Functional Hip Characteristics of Baseball Pitchers and Position Players

Article *in* The American Journal of Sports Medicine · October 2009

DOI: 10.1177/0363546509347365 · Source: PubMed

G Model
JSAMS-1065; No. of Pages 4
ARTICLE IN PRESS
Journal of Science and Medicine in Sport xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

The relationship between clinically measured hip rotational motion and shoulder biomechanics during the pitching motion

Kevin Laudner[a,b,*], Regan Wong[b], Takashi Onuki[b], Robert Lynall[c], Keith Meister[b]

[a] Illinois State University, United States
[b] Texas Metroplex Institute for Sports Medicine and Orthopedics, United States
[c] University of North Carolina at Chapel Hill, United States

ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form 17 July 2014
Accepted 19 July 2014
Available online xxx

Keywords:
Throwing athlete
Kinetic chain
Upper extremity
Lower extremity

ABSTRACT

Objectives: To examine how clinically measured hip motion is related to shoulder biomechanics during the pitching motion.
Design: Cross-sectional.
Methods: Bilateral hip rotational range of motion was measured clinically among 34 collegiate baseball pitchers. External rotation torque and maximum horizontal adduction range of motion of the throwing shoulder were measured using a three-dimensional, high speed video capture system.
Results: Separate standard multiple regression analyses showed that the total hip rotational range of motion of the lead leg had a significant relationship with shoulder external rotation torque during the throwing motion ($r = 0.56$, $P = 0.003$). Both lead leg hip external rotation range of motion ($r = -0.39$, $P = 0.02$) and internal rotation range of motion ($r = 0.42$, $P = 0.009$) made significant contributions to this dependent variable. Lead leg external rotation range of motion also had a significant negative relationship with shoulder horizontal adduction range of motion ($r = -0.36$, $P = 0.04$). The total rotational range of motion of the trail leg had a significant relationship with shoulder horizontal adduction range of motion ($r = 0.43$, $P = 0.04$). However, trail leg external rotation range of motion was the only significant contributor to this relationship ($r = -0.35$, $P = 0.04$). No other significant relationships were noted ($r < 0.37$, $P > 0.11$).
Conclusions: Our results demonstrate that altered hip rotational range of motion, measured clinically, has a direct effect on the amount of external rotation torque and horizontal adduction range of motion of the shoulder during the throwing motion.

1. Introduction

Described as one of the most highly dynamic skills in all sports,[1] baseball pitching requires contributions from the entire kinetic chain.[2,3] The lower extremity provides vital energy, which must be transferred through the trunk to the shoulder, arm, hand, and finally to the ball during every pitch. The large muscles in the legs, hip, and trunk act as force generators while the smaller musculature of the shoulder funnel these forces to the arm and ball.[4] Thus, when the kinetic chain is disrupted, pitchers may accommodate by placing a greater role on upper extremity force generation. Therefore, in order to optimize performance and reduce the risk of injury, especially in the upper extremity, all segments of the kinetic chain must effectively work together.

To maximize the energy transfer from the lower to the upper extremity, the lead leg (leg on opposite side of throwing arm) must be positioned correctly during the acceleration phase of the throwing motion, allowing for proper rotation of the pelvis, hips, and trunk.[1,5] The appropriate location of the lead leg foot as it contacts the ground has been described as being in front of the trail leg (leg on same side of throwing arm) foot with a slight toe-in orientation.[1,5] Because of the large amounts of torque transmitted to the upper extremity, improper sequencing of motion between the lower and upper extremity has been cited as a potential risk factor for shoulder pathology among these athletes.[6–9]

Because clinical measurements during the actual throwing motion are difficult to conduct without the use of sophisticated and expensive laboratory equipment, it is important to understand the relationships between clinical examination and throwing biomechanics. It is also critical to understand the effect specific lower extremity characteristics have on shoulder motion and forces generated during the throwing motion. Thus, the purpose of this study was to determine the relationship between clinical measurements

* Corresponding author.
E-mail address: klaudner@ilstu.edu (K. Laudner).

http://dx.doi.org/10.1016/j.jsams.2014.07.011

of hip rotational range of motion (ROM) and the amount of torque and motion developed in the shoulder during the throwing motion. We hypothesized that clinical measurements of hip rotational ROM would have a direct relationship with dominant shoulder torque and horizontal adduction ROM during the throwing motion. Being able to recognize lower extremity deficits clinically may be beneficial in the proper recognition and treatment of various upper extremity disorders that are the result of the accumulation of forces sustained during the throwing motion.

