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ORIGINAL RESEARCH

CHANGES IN HIP RANGE OF MOTION AND STRENGTH IN COLLEGIATE BASEBALL PITCHERS OVER THE COURSE OF A COMPETITIVE SEASON: A PILOT STUDY.

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ABSTRACT

Background: Adaptations in hip range of motion (ROM) and strength have been shown to influence performance and injury risk in overhead athletes. These adaptations in hip ROM and strength have not been examined longitudinally, and little is known regarding whether these changes are a result of pitching workload.

Hypothesis/Purpose: The authors hypothesized that hip rotation ROM and strength would change over the course of a season, and would be associated with pitching workload (number of pitches over the course of a season). The purpose of this exploratory, pilot study was twofold: 1) to examine changes in hip external rotation (ER) ROM, internal rotation (IR) ROM, isometric hip abduction and hip extension strength in pitchers occurring over the course of a competitive season, and 2) to determine the association between changes in hip ROM, strength, and pitching volume.

Study Design: Cohort (longitudinal) study

Methods: Bilateral hip rotation ROM and hip isometric strength was tested pre- and post-season in fourteen collegiate baseball pitchers. Pearson correlations were calculated to determine the association between changes in hip ROM, strength, and pitching workload.

Results: Trail and lead hip ER, trail and lead hip total rotational ROM, and trail and lead hip abduction strength in all pitchers decreased from preseason to postseason ($p < 0.01$). However, these changes were not significantly associated with pitching workload ($p > 0.05$).

Conclusion: This study demonstrates that changes occur in hip ROM and strength in collegiate pitchers over the course of a season. These changes were not associated with pitching workload

Level of Evidence: 3

Keywords: Baseball, hip strength, pitch count, range of motion

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Disclaimers

The authors have no financial disclosure or conflicts of interest to report for this manuscript

Acknowledgements

Aimee Struk MEd, ATC, Pat Hassell ATC, and The University of Florida Athletic Association.

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INTRODUCTION

The pitching motion is a complex sequence of movements involving the transfer of energy from the lower extremity to the upper extremity and finally to ball release. [1-8] In this dynamic process, the lower extremities act as force generators, while the upper extremities direct and control the generated forces before delivery of the ball. [1,2,5-8] This motion occurs repeatedly over the course of a season and may contribute to many unique lower extremity adaptations in the overhead athlete.[9,10] However, studies examining changes in hip rotational ROM (internal rotation [IR] and external rotation [ER] ROM) have been cross-sectional and it is not known whether these changes occur over the course of a season due to the constant loading of the lower extremities related to pitching workload.**[1,9,11,12]** These adaptations in hip rotation ROM may be analogous to the rotational changes that are known to occur in the upper extremity due to pitching volume.[143-25]

Restrictions in hip rotational ROM may interfere with proper pitching mechanics, disrupting the efficient transfer of energy as well as the sequential timing of the pitching motion.[1,3,11,26-27] Both lead (leg opposite to throwing arm) and trail (leg on same side of the throwing arm) hips are responsible for generating and transferring energy through the kinetic chain during the pitching motion.[1-7, 28, 29] Biomechanical changes in hip rotational ROM have been shown to influence gleno-humeral joint stress as well as ball velocity.[1,3,5,6,30] Therefore it is logical that if restrictions in hip rotational ROM occur over the course of a season due to increased pitching workload, these changes may directly contribute to upper or lower extremity injury. [5]

In addition to changes in hip rotation ROM, fatigue of hip musculature due to repeated exposure to loading while pitching may result in the failure of proper throwing mechanics over the course of a competitive season.[1,31-34] Specifically, a decrease in hip abduction and extension strength has been correlated with upper extremity injury. [1,5,32,33] Weakness in hip abductors and extensors may contribute to excessive lower extremity joint stress, which could lead to a higher risk of hip osteoarthritis and labral tears through a mechanism comparable to what has been documented in the shoulder. [1,5,9,28,35,36]

Pitching workload (number of pitches over the course of a season) may affect pitchers hip rotational ROM and strength differently based on pitching roles. In a cross-sectional study, Laudner et al[1] showed differences in hip internal rotation ROM and abduction strength between pitchers and position players.[1] This may be a result of inherent differences between pitching (mound), where the movement downward from the pitching rubber into lead foot contact generates the force, compared to flat ground throwing where force is generated strictly through the utilization of the athletes legs.[1] Alternatively, these differences may be a function of pitching or throwing volume.[1,37] Conversely, no study has reported on the relationship between pitching workload and the adaptations of hip ROM and strength over the course of a competitive season.

