ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2016/233–240/$2.00/©JCCA 2016

Differences in hip range of motion among collegiate pitchers when compared to youth and professional baseball pitcher data

Scott W. Cheatham, PT, PhD, DPT, OCS, ATC, CSCS[1]
Kathryn Kumagai Shimamura, PT, DPT, NCS, OCS, CSCS, FAAOMPT[2,3]
Morey J. Kolber, PT, Ph.D, OCS, Cert MDT, CSCS[4]

The purpose of this study was to measure passive hip internal (IR) and external rotation (ER) range of motion (ROM) in collegiate baseball pitchers and compare to published youth and professional values. Measures were taken on the bilateral hips of 29 participants (mean age 20.0±1.4, range 18-22 years). Results identified no significant differences between the stance and stride hip in collegiate right handed pitchers for IR (p= 0.22, ES 0.23) and ER (p=.08, ES= 0.25). There was no significant difference in left handed pitchers for IR (p= 0.80, ES= 0.11) and ER (p= 0.56, ES= 0.15). When comparing youth to collegiate, IR increased in the stance (2º) and stride (5º) hip and an increase in the stance (5º) and stride (5º) hip were present for ER as well. From collegiate to professional, IR increased in the stance (4º) and stride (3º) hip whereas a decrease

Le but de cette étude était de mesurer l'amplitude de mouvement passif de la hanche en rotation interne (RI) et en rotation externe (RE) chez les lanceurs de baseball au niveau collégial et la comparer aux valeurs publiées chez les jeunes et les professionnels. Des mesures ont été prises sur les deux hanches de 29 participants (moyenne d'âge de 20,0 ± 1,4, tranche d'âge de 18 à 22 ans). Les résultats n'ont révélé aucune différence significative entre la posture et la foulée de la hanche chez les lanceurs droitiers collégiaux pour la RI (p = 0,22, AE = 0,23) et la RE (p = 0,08, AE = 0,25). Il n'y avait pas non plus de différence significative chez les lanceurs gauchers pour la RI (p = 0,80, AE = 0,11) et la RE (p = 0,56, AE = 0,15). Lorsque l'on compare les jeunes aux joueurs collégiaux, la RI a augmenté dans la posture (2º) et la foulée (5º) de la hanche, et une augmentation était également constatée pour la RE : posture (5º) et foulée (5º) de la hanche. Par rapport aux professionnels, la RI a augmenté pour la posture (4º) et la foulée (3º) de la

[1] Division of Kinesiology, California State University Dominguez Hills
[2] Department of Physical Therapy, Azusa Pacific University
[3] Department of Physical Therapy, Southern California Kaiser Permanente
[4] Nova Southeastern University, Department of Physical Therapy

Corresponding Author: Scott W. Cheatham
Division of Kinesiology, California State University Dominguez Hills, 1000 E. Victoria St., Carson, CA 90747
Tel: (310) 243-3794
e-mail: Scheatham@csudh.edu

There were no conflicts of interest or sources of funding reported in the preparation of this manuscript.

in the stance (9º) and stride (12º) hip was present for ER. The data suggests an increase in passive ROM from youth to collegiate and a decrease from collegiate to professional. Understanding passive hip ROM values among the different levels of pitchers may assist clinicians in developing time dependent interventions to prevent future injury and enhance performance.

(JCCA. 2016;60(3):233-240)

KEY WORDS: hip joint, range of motion, baseball, collegiate

hanche, alors qu'une diminution de la posture (9º) et la foulée (12º) de la hanche était constatée pour la RE. Les données indiquent une augmentation de l'amplitude de mouvement passif des joueurs de niveau collégial par rapport aux jeunes et une diminution par rapport aux joueurs professionnels. La compréhension des valeurs d'amplitude de mouvement passif de la hanche chez les différents niveaux de lanceurs peut aider les cliniciens à développer des interventions ponctuelles pour prévenir les blessures futures et améliorer la performance.

