PRONATE GLOBALLY BUT SUPINATE LOCALLY: EVIDENCE OF RADIO-ULNAR SUPINATION AT BALL RELEASE

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The purpose of this study was to investigate the radio-ulnar longitudinal rotation during baseball pitching. We captured movements of nine skilled pitchers during pitching by using a system with 16 high-speed cameras (Vicon MX, 1000 Hz). Ten fastest trials which hit a target were averaged to obtain representative data for each participant. We found that the radio-ulnar joint supinated at around the moment of ball release (BRL), although the wrist continued rotating in the direction of pronation at around BRL in the global coordinate. The supination occurred due to the influence of the combination of elbow extension and shoulder internal rotation.

KEY WORDS: baseball pitching, throwing, pronation, arm movement.

INTRODUCTION: Previous studies have shown inconsistent results regarding radio-ulnar rotation around the moment of ball release during baseball pitching. On one hand, a few studies asserted that the radio-ulnar joint pronates at the instant of ball release (Atwater, 1979; Keeley et al., 2010; Nissen et al., 2007, 2009; Sakurai et al., 1993). On the other hand, Barrentine et al. (1998) illustrated that the joint supinates. To prescribe proper practice/training programs for baseball pitching, it is important to understand pitching mechanics correctly. The purpose of this study was to investigate the radio-ulnar movement during baseball pitching, especially around the instant of ball release.

METHODS: Nine healthy males, who were semi-professional pitchers (7 right handed, 2 left handed), participated in this study. Their mean height, weight, and age (±SD) were 1.80 ± 0.04 m, 72.9 ± 5.5 kg, and 22.1 ± 1.2 years, respectively. Their mean pitch velocity in this experiment was 36.1 ± 0.8 m/s. All participants were overhand or three-quarter-hand pitchers. They had no throwing injuries that required surgery over the last two years. They signed informed consent forms approved by the University Research Ethics Committee.

The participants were instructed to prepare to pitch as if they were participating in a competitive game. Then, they changed into a pair of spandex shorts, and 45 retro-reflective markers (14 mm diameter) were attached at different landmarks on their body, three small markers (6 mm diameter) were attached on the middle finger of the throwing side, and four markers (6 mm diameter) were attached on the ball. After the markers were attached, the participants were instructed to warm-up again, including practicing pitching on an indoor mound.

The test was composed of two sessions, and each session involved pitching 15 fastballs. The participants were requested to throw an official baseball at the target with concentric circles (19.97 m away from the pitcher’s plate, 0.63 m above the floor, and 0.42 m in diameter). A rest of approximately 15 min was allowed between sessions. The participants warmed-up before the 2nd session, including practicing pitching. Ten pitches, with the focus on both speed and accuracy, were selected for the following analyses in this study.

Each pitching was captured by using a 16-camera VICON MX motion analysis system (Oxford Metrics Inc., UK) with a sampling frequency of 1000 Hz. Based on the three-dimensional position of markers and vector algebra, joint angles of the upper extremity were calculated. The pronation/supination angle was defined as the angle between Wz and Fz in the plane FyFz (Figure 1). We also calculated the wrist rotation around the longitudinal axis of the forearm as the internal/external rotation of the forearm (WrstRot) as follows. Fg_y was defined as the cross product of Gz and Fx (Figure 1). Fg_z was defined as the cross product

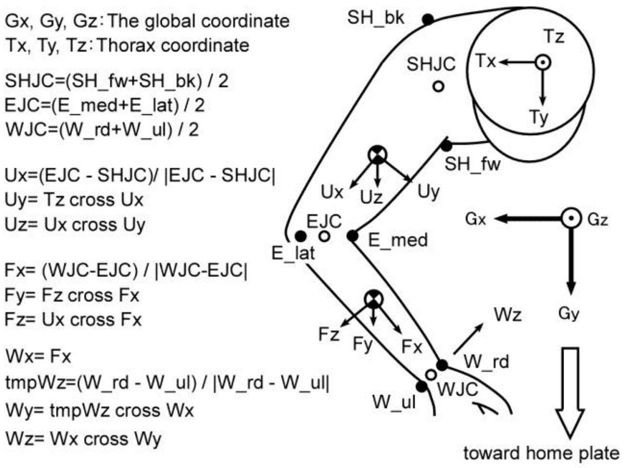

Figure 1. Selected marker positions and global and local coordinates

of Fx and Fg_y. WrstRot was defined as the angle between Fg_z and Wz in the Fg_y and Fg_z planes. Shoulder internal/external rotation was also calculated as the angle between Fx and Uy in the plane UyUz (Figure 1). The maximum shoulder external rotation was used for a time-landmark.

The center of the ball was calculated by using a non-linear least-square method with a trust-region-reflective algorithm. The distances between the marker on the tip of the middle finger and the center of the ball were calculated, and its derivative was used to identify the moment of ball release. The ball release was defined as the instant of the first frame of drastic increase in the derivative curve.

