

The potential impact from glenohumeral internal rotation deficit to the knee kinematics in baseball pitchers

A case-control study

Shih-Chung Cheng, PhD^{a,*} , Shu-Ming Lin, MPE^a, Won-Jean Lin, MD^b

Abstract

A recent study suggested that baseball pitchers with glenohumeral internal rotation deficit (GIRD) may tend to use trunk rotation as compensation to adjust ball placement, which may lead to subsequent counter movement at the knee of the leading leg.

This study aims to investigate the kinematic characteristics of the counter movements between the femur and the tibia (knee torsion), from the landing of the leading leg until the follow-through phase, during throwing between pitchers with and without GIRD at the dominant arm.

This is a case-control study. Twenty-one senior high school baseball pitchers were recruited in this study. The glenohumeral internal and external rotation, hip internal and external rotation of all participants were measured. Eight pitchers without GIRD and 13 pitchers with GIRD were enrolled into the control group and experiment group, respectively. The maximal angular movement between the femur and the tibia (knee torsion) of the leading leg was measured, using The Zebris 3D (Zebris Medizintechnik GmbH, Isny, Germany) motion analysis system, in the interval from the landing until the follow-through phase during pitching a fastball to the bottom-outside corner with their dominant arm.

The results showed that the maximal knee torsion of the leading leg in the experimental group (13.67 ± 0.9 degrees) was significantly greater than the control group (4.25 ± 1.369 degrees) ($P < .05$).

Pitchers with GIRD had greater counter movement in the knee joint than pitchers without GIRD.

Abbreviations: GIRD = glenohumeral internal rotation deficit, ROM = range of motion.

Keywords: anterior cruciate ligament, glenohumeral, kinematics, leading leg, range of motion

1. Introduction

Glenohumeral internal rotation deficit (GIRD) in baseball pitchers refers to either the deficit of the internal rotation of

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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the glenohumeral joint in their dominant arm being greater than the increase in the degree of external rotation or 10% larger than the total degree of rotation (internal and external) of the nondominant arm.^[1] GIRD is also a common comorbidity of a deficit in shoulder horizontal adduction. In baseball pitching, the lower limbs are also part of the kinetic chain. The leading leg initiates the movement, stepping out for support, then the force is transmitted via the torso and even to the upper limbs. When the force is transmitted from the lower limbs through the torso to the point where the baseball is released, the pitching arm exhibits maximum glenohumeral external rotation; simultaneously, the torso conducts forward rotation and inclination towards the opposite direction. Cheng et al (2011) found that when young pitchers with GIRD made fast and straight pitches, most balls could not hit the target but drifting towards the dominant side (i.e., a ball thrown by a right-handed pitcher would drift to the right side).^[2] In addition, Scher (2010) revealed that GIRD influences the range of motion (ROM) of the hip joints.^[3] Past studies also have found the relationship between GIRD and the hip ROM of the leading leg.^[3] Although the detailed mechanism of the relationship between GIRD and hip ROM is unclear, we would like to explore how GIRD may influence the knee joint during pitching. In addition, the knee joint has been reported with a potential risk factor from the leading leg landing with the foot fixed on the ground during pitching.^[4] A past study also suggested that internal tibial torque is an important loading mechanism of the anterior cruciate ligament (ACL) for an extended knee.^[5] Therefore, we were curious about the potential



Figure 1. Measurement of shoulder and hip external/internal rotation.

impact from GIRD to the anterior cruciate ligament. We were not able to directly identify the relationship between GIRD and ACL in this study, but we would like to explore the potential injury mechanism of pitchers' knee. The purpose of this study is to observe the difference in the angular movement between the femur and the tibia of the leading leg between pitchers with GIRD and without GIRD.

2. Methods

2.1. Participants

This is a case-control study. Twenty-one professional male pitchers from high school baseball teams were recruited in this study. The inclusion criteria were:

- (1) baseball pitchers,
- (2) use overhead pitching skill.

They were separated into 2 groups, including experiment group and control group. Eight pitchers with GIRD were enrolled into the experiment group, and 13 pitchers without GIRD were enrolled into the control group. Seventeen pitchers were right hand dominant and 4 pitchers were left hand dominant, all of them used overhead pitching skill.