(JCCA. 2016;60(3):233-240)

MOTS CLÉS : articulation de la hanche, amplitude de mouvement, baseball, collégial

Introduction

Hip injury among baseball pitchers has become an evolving area of study. Baseball pitchers may be at risk for injury due to the high volume of repetitive motions involved in pitching and comprehensive training schedules.[1] It has been reported that approximately 30% of all injuries in professional baseball pitchers occur in the lower extremity.[2] Emerging research suggests that the hip joint has a major influence on pitching performance at higher speeds, since the hip muscles are primary generators of power.[3-6] Thus, compulsory motions among pitchers are not limited to the throwing arm and the hip presents a viable region to consider from both a prevention and performance perspective.

Evidence suggests that in the presence of limited hip mobility, throwing mechanics are altered and may lead to both hip and shoulder pathology.[6,7] Specifically, baseball pitchers are susceptible to groin injuries, femoral acetabular impingement, and sports hernias as a result of limited hip mobility.[7-10] Limited hip mobility can also affect the shoulder by compromising normal pitching biomechanics, forcing the abdominal core and shoulder to work harder or compensate, due to the loss of range of motion (ROM) and muscle force generated by the hip musculature.[11] This may induce excessive forces through the glenohumeral joint which can affect the velocity of the pitch as well as increase the potential risk for upper quarter injury.[5,6,8,12,13]

The hip's influence on pitching mechanics needs to be considered when assessing professional, collegiate, and youth pitchers with a suspected shoulder pathology since movement of the lower extremity is part of the throwing motion and contributes to the generation of power.[14] Understanding hip ROM trends among the various levels of pitchers may help to recognize risk factors and develop time dependent mobility-based interventions to prevent injuries and mitigate impairments. A search of electronic databases that included: PubMed, CINAHL, SPORT Discus, ProQuest, Cochrane Database, and Google Scholar® revealed selected studies among baseball pitchers. Hip ROM studies have been reported for professional pitchers[8,11,15-17], youth pitchers[18,19], and one study for collegiate pitchers[12]. The majority of hip ROM studies have been in professional pitchers. Hip ROM trends in youth and collegiate pitchers are important to study given the relatively large proportion of pitchers compared to professional players. To date, there has been no comparison of existing data from professional, collegiate, and youth level pitchers. This leaves a gap in our knowledge of how hip ROM develops as pitchers mature from youth to collegiate and professional levels. Thus, the purpose of this investigation was to report passive hip internal and external ROM values in collegiate pitchers and compare to published values of youth and professional pitchers.

Methods

This cross sectional study involved the measurement of

Table 1.
Subject Demographics; m, meters; BMI, Body mass index; kg, kilograms

	Age (years)	Height (m)	Mass (kg)	BMI (kg/m^2)
Subjects (N=29) (mean ± SD)	20.0 ± 1.4 (Range 18 to 22)	1.9 ± 0.6	89.3 ± 10.7	25.3 ± 2.5

collegiate baseball pitchers. Each pitcher was assessed for bilateral passive seated hip internal rotation (IR) and external rotation (ER) ROM. Data were collected as part of a larger study investigating descriptive characteristics of collegiate pitchers. Comparisons were made between right and left handed pitchers and pooled data from all participants in this study were compared to the published passive hip ROM values for professional and youth pitchers.[17,19]

Participants

A convenience sample of 29 collegiate baseball pitchers (58 hips) were recruited from Azusa Pacific University and California State University San Bernardino (Table 1). Of the participants, 23 were right-handed pitchers and 6 left-handed pitchers. Participants had to be asymptomatic in both hips at the time of testing and free of any known hip pathology. Exclusion criteria included previous hip surgery or any other medical problem that would have limited their ability to participate in full activity during the regularly scheduled 2013-2014 baseball season. This study was approved by the University Institutional Review Board (IRB). All participants who qualified were adults and received detailed information of the study requirements. All participants completed the university approved consent process and signed a university approved consent form prior to participation.