In this study, no data-smoothing techniques were applied to a single time-series curve. Instead, an averaging method that synchronized with the instant of ball release (BRL) was used to determine a representative value for each participant.

RESULTS: Before the instant of the maximum shoulder external rotation (MER), which occurred at 27.3 ± 3.8 ms, the radio-ulnar joint had a different pronation/supination pattern for each participant. However, all the participants showed the radio-ulnar pronation from MER to the instant just before BRL (Figure 1). Then, they changed the rotational direction of the radio-ulnar joint to supination just before BRL.

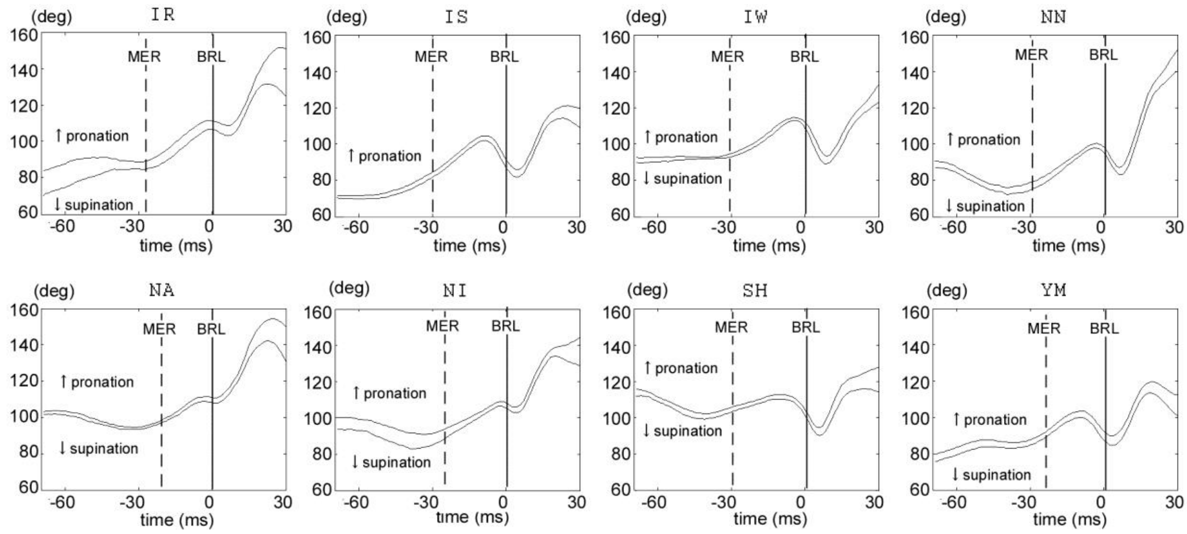

Figure 2: Pronation/supination around the moment of ball release. The two lines indicate mean ± SD. BRL is the moment of ball release, and MER is the moment of maximum shoulder external rotation. Two capital letters at the top of each plot shows initials of each participant. A subplot of one participant was eliminated due to limitations of space.

Thus, all the participants supinated their forearm at BRL, although the range of motion (ROM) and the duration of the supination were different among the participants. The ROM ranged from 1° to 19° (mean: 12.6° ± 8.1°), and the duration ranged from 4 to 16 ms (mean: 10.4 ± 4.0 ms).

The radio-ulnar joint did not have remarkable rotation before MER (Figure 2). After MER, all the participants began to rotate their wrist in the direction of pronation and continued it until dozens of milliseconds after BRL. The time-angle curves were relatively similar among the participants.

Discussion: Since the late 1970s, it was believed that the radio-ulnar joint pronated in the duration between MER and the instant of the maximum shoulder internal rotation (Atwater, 1979; Keeley et al., 2010; Nissen et al., 2007; Nissen et al., 2009). However, this study showed that the radio-ulnar joint supinated for a very short period (mean: 10.4 ± 4.0 ms) around BRL.