The exclusion criteria were:

- (1) history of the knee or shoulder surgeries,
- (2) having waist injuries,
- (3) history of knee injuries or knee joint instability.

Participants were provided with a detailed information sheet, informing them the nature of the study and any associated risks. All participants gave their written consent to take part in this study and allow disclosure of their anonymized personal details. This study has been granted ethical approval by the University Institutional Review Board (NTSU-10025, 29/12/2012I9).

2.2. Equipment and procedure

In this study, a goniometer (OSSUR, Iceland) was used to evaluate the ROM of the glenohumeral joint (shoulder) and the hip joint. We used data obtained from shoulder ROM to separate participants into the experiment and the control groups. The

Zebri 3D motion analysis system (Zebri CMS-HS, Zebri Medizintechnik GmbH, Germany) was used to evaluate the kinematic characteristics of the knee joint, the angular movement between the femur and the tibia (hereafter, knee torsion).^[6] Passive glenohumeral external rotation, internal rotation, and horizontal adduction were measured in a supine position^[7–9] while the hip external rotation and internal rotation were measured in a prone position (Fig. 1).

This study adopted an ultrasonic receiver with 6 sensors on 2 T-shaped plates (triplet passive sensors). One of the T-shaped plates was placed at the superior lateral thigh (10 cm below the trochanter major) to define the coordinate system of the thigh, and the other was placed 5 cm above the lateral malleolus to define the coordinate system of the shank. During measurement, the ultrasonic receiver was placed between 50 and 100 cm from the lateral side of the tested knee (Fig. 2). The absolute measurement error of the Zebri CMS-HS was demonstrated to be less than 1 mm.^[10] When analysing the angular kinematics of the limbs, the Euler angle was adopted for description. The local coordinate system defined motion as follows: rotation along the y -axis is flexion/extension, rotation along the x -axis is abduction/adduction, and rotation along the z -axis is internal/external rotation. The gain of the acoustic wave sensor was set to 255 times, which was the optimum gain after each sensor was automatically adjusted. The sampling frequency was set to 50 Hz. All sampled data were shown on the connected computer in real-time. The data were stored in the computer hard drive and subsequently analyzed offline. The high-frequency digital error signals were filtered through a Butterworth low-pass filter with a cut-off frequency of 6 Hz. To avoid noise generated from reflected signals, the areas around the participants were covered with sound-absorbing materials (i.e., black cotton and bubble wrap). Before the experiment, a foot trigger was taped to the foot sole of the pitcher's leading leg to distinguish the timings between take-off in the preparation phase and the landing during the pitching motion. The foot trigger was connected to the Zebri CMS-HS for simultaneous data collection. Data recording was triggered at the landing of the leading leg.

The experiment was conducted on the pitcher's mound in an actual bullpen in a high school. A batting practice backstop was placed behind home plate. A target pad was placed at the