Changes in hip ROM and isometric strength as potential injury risk factors have been examined cross-sectionally, but it is not known if these changes occur over the course of a season and whether these changes are a result of pitching workload. Despite the evidence describing the importance of hip rotation ROM and strength while pitching, there is no descriptive data, detailing the change of hip rotation and strength profiles in Division 1 baseball pitchers due to pitching workload over the course of a season. Establishing descriptive data on hip ROM and strength over the course of a season may help in determining whether there is a need to monitor changes in hip ROM and strength during examination to detect potential irregularities which may lead to injury or decreased performance. The purpose of this exploratory, pilot study was twofold: 1) to identify changes in hip ER ROM, IR ROM, isometric hip abduction and hip extension strength in pitchers occurring over the course of a competitive season, and 2) to determine the association between changes in hip ROM, strength, and pitching volume.

METHODS

Subjects

Fourteen Division 1 collegiate baseball pitchers (age = 19.4 $\pm$ 1.4 years, height = 189.0 $\pm$ 6.4 cm, weight = 96.1 $\pm$ 8.4 kg) consented to participate in this study. Nine subjects were right hand dominant and five were left hand dominant. Descriptive data (including collegiate playing year, innings pitched, pitching workload, and maximum velocity measured with a radar gun) for all subjects are shown in Table 1.

Operational Definitions

The dominant-side hip was defined as the hip on the same side of the throwing arm and referred to as the "trail hip". The non-dominant-side hip was defined as the hip contralateral to the throwing arm and referred to as the "lead hip". Strength was defined as the maximum amount of force produced during a five second isometric muscle contraction.

Procedure

All subjects were tested twice: once prior to the beginning of the season before preseason workouts, and again at the end of post-season (Super regional) play, which totaled 66 games (over five months). The individual pitching workload of each subject (calculated by number of pitches thrown during each game) was documented over the course of the season by the University coaching staff. The variability between number of pitches thrown over the course of the season by the subjects is due to the specific pitching role i.e. starter only, starter-reliever, and relief only pitcher. The Institutional Review Board of The University of Florida approved this study.

Hip joint ROM measurements

Subjects were placed in a prone position on a treatment table with the testing hip (hip being measured) in 0 degrees of extension and abduction and knee in 90 degrees of flexion.[9] (Figure 1) A two-tester method was used. One tester stabilized the pelvis with one hand to minimize excess movement and used the other hand to move the hip passively until the end of hip joint ROM (first resistance) was observed. The second tester placed the bubble inclinometer proximal on the medial malleolus and recorded the amount of external and internal rotation. This method was chosen because it has shown good interclass correlation (ICC = . 98), ease of use, and similarity to the extended hip position present when throwing a baseball.[9] Total rotational arc of motion was calculated as the sum of hip IR ROM plus hip ER ROM.

Isometric Strength Testing

All isometric strength testing was performed using the microFET 2 digital handheld dynamometer (Hoggan Health Industries, Salt Lake City, Utah). The microFET 2 has a certificate of calibration and

Table 1. *escriptive Statistics for Pitchers. Numbers represent mean + standard deviation*

Sample	14 pitchers 4 starter only 3 starter/reliever 7 reliever
Age (years)	19.35 ± 1.4
Height (Cm)	189 ± 6.4
Weight (Kg)	96.1 ± 8.4
Throwing Hand Dominance	Right handed = 9 Left handed = 5
College Playing Year	Freshman = 5 3rd Year Sophomore = 2 Sophomore = 2 Junior = 1 Senior = 4
Innings Pitched (innings)	45.6 ± 28.6
Pitching Workload (pitches)	674.7 ± 406.1
Max Velocity (mph)	92.8 ± 2.5

Cm = centimeters; Kg = kilograms; mph = miles per hour

Figure 1. *Hip External and Internal Rotation measured with a Bubble Inclinometer.*

documented accuracy up to 1% and Krause et al[38] reported interrater reliability for hip abduction (ICC = .86 to .92) and hip extension (ICC= .91 to .93)) and intrarater reliability (hip abduction (ICC = .81) and hip extension (ICC = .88).[38,39] All measurements were recorded in Newton-meters (Nm) and included one trial for each measurement. Make tests were performed for all strength measures.[40]

Hip abduction strength testing was performed with the subject in a side-lying position, with their testing hip facing up. (Figure 2)[38-41] The test hip was positioned slightly extended beyond the midline of the pelvis.[38-41] The non-tested lower extremity was positioned into 30 to 40 degrees of hip flexion and 90 degrees of knee flexion. [38-41] A second examiner stood behind the subject and stabilized the pelvis by placing their hands along the lumbar spine and anterior iliac spine. The dynamometer force pad was placed proximal the lateral femoral condyle and the subject was asked to push into the force pad as hard as they could for five seconds. The repetition was excluded if the subject could not maintain a proper testing position during their maximal contraction. The process was then repeated on the contralateral side.