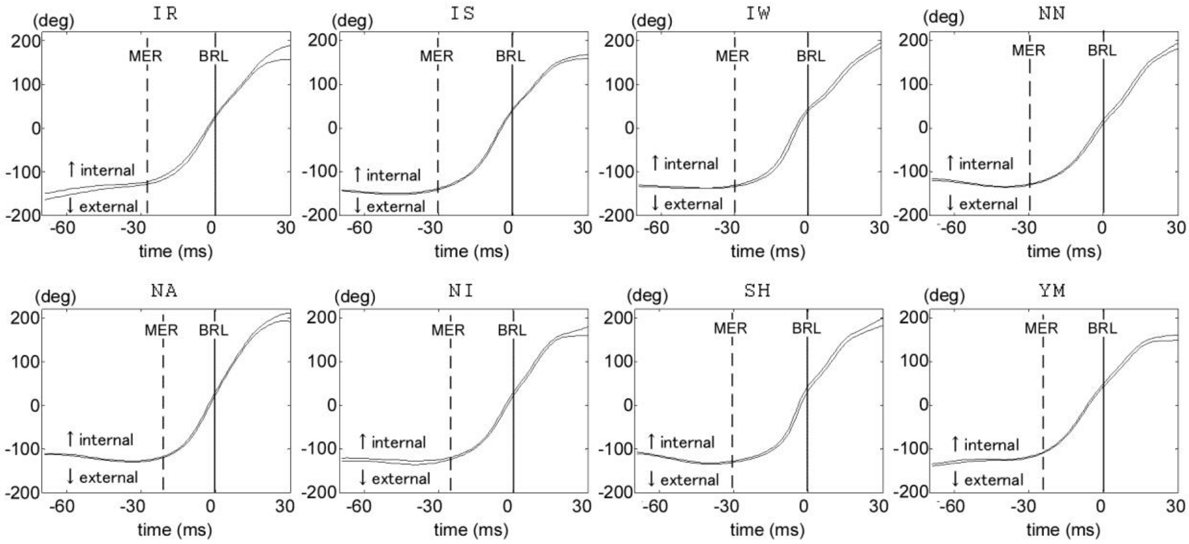

Figure 3: Internal/external rotation of forearm around the moment of ball release. The two lines indicate mean ± SD. BRL and MER are the moment of ball release and maximum shoulder external rotation, respectively. Two capital letters at the top of each plot shows initials of each participant. A subplot of one participant was eliminated due to limitations of space.

The pronation/supination angle, which was the relative angle between the vector from the medial elbow to the lateral elbow and the vector from the ulnar side of the wrist to the radial side of the wrist, was susceptible to the elbow orientation under a certain condition. When the elbow angle was around 90°, the radio-ulnar rotation was independent of the shoulder external/internal rotation. However, when the elbow angle was around 180°, the radio-ulnar rotation was not independent of the shoulder external/internal rotation; in fact, they were dependent on each other.

During the short-period supination, the elbow extended rapidly and the shoulder experienced a drastic internal rotation. Therefore, the radio-ulnar pronation/supination angle at around BRL was influenced by the shoulder internal rotation. As a result, the short-period supination occurred by the rapid change in the elbow orientation resulting from the large shoulder internal rotation.

This result was inconsistent with some previous studies in which the radio-ulnar pronation was shown to occur at around BRL (Atwater, 1979; Keeley et al., 2010; Nissen et al., 2007, 2009). In the global coordinate, the wrist joint began to rotate in the pronation direction from around MER, and continued doing so until dozens of milliseconds after BRL (Figure 2). This might cause misjudgment in some observers. The qualitative analysis performed by Atwater (1979) might have suffered from such misjudgment.

Regarding the inconsistency in results compared to those of previous studies, one possible explanation is the difference between methods that have been used. We used a 1000 Hz high-speed camera system and averaging multiple trials without smoothing. Keeley et al. (2010) used a 300 Hz high-speed digital video camera system and Butterworth filtering with a 16.7 Hz cut-off frequency. Nissen et al. (2007, 2009) used a 250 Hz high-speed camera system and Butterworth filtering with a 15 Hz cut-off frequency. These methods might have concealed the short-period supination. Another possible explanation is the difference in the skill level or age of participants. For example, our results were obtained from skillful adult pitchers, whereas Nissen et al. (2007, 2009) obtained their results from adolescent baseball pitchers. This might have influenced the results.

Another explanation for the inconsistent results was the large standard deviations reported in the previous studies. The large standard deviations indicate that there were large individual differences (Keeley et al., 2010; Nissen et al., 2007, 2009). It appears that the inconsistency in the radio-ulnar rotation was due to some methodological faults related to the treatment of large individual differences. Most of the pitchers had relatively small supination between large pronation, and the timings of pronation and supination were different among pitchers. Averaging the curves with different amplitudes and timings might have concealed small supination that might have actually occurred.

CONCLUSION: This study investigated the radio-ulnar longitudinal rotation before and after BRL during baseball pitching. We found that the radio-ulnar joint supinated during a short period around BRL (mean: 10.4 ± 4.0 ms). However, the wrist continued rotating in the direction of pronation in the global coordinate. The supination occurred because of the influence of the combination of the elbow extension and the shoulder internal rotation. Our results, which show the existence of a quick reverse rotation of the radio-ulnar joint, would be helpful in understanding pitching mechanics correctly, developing practice/training programs, and preventing throwing injuries.

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Acknowledgement

This study was supported by JSPS KAKENHI Grant-in-Aid for Scientific Research (B) (Grant Number: 25282193) and JSPS KAKENHI Grant-in-Aid for Challenging Exploratory Research (Grant Number: 24650385). We also thank Ms. Tsubasa Sugimoto for helping data collection.