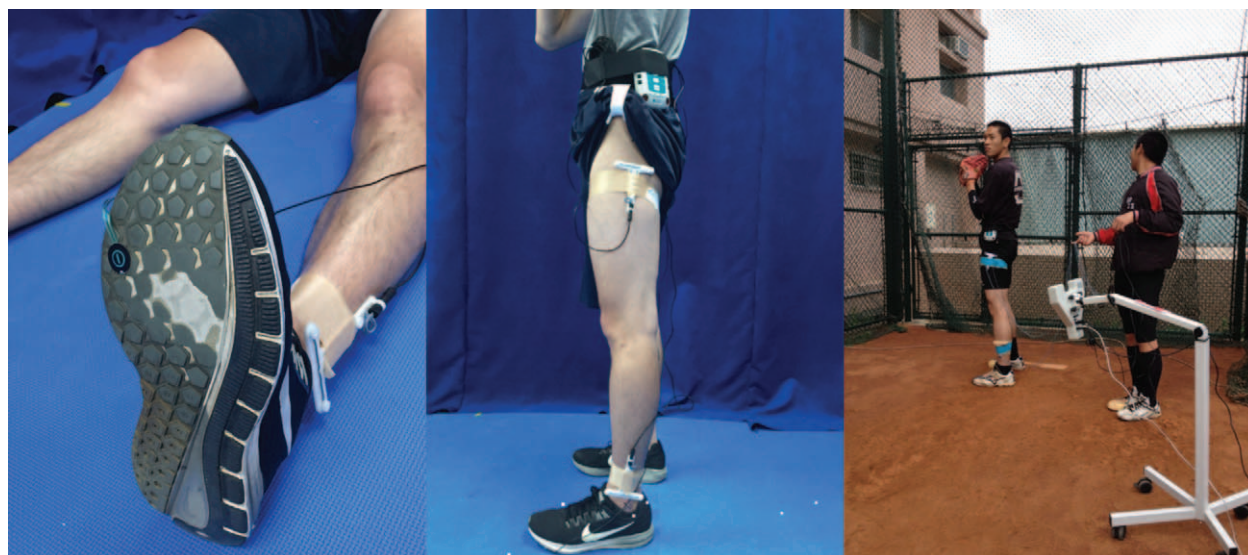


Figure 2. Experimental setup. The study was carried out in a bullpen in a senior high school using Zebris 3D motion system and T-shape sensors on the leading leg.

experimental site according to the strike zone, which generally refers to the area directly above the home plate, approximately between a batter's knees and waist. In this experiment, we set the target pad 30 cm above the ground. After the pitcher had warmed up sufficiently, he stepped on the pitcher's mound and aimed at the target shown on the target pad. The target pad was placed above the space in front of home plate. The distance between the pitcher's mound and home plate was the standard 18.44 m. The participant first warmed up (stretching and practice pitches) for 15 to 20 minutes. Next, he was fitted with 2 sets of passive sensors and 1 set of simultaneous data recording activation device.

We asked participants to throw 30 fastballs at maximum endeavour. The target was set at the bottom-outside corner of the strike zone (Fig. 3). During the experiment, pitchers were asked to throw a fastball to the bottom-outside corner with their dominant arm.

2.3. Data processing and statistical analyses

Among all pitches, data from the 5 pitches that hit the target were recorded. From the filtered data, the maximum knee torsion after the landing of the leading leg was obtained.

This study used the SPSS 13.0 statistical software for Windows (version 12.0, Chicago, IL) for analysis. All data are presented as mean ± standard deviation (SD). First, we used independent-samples *t* testing on the groups with and without GIRD on their dominant arms to compare their successful pitch movements and determine the differences in knee torsion. The significance level α was set to 0.05.

3. Results

Twenty-one pitchers were recruited, including 8 pitchers with GIRD in the control group (mean age 18.38 ± 1.49 years old,