2. Methods

Thirty-four NCAA, Division I baseball pitchers (age = 20 ± 1.3 years; height = 187.2 ± 5.8 cm; mass = 86.9 ± 6.8 kg) voluntarily participated in this study. All participants had no recent history of upper or lower extremity injury (past 3 months) and no history of upper or lower extremity surgery.

Each participant attended one testing session in a motion analysis laboratory and provided informed consent as approved by the university's ethics review committee (IRB# 2011-0010). Height, mass, radius length, humerus length, and past medical history were obtained. The lead leg was defined as the leg on the opposite side of the throwing arm and has been previously described as the leg that contacts the ground at the initiation of the cocking phase.[4] The trail leg was defined as the leg on the same side as the throwing arm, which remains in contact with the ground during the stride phase of the throwing motion.[10]

Prior to any warm up, stretching, or throwing, bilateral hip rotational ROM were taken with the participant lying in a prone position and the knee flexed to 90°. The shank was passively rotated by one examiner until reaching the end ROM while the same examiner applied a stabilizing force to the posterior pelvis to limit pelvic rotation. The end ROM was defined as the point of first resistance without applying any overpressure. In this position, a second examiner aligned the Pro 3600 Digital Inclinometer (SPI-Tronic, Garden Grove, CA) with the tibial tuberosity and the midpoint between the medial and lateral malleoli. This digital inclinometer was modified with a reference line positioned along the midline of the device, which was used for proper alignment of anatomic landmarks. This alignment created an angle between the shank and a vertical reference line determined by the inclinometer. To determine the reliability of this measurement 22 participants (different individuals than those used for primary purpose of this study) completed pretest and posttest sessions, which were a minimum of 24 h apart. Our intraclass correlation coefficients for these internal and external hip rotation measurements were 0.95 and 0.92, respectively. Furthermore, the standard error of measurement values for assessing hip internal and external rotation ROM were 2.8° and 3.3°, respectively.

Prior to pitching data collection, all participants were instructed to proceed through their preferred warm-up routine (e.g. static and dynamic stretching, throwing exercises, and pitching specific exercises). Upon completion of the warm-up, 26 spherical 1.27 cm diameter reflective markers (Motion Analysis Corporation, Santa Rosa, CA) were placed on each participant using a standard setup and secured with electrode collars and tape.[11–13] Markers were placed on the throwing arm side radial and ulnar styloids and third metacarpal. Bilateral markers were placed at the superior lateral acromions, lateral humeral epicondyles, anterior and posterior hips, medial and lateral femoral epicondyles, medial and lateral malleoli, between the second and third metatarsal heads, and on the calcaneus. Markers were also placed on the right side, left side, and top of the head (markers were attached to a hat worn by each pitcher). Participants wore spandex shorts and no shirt to limit movements of the markers from the anatomical landmarks during the pitching motion.

Table 1
Descriptive statistics for hip range of motion measured clinically.[a]

Hip motion	Lead leg (°)	Trail leg (°)
Internal rotation	27.7 ± 5.9	28.9 ± 7.2
External rotation	35.8 ± 3.4	35.4 ± 6.2
Total arc of motion	63.4 ± 7.0	64.2 ± 8.4

[a] Values are presented as mean ± standard deviation.

Once this set-up was complete each participant acclimated himself to a collegiate regulation indoor pitching mound (Osborne Innovative Products, Inc., Jasper, IN) and threw to a strike zone target positioned 18.4 m away. Five representative fastball trials were gathered for each pitcher with typical throwing mechanics by what felt natural for each respective participant. Wild pitches and those pitches excluded by the athlete were not part of the subsequent data collection. All pitches were charted for location from behind the athlete and pitch velocity was assessed using a radar gun (Stalker Sport, Plano, TX) at a point directly behind the target zone for accuracy and consistency of readings. These pitches were recorded using 8 electronically synchronized high-speed (240 Hz) Eagle digital cameras (Motion Analysis Corporation, Santa Rosa, CA) that surrounded the pitching mound. The average of three fastballs, thrown for strikes, with the highest ball speeds was used for analysis.

