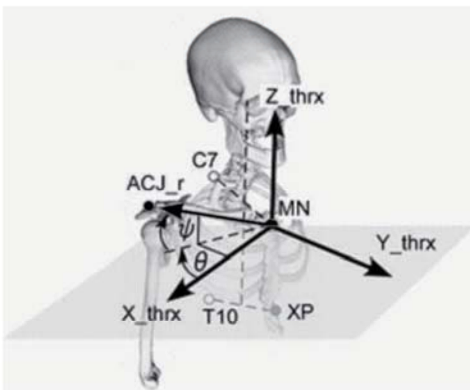
INTRODUCTION: Pathomechanics of throwing injuries have been investigated from both orthopedic and biomechanical viewpoints. From the orthopedic viewpoint, the cause of injury is estimated on the basis of observation of the affected part of the body during surgical and/or endoscope intervention (Andrews & Angelo, 1988; Braun, Kokmeyer & Millett, 2009). From the biomechanical viewpoint, kinetic values such as joint force and joint torque are calculated for healthy pitchers without injuries and these values are used to evaluate risk of injury (Keekey, Oliver & Dougherty, 2012; Sabick, Torry, Kim & Hawkins, 2004). Both approaches are necessary for a deeper understanding of joint pathomechanics.
We think that the longitudinal or prospective approach is needed to confirm whether the estimated cause of injury or the risk of injury leads to the injury or whether the pitchers with some defective movement suffer from the throwing injury with a higher probability. Therefore, we planned to a longitudinal study in which healthy participants were evaluated for kinematics and kinetics during pitching. We also collected data about medical history, once a year, for 5 years. Once these data were collected, we investigated the relationship between the pitching mechanics and throwing injuries. During this longitudinal study, two participants complained of shoulder pain. The purpose of this study was to demonstrate the characteristic of joint movements performed by the participants suffering from shoulder pain.

METHODS: Fourteen semi-professional baseball pitchers participated in this longitudinal study. The participants had their pitching captured and were asked about personal medical history once a year in autumn, after the season. Four participants were eliminated from the following analysis due to the side-hand delivery for one participant and retirement for three participants. Consequently, 10 overhand and three-quarter-hand pitchers were included in the following analyses. Their mean height, weight, and age were 1.79± 0.05 m, 73.4 ± 5.0 kg, and 23.2 ± 2.0 years, respectively. The mean of maximum pitched velocity in this study was 37.8 ± 1.6 m/s.
After providing both, written informed consent and medical history, the participants were instructed to warm-up just as if they were going to pitch in a competitive game. Afterwards, they changed into a pair of spandex shorts and 45 retro-reflective markers (14 mm diameter) were attached on specific body landmarks, most of which were placed according to the

standard Plug-in-Gait marker placement protocol (Vicon Motion Systems, 2002). Additional four small markers (6 mm diameter) were placed on the middle finger of the throwing side and other four smaller markers were placed on a standard baseball (0.145 kg). After attaching the markers, the participants were instructed to warm-up again, including practice pitching on an indoor mound.

The participants were requested to throw five fastballs at a target, with as much ball velocity and accuracy as possible. The target was a concentric circle with a diameter of 0.42 m and this was set at the distance simulaing the position of catcher's mitt (19.97 m from the indoor pitcher's plate and 0.63 m above the floor). Each pitching was performed on an indoor mound surrounded by a 16-camera optical motion capture system (VICON MX, 1,000 Hz, VICON, UK). Three dimensional positions of each marker were calculated, using Vicon Nexus software (VICON, UK). Kinematics of the throwing arm joints were calculated, using the vector algebra.

Throx local coordinate system is an orthogonal coordinate system, composing X_thrx, Y_thrx, and Z_thrx (Figure 1). Three shoulder joint angles (abduction/adduction, horizontal abduction/adduction, and external/internal rotation) were calculated, using the conventional anatomical representation method (Fleisig, Escamilla, Andrews, Matsuo, Satterwhite & Barrentine, 1996) (Figure 2).