Instrumentation

Bilateral passive hip IR and ER ROM was performed with a wireless micro*FET*3 hand held digital inclinometer (Hoggan Health Industries., Salt Lake City, UT, USA). The manufacturer reports accuracy for ROM within 1° when using this device. Hand held digital goniometers have shown good reliability in measuring hip ROM[20,21]

Prior to data collection, a three session intrarater reliability analysis was conducted, over 1 week, using one examiner. The examiner was a licensed physiotherapist with over 12 years of experience and board certified in orthopedics. The examiner was blinded to the recording of the data outcomes. The measurements were performed on 29 independent participants chosen for this portion of the study. The intrarater reliability was calculated using the Intraclass Correlation Coefficient (ICC model 3, k).[22] There was good intrarater reliability for both passive IR (ICC= 0.91) and ER (ICC= 0.92) ROM. These coefficients are in accordance with the minimum threshold of ≥ 0.90 for ICC values postulated to be acceptable for clinical decision making.[22]

Data Collection

For all measurements, the participants were examined in their collegiate training facility and all procedures were explained in detail and demonstrated by the examiner. Measurements were performed seated based on previously described measurement procedures.[17,19] For each hip, two measurements were recorded for both passive IR and ER and the average was used for data analysis.[17]

For the measurement of hip IR, the participants were sitting on an athletic training table with their unsupported knees flexed to 90°. The examiner stood along the lateral side of the limb being measured and placed one hand behind the distal tibia above the malleoli. The examiner used the other hand to hold the digital inclinometer on the lateral malleolus. The examiner passively moved the participant's hip into IR by moving the foot laterally to the end of the available range when an "unyielding" endfeel was felt and then took the measurement (Figure 1).[17] The measurement for passive hip ER was then performed. The examiner stood along the medial side of the limb being measured and placed one hand behind the distal tibia above the malleoli. The examiner used the other hand to hold the digital inclinometer on the medial malleolus. The examiner passively moved the participant's hip into ER

Figure 1.
Passive hip internal rotation measurement.

by moving the foot medially to the end of the available range when an "unyielding" end-feel was felt then took the measurement.[17] The examiner monitored the participant during testing to prevent any excessive movement of the test leg or lumbopelvic region.

Data Sources: Youth and Professional

For the data comparison, we used two prior publications for our analysis with similar methods to our current investigation. These were the only known published studies that could be directly compared. Oliver et al[19] measured bilateral passive seated hip ROM in 26 youth pitchers (mean age of 11.3 ± 1.0 years) and Sauer et al[19] measured 50 professional pitchers (mean age of 22.6 ± 2.8 years) using the same methods. Data from these studies were compared to the pooled data obtained in this investigation.

Statistical Analysis

Statistical analysis was performed using SPSS version 22.0 (IBM SPSS, Chicago, IL, USA). Participant descriptive data was calculated and reported as the mean and standard deviation (SD) for age, height, mass, and body mass index (Table #1). A two tailed independent *t*-test was used to compare mean passive hip IR and ER ROM differences between the stance (*back*) and stride (*forward*) hip for left and right handed pitchers. A two-way factorial ANOVA (mixed general linear model) was conducted to compare the variables IR and ER passive hip ROM measures with handedness as a between factor and stance and stride hips as within factors between right and left handed pitchers.[21] Effect size (ES) was also calculated using Cohen's d ($d=(M_1-M_2)/SD_{pooled}$) from the available data.[21] Effect size of 0.50 was considered large, 0.30 was moderate, and 0.10 was small.[23] Statistical significance was considered as $p< 0.05$.

Results

Collegiate Pitchers

The calculated values among collegiate pitchers can be found in Table 2. For *right handed pitchers*, there was no significant difference in passive seated IR (p= 0.22) and ER (p= 0.08) ROM between the stance and stride hips. For the *left handed pitchers*, there was no significant difference in seated IR (p= 0.80) and ER (p= 0.56) ROM between the stance and stride hips. When comparing *right*

Table 2.
Comparison of seated hip PROM in collegiate baseball pitchers.