The reflective markers were tracked using ExpertVision software (EVa 6.0, Motion Analysis Corporation) and three-dimensional coordinate data was determined using the direct linear transformation method. The joint centers of the throwing and non-throwing shoulder and elbow were estimated as previously described by Fleisig et al.[8] Coordinate data were then filtered using a Butterworth fourth-order, zero-lag digital filter (cutoff = 10 Hz). In order to calculate shoulder torque the methods previously described by Feltner and Dapena[14] were used. Shoulder horizontal adduction ROM was calculated using the methods described by Werner et al.[11,12] To normalize data between participants, torque was expressed as percent body weight × height.

Separate standard multiple regression analyses with Predictive Analytics Software (Version 18.0, International Business Machines Corp, Armonk, NY) were used to determine if relationships existed between hip external rotation ROM variables (independent variables) and external rotation torque produced at the throwing shoulder, as well as maximum shoulder horizontal adduction ROM during the throwing motion (dependent variables). The alpha level was set at 0.05 prior to all analyses.

3. Results

The average and standard deviation for shoulder external rotation torque and shoulder horizontal adduction ROM while throwing were 5.1 ± 1.0% body weight x height and 21.0 ± 8.1°, respectively. The descriptive characteristics for clinical hip ROM measurements can be found in Table 1. Paired t tests showed that there were no bilateral differences in either hip external rotation ($P = 0.64$) or internal rotation ($P = 0.39$).

All relationships between lead leg hip characteristics and throwing biomechanics can be viewed in Table 2. A moderate relationship was found for total hip rotational ROM measured clinically of the lead leg and shoulder external rotation torque during the throwing motion ($r = 0.56$, $P = 0.003$). Both lead leg hip external rotation ROM ($r = -0.39$, $P = 0.02$) and internal rotation ROM ($r = 0.42$, $P = 0.009$) made significant contributions to the dependent variable. Lead leg external rotation ROM also had a significant negative relationship with shoulder horizontal adduction ROM ($r = -0.36$, $P = 0.04$).

All relationships between trail leg hip characteristics and throwing biomechanics can be viewed in Table 3. Total hip rotational ROM

Table 2
Relationship between lead leg clinical hip ROM and pitching biomechanics.[a]

Lead leg hip motion (°)	Shoulder ER torque (% body wt × ht)	Shoulder horizontal adduction (°)
Internal rotation	0.42, 0.009[b]	0.07, 0.67
External rotation	−0.39, 0.02[b]	−0.36, 0.04[b]
Total arc of motion	0.56, 0.003[b]	0.37, 0.11

[a] Values are correlation (r), significance value (P).
[b] Indicates statistically significant relationship ($P < 0.05$).
ROM: range of motion; ER: external rotation; wt: weight; ht: height.

Table 3
Relationship between trail leg clinical hip ROM and pitching biomechanics.[a]

Trail leg hip motion (°)	Shoulder ER torque (% body wt × ht)	Shoulder horizontal adduction (°)
Internal rotation	0.16, 0.40	0.18, 0.27
External rotation	0.03, 0.16	−0.35, 0.04[b]
Total arc of motion	0.15, 0.70	0.43, 0.04[b]

[a] Values are correlation (r), significance value (P).
[b] Indicates statistically significant relationship ($P < 0.05$).
ROM: range of motion; ER: external rotation; wt: weight; ht: height.

of the trail leg had a significant relationship with shoulder horizontal adduction ROM ($r = 0.43$, $P = 0.04$). However, trail leg external rotation ROM was the only significant contributor to this relationship ($r = -0.35$, $P = 0.04$). No other significant relationships were noted ($r < 0.37$, $P > 0.11$).

4. Discussion

With the already large amounts of force produced at the shoulder during the pitching motion,[1,10,15] deficits within the kinetic chain may lead to dangerously heightened torques of the upper extremity.[7] More specifically, clinicians have speculated that insufficient hip rotation ROM may increase the force placed on the shoulder during the throwing motion.[1,5] However, to date this relationship has never been empirically confirmed. Our study is the first to show an association between reduced clinical hip ROM measurements and increased shoulder torque and motion during the throwing motion. These results provide valuable insight into the complexities of monitoring the kinetics and kinematics of the throwing shoulder.