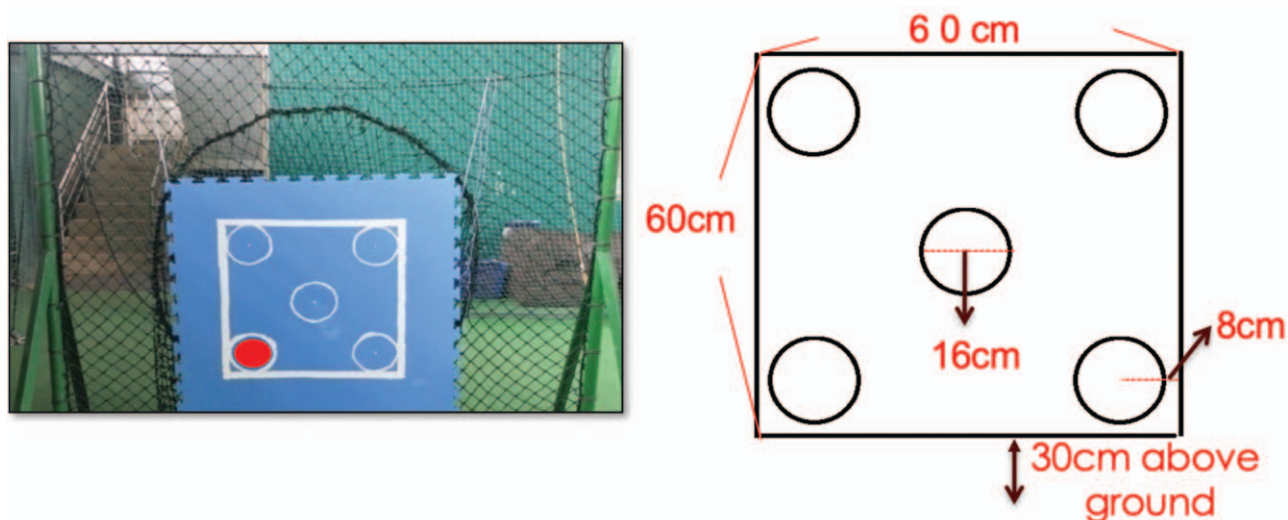


Figure 3. The design of the target. Pitchers were asked to throw fast ball to the bottom-outside corner of the strike zone.

Table 1
Baseline information of participants.

	Experimental group: GIRD [†] mean ± SD	Control group: non-GIRD mean ± SD	P
Height (cm)	181.0 ± 3.27	177.43 ± 4.84	.086
Weight (kg)	72.14 ± 8.35	73.57 ± 9.14	.389
Age (yr old)	18.14 ± 1.15	18.38 ± 1.49	.384
Playing history (yr)	7.71 ± 1.49	7.71 ± 1.48	.5
Number of participants	8	13	

[†] GIRD = glenohumeral internal rotation deficit.

mean height 177.43 ± 4.84 cm, mean weight 73.57 ± 9.14 kg, playing history 7.71 ± 1.48 years) and 13 pitchers with GIRD in the experiment group (mean age 18.14 ± 1.15 years old, mean height 181.0 ± 3.27 cm, mean weight 72.14 ± 8.35 kg, playing history 7.71 ± 1.49 years) (Table 1 and Table 2). Shoulder ROM all participants were evaluated, and the results showed significant differences in the internal rotation of the shoulder joints of the dominant arms. The internal shoulder rotation deficit of the experimental group was significantly larger than that of the control group (experimental group 41.67° ± 10.0°; control group 51.58° ± 5.55°; $P < .05$). By contrast, no significant difference was observed among the pitchers in the common phenomenon of increasing external shoulder rotation between the 2 groups.

The differences between the 2 groups in the ROM of the hip joints of the leading and trailing legs were listed in Table 2. The results revealed no statistical differences between the 2 groups, indicating that the ROM of the joints and the movement performance of the leading and trailing legs were highly homogeneous.

3.1. Knee torsion

Table 2 also lists the differences between the 2 groups in knee torsion. The maximum torsion of the experimental group (13.67° ± 0.9°) was larger than that of the control group (4.25° ± 1.369°, $P < .05$). The maximum value occurred mostly when the ball left the hand.

Table 2
Shoulder, knee, and hip range of motion measurements of participants.

	Experimental group: GIRD [†] mean ± SD	Control group: non-GIRD mean ± SD	P
Dominant arm			
Shoulder external rotation	112.78 ± 10.03	108.75 ± 6.49	.188
Shoulder internal rotation	41.67 ± 10.00	51.58 ± 5.55	.015*
Shoulder adduction	52.78 ± 8.54	57.50 ± 8.29	1.111
Non-dominant arm			
Shoulder external rotation	96.67 ± 10.27	96.88 ± 6.09	.62
Shoulder internal rotation	71.67 ± 15.63	61.88 ± 6.58	1.04
Shoulder adduction	56.11 ± 8.43	56.25 ± 8.57	.48
Trailing leg			
Hip external rotation	42.50 ± 8.66	40.0 ± 5.00	.339
Hip internal rotation	33.75 ± 4.78	38.33 ± 5.77	.15
Leading leg			
Hip external rotation	43.75 ± 6.29	41.67 ± 5.77	.336
Hip internal rotation	33.8 ± 7.50	38.3 ± 2.89	.18
Knee torsion			
Max (°)	13.67 ± 0.9	4.25 ± 1.37	.005*

[†] GIRD = glenohumeral internal rotation deficit.

* Significant differences in range of motion between 2 groups ($P < .05$).

Table 3
Knee torsion measurements for all pitches.