	Stance: IR	Stride: IR	P	ES		Stance: ER	Stride: ER	P	ES
Right Hand Pitchers	33.6 ± 9.4°	35.6 ± 8.1°	P= 0.22	0.23		36.9 ± 9.8°	39.4 ± 10.3°	P= 0.08	0.25
Left Hand Pitchers	33.0 ± 9.5°	32.1 ± 7.4°	P= 0.80	0.11		43.2 ± 13.6°	45.2 ± 13.6°	P= 0.56	0.15
Right versus Left Hand Pitchers	P= 0.90	P= 0.34				P= 0.20	P= 0.26		

IR: internal rotation; ER: external rotation; P=statistical significance using t-test; P<0.05 = statistically significant; data reported as mean ± SD; ES= effect size

Table 3.
Comparison of collegiate pitchers seated hip PROM to published values for youth and professional pitchers.

	Youth Pitchers [19] (N=26)	Collegiate Pitchers (N=29)	Effect Size (CI)		Collegiate Pitchers (N=29)	Professional Pitchers[17] (N=50)	Effect Size (CI)
Stance: IR (degrees)	31.3 ± 8.3°	33.3 ± 9.4°	-0.22 (–0.75, 0.31)		33.3 ± 9.4°	37.2 ± 5.7°	-0.54 (–1.00, –0.07)
Stance; ER (degrees)	35.0 ± 6.2°	40.0 ± 11.7°	-0.53 (–1.06, 0.02)		40.0 ± 11.7°	30.9 ± 5.9°	1.07 (0.58, 1.55)
Total Hip ROM (degrees)	66.4 ± 10.6°	73.3 ± 10.5°	-0.65 (–1.19, –0.10)		73.3 ± 10.5°	68.1 ± 7.7°	0.59 (0.12, 1.05)
Stride: IR (degrees)	28.5 ± 6.1°	33.8 ± 7.8°	-0.75 (–1.29, –0.19)		33.8 ± 7.8°	37.0 ± 5.6°	-0.49 (–0.95, –0.02)
Stride: ER (degrees)	37.0 ± 6.6°	42.3 ± 11.9°	-0.54 (–1.07, 0.00)		42.3 ± 11.9°	30.1 ± 5.4°	1.46 (0.93, 1.95)
Total Hip ROM (degrees)	65.7 ± 8.4°	76.1 ± 9.8°	-1.13 (–1.69, –.055)		76.1 ± 9.8°	52.0 ±8.3°	2.71 (2.06, 3.30)
**IR: internal rotation; ER: external rotation; data reported as Mean ± SD; CI: Confidence Interval*							

and left handed pitchers, there were no significant differences in the stance hip for seated IR ROM [F (1, 27) =0.16, p= 0.90] and ER ROM [F (1,27) =1.72, p= 0.20]. There was no significant difference in the stride hip for seated IR ROM [F (1,27) =0.94, p= 0.34] and ER ROM [F (1,27) =1.33, p= 0.26].

Comparison of Collegiate Data with Youth and Professional Pitcher Data

All data from this investigation were pooled (right and left handed pitchers) for this comparison analysis and presented in Table 3. For the *stance hip* passive seated IR ROM, there was a 2° increase (ES= –0.22) from youth to collegiate level and a 4° increase (ES= –0.54) from collegiate to professional. For the *stance hip* seated ER ROM, there was an approximate 5° increase (ES= –0.53) from youth to collegiate level and a 9° decrease (ES= 1.07) from collegiate to professional. For the *stance hip total ROM*, there was an approximate 7° increase (ES= –0.65) from youth to collegiate level and a 5° decrease (ES= 0.59) from collegiate to professional.

For the *stride hip* seated IR ROM, there was an approximate 5° increase (ES= –0.75) from youth to collegiate level and a 3° increase (ES= –0.49) from collegiate to professional. For the *stride hip* seated ER ROM there was an approximate 5° increase (ES= –0.54) from youth to collegiate level and a 12° decrease (ES= 1.46) from collegiate to professional. *For the stride hip total ROM*, there was an approximate 10° increase (ES= –1.13) from youth to collegiate level and a 9° decrease (ES= 2.71) from collegiate to professional. A graphical comparison of the three groups is provided in Figure 2.