During the acceleration phase of the throwing motion, it is important for the lead foot to contact the ground with the toes pointed in the relative direction of the intended target, which requires external rotation of lead leg hip.[16] Several authors have stated that if pelvis does not produce optimal rotation with respect to the intended target during the acceleration phase, the pitcher may end up throwing across their body.[1,7] This can then cause a decrease in the transfer of energy from the lower to upper extremity and potentially expose the pitcher to a greater risk of shoulder injury.[1,10] The results of our study support these previous studies. More specifically, we saw that decreased hip external rotation ROM of the lead and trail legs led to increased shoulder horizontal adduction ROM of the throwing arm, which means these athletes were throwing more across their bodies. Furthermore, the decreased lead leg hip external rotation ROM also correlated with increased shoulder external rotation torque of the throwing arm meaning more stress was being placed on the shoulder. Therefore, our findings support previous theories that decreased hip rotation ROM can cause pitchers to not only throw more across their body, but also may disrupt the transference of kinetic force, subsequently leading to increased torque being placed on the throwing shoulder.

Conversely, authors have stated that if too much hip motion rotation occurs the transference of kinetic energy from the lower to upper extremity can also be disrupted placing undue stress on the shoulder.[1] However, the negative relationship found between our variables does not support this hypothesis. Although, other variables, such as trunk rotation and trail leg hip internal rotation, could lead to this over rotation and subsequent increased upper extremity stress. Future research in this area is needed to confirm this hypothesis.

To the best our knowledge, our study is the first to investigate clinical measures of hip rotation ROM and establish a correlation to shoulder biomechanics during the throwing motion. Thus, clinicians may use this common and inexpensive hip ROM measurement to partially determine the force and motion created at the shoulder during the throwing motion. This information may further be used to identify and combat hip external rotation ROM deficits prior to the development of shoulder pathology among baseball players.

Our results demonstrate the relationship between clinically measured hip rotation ROM and shoulder biomechanics during the throwing motion. However, this is only one, small piece of the complex sequence of events which occurs within the kinetic chain during the throwing motion. Robb et al.[17] showed that passive hip ROM was correlated with biomechanical changes in trunk and pelvis movement during the throwing motion. Although, these authors did not investigate shoulder biomechanics, their results show that alterations at the distal segment affect those of the proximal segments. Our results provide further examples of how distal segment motion can affect proximal segments further up the kinetic chain. Furthermore, our results show that hip ROM alterations do not just affect the closest proximal segments (i.e. pelvis and trunk), but rather can have detrimental effects to segments further up the kinetic chain (e.g. shoulder). As such, it would be interesting to note what biomechanical changes may present in the elbow and wrist as a result of hip ROM.

While our study is unique in its design, several limitations exist. First, as previously mentioned, hip rotation ROM is only one small segment of the kinetic chain necessary during the throwing motion. The contribution of subsequent lower and upper extremity motions may provide some explanation of the variance in our reported relationships. As such, other clinical ROM measurements of the lower extremity and trunk, such as thoracolumbar rotation, trunk flexion and extension, and hip abduction, adduction, flexion, and extension, are necessary to fully understand how the lower extremity affects the upper extremity while throwing. Clinical measurements of the shoulder and elbow should also be investigated for possible correlations with upper extremity biomechanics during throwing. Second, during high-speed video analysis of the throwing motion, skin movement where markers are placed in inevitable. However, efforts to minimize this movement were conducted and numerous previous studies using similar methodology have been published in various peer-reviewed publications.[13,18–20] Third, it is impossible to directly tie our findings to shoulder injuries among baseball pitchers. As we only investigated the relationships between ROM and throwing biomechanics, further prospective studies should be conducted to determine if hip ROM deficiencies lead to shoulder pathology. Furthermore, all of our participants were currently asymptomatic and our results reflect collegiate level pitchers and should be cautiously applied to all other levels of baseball competition. However, our data provide ranges of hip external rotation ROM that should be considered potentially pathologic in regards to shoulder injury among such athletes.

5. Conclusions

Our results demonstrate that baseball pitchers who have decreased lead leg hip external and internal rotation ROM during clinical measurements have increased amounts of dominant

Please cite this article in press as: Laudner K, et al. The relationship between clinically measured hip rotational motion and shoulder biomechanics during the pitching motion. *J Sci Med Sport* (2014), http://dx.doi.org/10.1016/j.jsams.2014.07.011

shoulder external rotation torque during the throwing motion. Decreased hip external rotation ROM also resulted in increased horizontal adduction ROM while throwing. Decreased hip external rotation ROM of the trail leg was also associated with increased horizontal adduction ROM of the throwing arm during this motion. As such, our findings support previous theories that decreased hip rotation ROM can cause pitchers to not only throw more across their body, but also may disrupt the transference of kinetic force, subsequently leading to increased torque being placed on the throwing shoulder. Therefore, clinicians should consider measuring bilateral hip rotational ROM to partially predict shoulder motion and torque during the throwing motion. Deficits in this hip ROM should also be addressed in the prevention and rehabilitation of the various shoulder pathologies that are common among baseball players.