Knee torsion	Hit the target (mean ± SD)	Missed the target (mean ± SD)	P
GIRD [†]			
Max (°)	13.67 ± 0.9	12.25 ± 0.46	.01*
Non-GIRD			
Max (°)	4.25 ± 1.369	4.63 ± 0.51	.05

[†] GIRD = Glenohumeral Internal Rotation Deficit.

* Significant differences in knee torsion angles between 2 groups ($P < .05$).

Each group was analyzed separately for differences in knee torsion between pitches that successfully hit the target and those that missed. In the GIRD group, less knee torsion was observed from unsuccessful pitches (target missed) than successful pitches ($P < .05$); nonetheless, the torsion angles were significantly greater than those in the control group (Table 3). In the control group, no significant difference was found on the knee torsion between successful and unsuccessful pitches.

4. Discussion

A past study by Chen et al (2013) showed that young pitchers generated the phenomenon of GIRD after playing baseball for over 3 years.^[11] Furthermore, a study by Cheng et al (2011) showed that most ball placements of fast and straight pitches from young pitchers (11–15 years old) with GIRD drifted towards the dominant side.^[2] Possible explanation for this phenomenon could be an early release of the ball as a result from GIRD.^[12–14] However, pitchers with GIRD in the senior high school stage (16–18 years old) seem to be able to adjust the fast ball placement in order to hit the target. The results from the study by Cheng et al (2011) implied that there might be compensation movement from the trunk for pitchers with GIRD during pitching. In this study, the results in Table 3 show that greater knee torsion was observed from successful pitches than target missed pitches in pitchers with GIRD. Interestingly, the study by Chen et al (2015) compared pitchers' performances before and after treatment intervention with soft tissue management on pitchers with GIRD, they found that success rate became higher after glenohumeral internal rotation was improved.^[14] Another study by Wan (2019) found that pitchers with GIRD used greater trunk rotation to the non-dominant side for the pitching target at the bottom-outside corner of the strike zone.^[15] The results from Chen et al (2015) implied that GIRD could bring an negative impact on pitching performance, while Wan's study and present study implied that the impact from GIRD could lead to joints in the lower limbs.

Cross-examination of the groups did not reveal significant differences in the hip ROM at both sides of the same pitchers. However, pitchers with GIRD exhibited significantly greater hip external rotation of the leading leg than the trailing leg as well as greater angles for both hips than those of the control group. Ellenbecker et al (2007) also recorded the hip internal and external rotation angles (23° and 35°, respectively) of professional baseball pitchers.^[16] In the present study, the senior high school pitchers all used their dominant arms to pitch. When they pitched, all of them used their leading legs as pivots to rotate their pelvis and torsos anticlockwise. In other words, when their leading legs touched the ground, their pelvis rotated externally, which may result in the hip joint being passively carried to a

relatively externally rotated position. The hip joint was pressurised in this externally rotated position repeatedly. In addition, the knee torsion in the leading leg of the 2 groups of pitchers demonstrated significant differences ($P = .005$) in maximum angles. This phenomenon may lead to a hypothesis that pitchers with GIRD pitching to the bottom-outside corner (to non-dominant side), their body compensates by increasing torso rotation or external hip rotation to alter the direction towards that of the ball. This compensatory movement may lead to accumulative microtrauma to stabilisers of the knee joint in the long term. There are some limitations for this study, including small number of participants, uneven distribution in groups, participants were from 1 team only, potential movement between the skin 2 and the T-shaped sensors, and all participants were male. However, the finding from this study may be used as a reference for injury prevention.

5. Conclusion

Pitchers with GIRD in their dominant arm showed greater knee torsion than pitchers without GIRD, which may lead to unstable knee since the leading leg serves as a brake during pitching. Pitchers with GIRD may obtain benefit from treatment to improve shoulder ROM in order to avoid potential injury to the anterior cruciate ligament of the leading leg. Future studies could adopt treatment intervention for GIRD to identify its impact on knee torsion.

Author contributions

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Project administration: Shih-Chung Cheng.

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Writing – original draft: Shih-Chung Cheng.

Writing – review & editing: Shih-Chung Cheng.

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