Discussion

This investigation measured bilateral passive seated hip rotation ROM in 29 collegiate pitchers and found no statistical significance between right and left handed pitchers for both stance and stride hip IR and ER ($p \geq 0.31$). These findings were consistent with Sauer et al [17] who reported similar findings of no significant difference of right and left passive seated hip ROM in a group of professional pitchers (N= 50) tested with similar methods. These results suggest that within each population there is similar values of passive hip ROM for the stance and stride leg among pitchers. Clinically, bilateral examination of both hips is warranted since loss of ROM in either hip can have an effect on the throwing motion.[12]

When comparing the data of the collegiate pitchers to published youth and professional values there were moderate differences in ROM. From youth to collegiate, IR ROM showed an increase in both the stance (2º) and stride (5º) hip. For ER ROM, there also was an increase in the stance (5º) and stride (5º) hip. For total change in ROM, there was an increase in the stance (7°) and stride hip (10°). The increase in ROM could be due to many factors such as the population sampled, maturation and growth

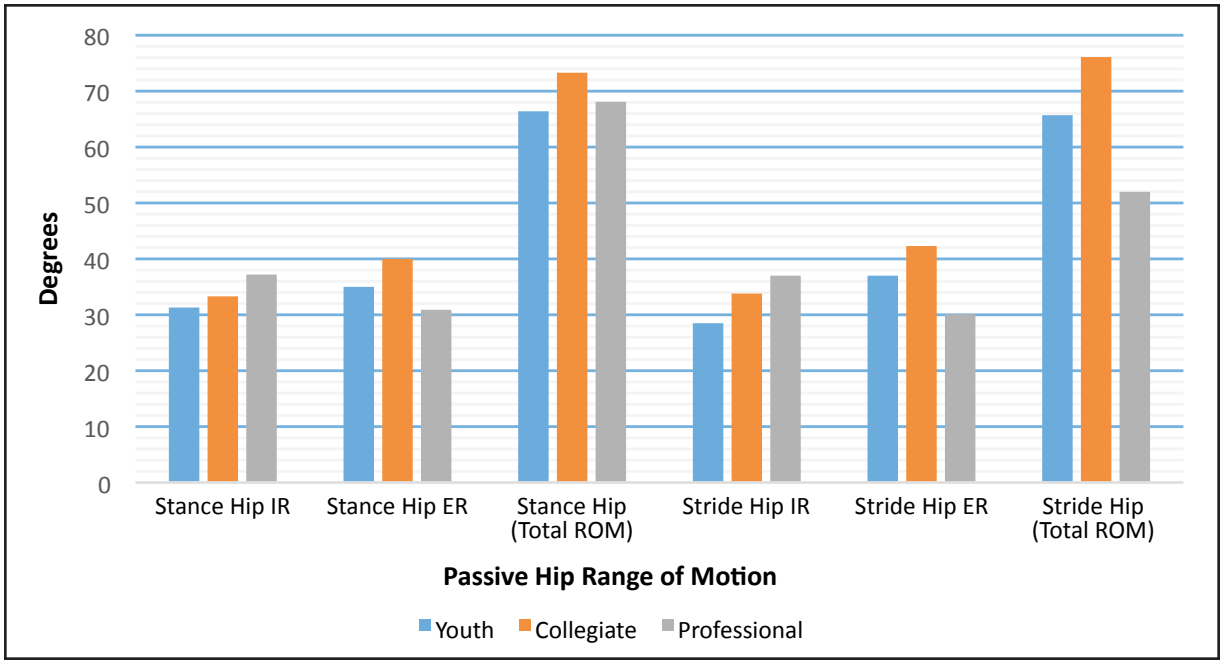

Figure 2.
Comparison of Youth, Collegiate, and Professional Pitchers.

of the athlete, number of game and practice exposures, physical conditioning, and sports specific training. Nevertheless, it seems there is an increase in hip mobility from youth to collegiate levels when considering hip IR and ER ROM. From collegiate to professional, hip IR ROM showed an increase in both the stance (4º) and stride (3º) hip. For ER ROM, there was decrease in the stance (9º) and stride (12º) hip. For total change in ROM, there was a decrease in the stance hip (5°) and stride hip (9°). These findings are similar to Lauder et al [12] who found that decreased ER ROM of the stance and stride hips increased horizontal adduction of the throwing shoulder during the pitching motion. Decreased stride hip IR and ER also created a significant increase in torque across the throwing shoulder. It appears that a total loss of hip ROM from the collegiate to professional levels may exist. The data also suggests that changes in ER ROM may contribute the most to this loss of motion.