Practical implications

- Alterations in hip range of motion measured clinically showed direct relationships to alterations in shoulder biomechanics during the throwing motion.
- Clinicians should consider measuring bilateral hip rotational ROM to partially predict shoulder motion and torque during the throwing motion.
- These results should be considered in the prevention, evaluation, and treatment of shoulder injuries common among baseball players.

Acknowledgements

There was no financial and technical or other assistance provided for this study.

References

1. Dillman CJ, Fleisig GS, Andrews JR. Biomechanics of pitching with emphasis upon shoulder kinematics. *J Orthop Sports Phys Ther* 1993; 18:402–408.
2. Hirashima M, Yamane K, Nakamura Y et al. Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. *J Biomech* 2008; 41:2874–2883.
3. Kibler WB, Thomas SJ. Pathomechanics of the throwing shoulder. *Sports Med Arthrosc* 2012; 20:22–29.
4. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy* 2003; 19:641–661.
5. Wilk K, Meister K, Fleisig G et al. Biomechanics of the overhead throwing motion. *Sports Med Arthosc Rev* 2000; 8:124–134.
6. Stodden DF, Fleisig GS, McLean SP et al. Relationship of pelvis and upper torso kinematics to pitched ball velocity. *J Appl Biomech* 2001; 17:164–172.
7. Wight J, Richards J, Hall S. Influence of pelvis rotation styles on baseball pitching mechanics. *Sports Biomech* 2004; 3:67–83.
8. Fleisig GS, Barrentine SW, Zheng N et al. Kinematic and kinetic comparison of baseball pitching among various levels of development. *J Biomech* 1999; 32:1371–1375.
9. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. *Sports Med* 2006; 36:189–198.
10. Wilk KE, Meister K, Fleisig G et al. Biomechanics of the overhead throwing motion. *Sports Med Arthrosc Rev* 2000; 8:124–134.
11. Werner SL, Guido JA, Delude NA et al. Throwing arm dominance in collegiate baseball pitching: a biomechanical study. *Am J Sports Med* 2010; 38:1606–1610.
12. Werner SL, Guido Jr JA, Stewart GW et al. Relationships between throwing mechanics and shoulder distraction in collegiate baseball pitchers. *J Shoulder Elbow Surg* 2007; 16:37–42.
13. Werner SL, Suri M, Guido Jr JA et al. Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *J Shoulder Elbow Surg* 2008; 17:905–908.
14. Feltner M, Dapena J. Dynamics of the shoulder and elbow joints of the throwing arm during a baseball pitch. *Int J Sport Biomech* 1986; 2:235–259.
15. Werner SL, Fleisig GS, Dillman CJ et al. Biomechanics of the elbow during baseball pitching. *J Orthop Sports Phys Ther* 1993; 17:274–278.
16. Fleisig G, Dillman CJ, Andrews J. Proper mechanics for baseball pitching. *Clin Sports Med* 1989; 1:151–170.
17. Robb AJ, Fleisig G, Wilk K et al. Passive ranges of motion of the hips and their relationship with pitching biomechanics and ball velocity in professional baseball pitchers. *Am J Sports Med* 2010; 38:2487–2493.
18. Fleisig GS, Andrews JR, Dillman CJ et al. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med* 1995; 23:233–239.
19. Sabick MB, Torry MR, Lawton RL et al. Valgus torque in youth baseball pitchers: a biomechanical study. *J Shoulder Elbow Surg* 2004; 13:349–355.
20. Dun S, Loftice J, Fleisig GS et al. A biomechanical comparison of youth baseball pitches: is the curveball potentially harmful? *Am J Sports Med* 2008; 36:686–692.

Please cite this article in press as: Laudner K, et al. The relationship between clinically measured hip rotational motion and shoulder biomechanics during the pitching motion. *J Sci Med Sport* (2014), http://dx.doi.org/10.1016/j.jsams.2014.07.011