Hip extension strength was tested using a two-tester method. The subject was placed prone with their knee flexed to 90 degrees. (Figure 3) One tester stood on the ipsilateral side of the test hip and stabilized the pelvis by gripping the lumbar spine, while the other tester positioned the handheld dynamometer force pad over the posterior aspect of the thigh just proximal to the popiteal fossa.[38-41] All subjects hip extension ROM was measured to ensure that they were able to extend their hip into the test position and no modification to the test had to be made due to hip flexor tightness.[18] The subject was instructed to push into the pad as hard as they could for five seconds. The process was also repeated on the contralateral side.

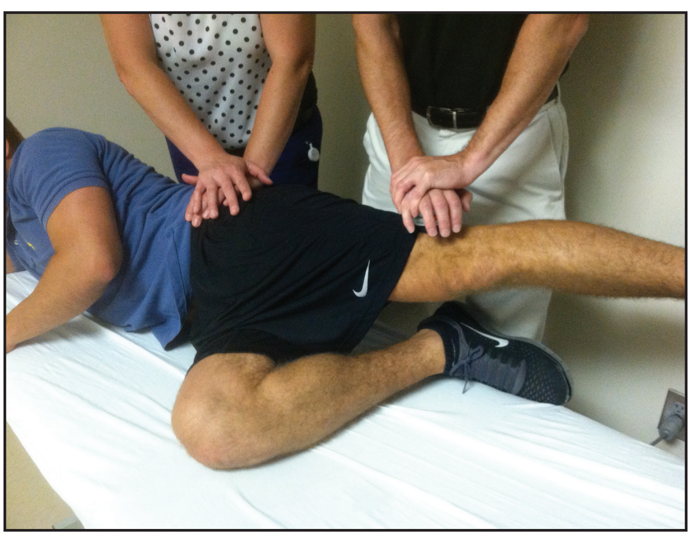

Figure 2. *Hip Abduction Strength measured with a Digital Hand Held Dynamometer (Hoggan Health Industries, Salt Lake City, UT)*

Figure 3. *Hip Extension Strength measured with a Digital Hand Held Dynamometer (Hoggan Health Industries, Salt Lake City, UT)*

Statistical Methods

All statistical analyses were performed with SPSS version 20.0 (Chicago, IL) with an α = .05. Descriptive statistics were calculated for selected demographic variables. Dependent t-tests were used to calculate differences in lead and trail hip ROM and strength from pre- to post- season. Pearson correlations were used to evaluate the association between number of pitches over the course of a season and changes in hip ROM and strength.

RESULTS

Changes from pre to post season hip rotational ROM measures

Mean changes in pre to post season hip ROM and strength for all pitchers are shown in Table 2. Pitchers displayed significant changes in trail (t= 5.365, df=13, p = .001, mean change =-10.3 deg ± 7.2) and lead (t=2.887, df=13, p=.01, mean change = -7.9 deg ± 10.2) hip ER, and trail (t=4.110, df=13, p=.001, mean change = -8.4 deg ± 7.9) and lead (t=2.718, df=13, p=.02, mean change =-9.2 deg ± 11.9) hip total rotational ROM.

Changes from pre to post season hip strength measures

Pitchers displayed significant changes in lead (t=3.211, df=13, p=.007, mean change = -14 ± 16.9Nm) and trail (t=4.352, df=13, p = .001, mean change = -21.7 ± 18.6 Nm) hip abduction strength over the course of the season. There were no significant changes in lead (t= 2.322, df=13, p=.24, mean change = -4.5 ± 16.9 Nm) and trail (t=3.410, df=13, p=.06, mean change = -8.7 ± 18.2) hip extension strength over the course of the season.