VCT_thrx = (MN+C7) /2 - (XP+T10) /2
Z_thrx = (VCT_thrx) / (length of VCT_thrx)
Y_thrx_tmp = (XP- T10) / (length of (XP- T10))
X_thrx = (Y_thrx_tmp) X (Z_thrx)
Y_thrx = (Z_thrx) X (X_thrx)

VCT_thrx: vector of thorax. MN: Manubrium of sternum. XP: Xiphoid process. C7: The 7th cervical vertebrae. T10: The 10th thoracic vertebrae. X_thrx, Y_thrx, and Z_thrx are the components of the thorax local coordinate sysytem. X: cross product.

Figure 1: Local coordinate system of thorax and sternoclavicular joint angle.
ϕ :depression/elevation. Θ: protraction/retraction.

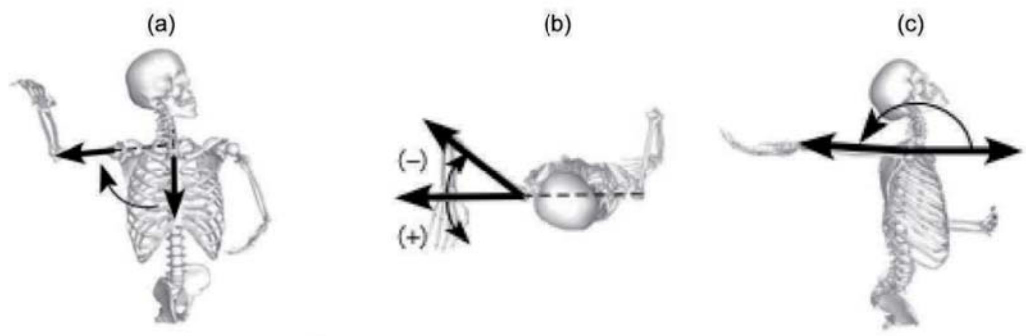


Figure 2: Shoulder angles. (a) abduction angle, (b) horizontal adduction angle (+) and horizontal abduction angle (-), and (c) external rotation angle

Two sternoclavicular (SC) joint angles (depression/elevation and protraction/retraction) were also calculated. The depression/elevation angle (ψ in Figure 1) was defined as the angle between the clavicular vector, which extends from the manubrium of sternum (MN) to the acromion joint (ACJ_r), and the X_thrx in the plane formed by X_thrx and Z_thrx. The depression was represented as a positive value and the elevation was represented as a negative value. The protraction/retraction angle (θ) was defined as the angle between the clavicular vector and the X_thrx in the plane of X_thrx and Y_thrx. Positive values show protarction and negative values show retraction.

The center of ball was calculated using non-linear least-square method with equation of a sphere. Distances between the marker on the tip of middle finger and the center of ball were calculated in time series, and the first derivative of the distance was used to identify the instant of ball release. The instant of ball release was defined as the first frame of drastic increase of the derivative curve. The instant of lead foot contact was defined as the instant when either the velocity of the heel or toe marker of the lead foot fell below 1.5 m/s (Nissen, Westwell, Ounpuu, Patel, Solomito & Tate, 2009).
In this study, we used the motion data which were captured before the injury.

RESULTS: The diagnosis for a participant with shoulder pain was a labrum lesion of the glenohumeral joint and for another participant, shoulder pain resulting from limitation of the scapular range of movement due to pectus excavatum.
Both participants with the shoulder pain showed similar angles in shoulder abduction, horizontal abduction/adduction, and external rotation to the asymptomatic participants (Figure 3a, 3b, & 3c). In addition, their depression/elevation movement of the SC joint was similar to the asymptomatic participants. However, they clearly showed a lower retraction angle during the arm cocking and acceleration phases, beginning from the contact of lead foot and ending at the ball release (Figure 3f). The mean retraction angle of the SC joint during the arm cocking phase was -56.8° ± 4.9° for non-injured participants. Those for the injured participants were -43.2° and -45.2°, which were lower than twice the standard deviation.