Table 1. *Pre- to Post-Season Hip Range of Motion and Strength Changes for Pitchers*

Measurement	Pre Season Measurement ± SD	Post Season Measurement ± SD	Change ± SD (± SEM)	p-value
Lead Hip ER ROM (degrees)	33.4 ± 9.8	25.6 ± 5.7	-7.9 ±10.2 (± 2.7)	.01*
Trail Hip ER ROM (degrees)	37.1 ± 7	26.9 ± 5	-10.3 ± 7.2 (± 1.9)	.001*
Lead Hip IR ROM (degrees)	17.1 ±7.2	15.1 ± 4.2	-2 ± 6.2 (± 1.7)	.23
Trail Hip IR ROM (degrees)	15.1 ± 4.6	14.7 ± 5.1	-.4 ± 3.9 (± 1.0)	.69
Lead Total Arc ROM (degrees)	50.6 ±14.8	41.4 ± 8.1	-8.5 ± 11.9 (± 3.2)	.02*
Trail Total Arc ROM (degrees)	50.3 ± 10.5	41.7 ± 5	-8.4 ± 7.9 (± 2.1)	.001*
Lead Hip Abduction Strength (Nm)	107 ±10.6	93 ± 10.7	-14 ± 16.9 (± 4.4)	.007*
Trail Hip Abduction Strength (Nm)	109 ± 16.4	87.7 ± 10.6	-21.7 ± 18.6 (± 4.9)	.001*
Lead Hip Extension Strength (Nm)	74.6 ± 10.2	70.1 ± 11.9	-4.5 ± 13.5 (± 3.6)	.24
Trail Hip Extension Strength (Nm)	77.4 ± 11.5	68.7 ± 11.9	-8.7 ± 18.2 (± 3.4)	.06

* Denotes statistically significant difference
SD=standard deviation; Nm=Newton meter; SEM=standard error of measurement.

Relationship between pitching volume and hip ROM

The results of the correlations can be seen in Table 3. There were no significant correlations between changes in lead hip ER (r= -.430, P=.142), trail hip ER (r= -.181, p = .555), lead hip IR (r= -.208, p= .494), trail hip IR (r = -.173, p=.571), lead hip total rotational arc of motion (r= -.371, p=.212), and trail hip total rotational arc of motion (r= -.100, p=.745) and pitching workload.

Relationship between pitching volume and hip strength

Furthermore, there were no significant correlations between pitching workload and changes in lead abduction strength (r = -.145, p = .637)), trail abduction strength (r = -.327, p= .275), lead hip extension strength (r = -.085, p = .781), or trail hip extension strength (r = -.006, p= .983).

DISCUSSION

This is the first longitudinal study to describe the changes of lead and trail hip ROM and strength throughout the course of a competitive season. Although, numerous studies have established descriptive profiles of pitchers compared to position players, they have been cross-sectional and have not looked at the changes in these parameters due to pitching volume.[1]

The current results illustrate that throughout the course of the season, pitchers, on average, exhibit a statistically significant decrease in lead and trail hip ER and total arc hip ROM, however these changes may not be clinically observable. Due to the excessive positioning of the trail leg into internal rotation while driving and initiating the pitching motion, adaptations may occur in the trail hip restricting the amount of external rotation throughout the course of the season. Conversely, the decrease in lead hip ER may be a result of landing in excessive lead foot IR during the stride phase. Wilk et al[8] described the ideal position of lead foot contact to be between 5 to 25 degrees internal rotation.[1,28] Therefore, repetitively landing in lead hip internal rotation may result in a decrease in lead hip ER over the course of the season. Hence, changes in total arc of hip rotational motion seen in this study may have been driven by changes in trail hip ER in this sample of athletes. Trail leg internal rotation is critical for the essential positioning of the lead leg during the pitching motion.[1,26,27,29] This repetitive exposure could occur on average of 200 to 1500 times during the course of the season based on the distinctive role of the pitcher, which may explain these changes in total hip rotational ROM.[37]

The findings also detail a decrease in lead and trail hip abduction strength. These findings are important when considered within the context of previous studies detailing the importance of the lower extremity strength while pitching.[1,27,28,32] During the pitching motion, trail hip abductors stabilize the pelvis during wind-up and initiate the forward