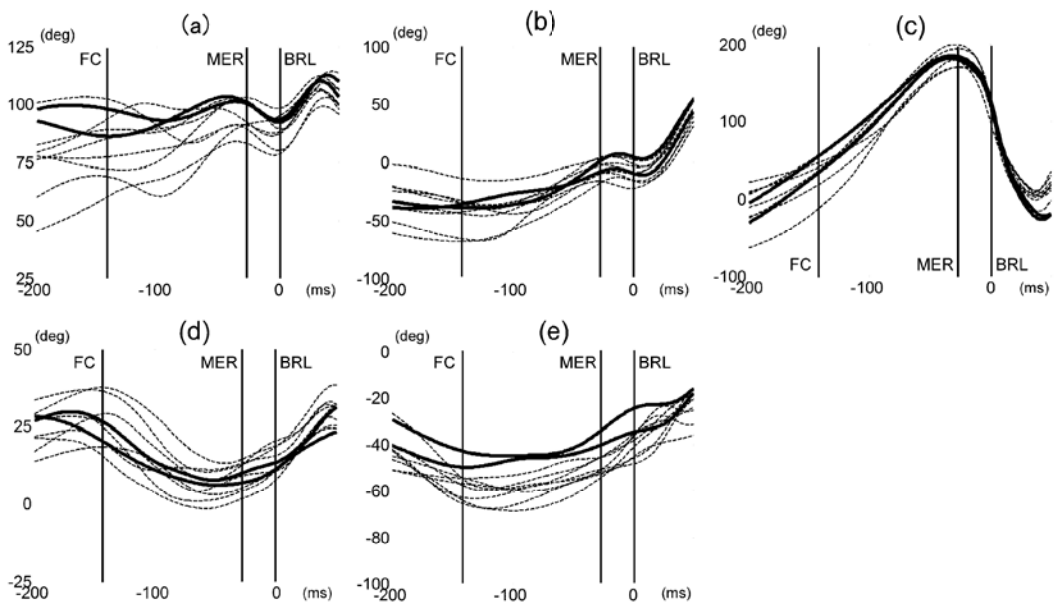


Figure 3: Shoulder and sternoclavicular (SC) angles during pitching. (a) Shoulder abduction (+), (b) shoulder horizontal adduction (+) and abduction (-), (c) shoulder external rotation (+), (d) SC joint depression (+) and elevation (-), and (e) SC joint retraction (-). FC: the instant of lead foot contact. MER: the instant of maximum shoulder external rotation. BRL: the instant of ball release. The bold solid lines show the injured participants and the thin dashed lines show the non-injured participants.

DISCUSSION: The lower retraction angle at the SC joint in the arm cocking and acceleration phases was a characteristic of the participants with shoulder pain. The SC joint does not move independently because there are no muscles acting on it directly. Instead, movement of the SC joint is closely coupled with the scapular movement (Lawrence, 2014). This means that the scapular movement for the participants with shoulder pain was decreased.

It is known that malfunctioning of scapula leads to some shoulder injuries (Kibler, Sciascia & Wilkes, 2012). The results in the current study supported this theory from the longitudinal viewpoint.

All participants in the current study showed the greater shoulder horizontal abduction at the lead foot contact, in comparison with a previous study (Escamilla, Fleisig, Barrentine, Andrews & Moorman, 2002). Greater horizontal abduction during the arm cocking phase is regarded as a defective movement and is termed ‘hyperangulation’. The hyperangulation increases shear force at the glenohumeral joint, leads to attenuation of the shoulder anterior capsular structures, and results in shoulder instability and/or injuries (Takagi, Oi, Tanaka, Inui, Fujioka, Tanaka, Yoshiya, Nobuhara, 2015; Whiteley, 2007). The participants may have high risk of shoulder injury.

It is reasonable to think that, especially, the participants who presented with the shoulder pain were exposed to the risk of injury, because their glenohumeral joint had a much greater horizontal abduction in order to compensate for the lower sternoclavicle retraction angle. Thus, the greater glenohumeral horizontal abduction might result in the shoulder pain..

CONCLUSION: This study revealed that the smaller range of motion in the sternoclavicular retraction during the arm cocking and acceleration phases led to the shoulder pain, from the longitudinal perspective. The lower retraction showed by two participants who presented with shoulder pain indicates that their scapula did not move sufficiently. People interested in playing baseball should take care of their clavicular and/or scapular movement in order to prevent shoulder injuries. It may be recommendable, in the field, to observe clavicular movement, because it is difficult otherwise to observe the scapular movement.

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