Table 3. *Correlations Between Pitching Volume and Changes in Hip ROM and Strength*		
Pitching Volume - Lead Hip ER	r = -.430	p = .142
Pitching Volume - Trail Hip ER	r = -.181	p = .555
Pitching Volume - Lead Hip IR	r = -.208	p = .494
Pitching Volume - Trail Hip IR	r = -.173	p = .571
Pitching Volume - Lead Hip Total Arc of Motion	r = -.371	p = .212
Pitching Volume - Trail Hip Total Arc of Motion	r = -.100	p = .745
Pitching Volume - Lead Hip Abduction Strength	r = -.145	p = .637
Pitching Volume - Trail Hip Abduction Strength	r = -.327	p = .275
Pitching Volume - Lead Hip Extension Strength	r = -.085	p = .781
Pitching Volume - Trail Hip Extension Strength	r = -.006	p = .983
ER= external rotators; IR= internal rotators		

movement of the pitcher off the mound during the stride phase.[1,27,28,32,34] Lead hip abductors are active to maintain single leg stance, while the trunk and upper extremity rotate during the deceleration and follow-through phase.[1,27,29,31,32] These results demonstrate that over the course of a season the repetitive nature of the pitching motion may cause an overall decrease in lead and trail hip abduction strength, which may lead to improper sequencing of force production from the lower extremity to upper extremity. This sequencing pattern may place an increased burden on the upper extremity to generate force when pitching, leading to diminished velocity and increased risk for upper extremity injury.[5]

The results of the current study indicate that changes in ROM and strength were not related to the number of the pitches thrown over the course of a season. Additionally, pitch count did not relate to hip abduction and extension strength. One potential explanation for this is the study's definition of pitch count. Pitch count may not be a true indicator of overall pitching volume as pitch count only takes into account in game pitching volume and not pitching volume in practice or before or during games. These findings do not support the hypothesis that ROM and strength changes would be dependent on pitch count, however other factors such as the periodization (decrease in-season weight training) and anthropometric factors may play a role.

These results can be used to generate preliminary description of changes that occur throughout the course of a season that do not appear to be related to pitching workload. Based on the current results, changes do occur in pitcher's hip ROM and strength, however it cannot be determined whether these changes are protective or harmful. The current findings illustrate that these unfavorable adaptations hip ROM and strength which are described by previous authors are occurring through the course of a season and may lead to previously reported upper and lower extremity pathology and decreased overall sport performance.[1,3,5,6,30] These findings suggest that hip ROM and strength testing should be routinely conducted and changes must be monitored in order to determine if decreases or increases in motion and strength may contribute to dysfunctional throwing mechanics, which will increase injury risk and diminished athletic performance. Additionally, these changes should be monitored to determine if potential subjects should be placed on specific preventive hip rehabilitation programs.

Future research and limitations

This pilot study has limitations that should be considered when interpreting the data. This sample consisted of 14 Division 1 collegiate baseball players, which may have been too small to accurately detect changes or relationships. Future research should look at tracking these parameters over the course of a season with a larger sample size. Additionally, repeated testing over multiple years may give an accurate assessment of changes that occur throughout a competitive season. The current study focused on lead and trail hip IR and ER ROM, abduction strength, and extension strength while pitching. The authors acknowledge that pitching is a complex and dynamic movement that involves the interaction of many other lower extremities ROM and strength variables to perform the task. Therefore other ROM and strength relationships should be examined over the course of the season to better develop the picture of what changes are occurring over time. Future research should also determine if changes in hip rotational ROM and strength throughout the course of a season are related to increased risk of injury or decreased performance in form of decreased velocity or increased earned run average (ERA). While good intra-rater reliability has been previously documented for the strength and ROM measurement methods that were used, an intra-rater reliability analysis for the current measurements was not conducted.[38,39] This limitation should be considered when evaluating the change measures in the current study; however the authors aimed to maximize reliability by using the same two examiners, one tester and one stabilizer, at both preseason and post season. Also, the study featured a single repetition of isometric strength testing, using a make test, with a handheld dynamometer. There are inherent weaknesses to this type of testing such as the testers strength relative to strength of the lower extremity, size of muscle group tested, and the use of a single trial, which may have led to measurement error.[38,40,41] A make test was chosen since multiple studies report that testers need greater strength to perform a "break test" due to eccentric muscle activation.[38,40,41]

CONCLUSIONS

This study offers preliminary ROM and strength profiles for lead and trail hip ER, IR, total arc, hip abduction, and hip extension strength in Division 1 collegiate pitchers over the course of a season. However, the changes described may not be a result of pitching workload. Results of this study will inform clinical evaluations and rehabilitative strategies in this population.

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