Limitations

The main limitation of this investigation was the comparison of data from studies with similar methods which only represented a portion of the available literature. All the studies analyzed, tested pitchers' bilateral passive hip ROM (IR and ER) in the seated position which provided a direct comparison. Previous studies have tested pitchers in seated but used different testing methods such as active ROM thus results cannot be extrapolated to passive ROM.[24] Several other investigations have measured hip ROM in collegiate and professional pitchers in the prone position making it difficult for a direct comparison to this investigation.[12,25,26] Due to the variability in results among studies, future comparisons should be made using similar methodology. A second limitation was the small sample of pitchers, specifically left-handed pitchers. Future studies should include larger samples of left handed pitchers. A third limitation was the absence of data from all the age groups in youth pitchers. To date, there is only one study that has evaluated hip ROM among the various age groups of youth pitchers. Beckett et al[27] measured hip ROM in youth players using two age groups: preadolescents (players aged 7-12 years) and adolescents (players aged 13-18 years). The authors did not use this data for comparison since they tested all the players in

the prone position. A fourth limitation was that other hip motions such as flexion or extension or abduction or adduction were not measured. Future studies should attempt to measure these motions to determine their influence on the pitching motion.

Despite limitations, these data are a starting point for researchers to analyze how passive range of hip motion changes through the various levels of play. The clinical relevance of these findings is that passive hip IR and ER ROM increases from youth to collegiate and then decreases from collegiate to professional. Knowing time points for change may allow appropriate staging of interventions to enhance performance or prevent future injuries. We chose to collect data from collegiate pitchers since there are fewer studies published versus youth and professional. Future research should attempt to use larger sample sizes and similar methodology of testing subjects in one standard position or in both seated and prone in order to provide means for a direct comparison.

At this point, there is not enough evidence to determine if this increase in ROM impacts performance or increases the risk of injury. Future studies will need to determine if these ROM changes are just growth trends or adaptation from playing. Possible causes of joint ROM loss could be adaptations from the high volume of throwing and rigorous training schedules. Further research is needed to confirm these hypotheses.

Conclusion

The hip joint has an important biomechanical role in the pitching motion since it is a primary generator of power, plays a major role in pitching performance at higher speeds, and is related to shoulder injuries.[3-6] This study measured passive hip IR and ER ROM in collegiate baseball pitchers and compared to published youth and professional values. This study provides a starting point for clinicians and researchers to look at hip ROM in pitchers from youth to collegiate to professional. Understanding hip ROM trends in this population may provide insight into injury patterns among the different levels of play and may assist clinicians in developing time dependent interventions to prevent future injury (e.g. hip and shoulder) and enhance performance. The data presented are limited by the small samples size, limited access to normative data, and passive testing in the seated position. The results of this study suggest that a loss of total passive hip ROM may occurs from the collegiate to professional level. The data also suggest that changes in ER ROM may contribute the most to this loss of motion. The reasons for these occurrences are still unknown. Future studies are needed to confirm these findings and determine plausible factors.

References:

1. Li X, Zhou H, Williams P, et al. The epidemiology of single season musculoskeletal injuries in professional baseball. Orthop Rev (Pavia). 2013;5(1):e3.
2. Posner M, Cameron KL, Wolf JM, et al. Epidemiology of Major League Baseball injuries. Am J Sports Med. 2011;39(8):1676-1680.
3. Roach NT, Lieberman DE. Upper body contributions to power generation during rapid, overhand throwing in humans. J Exp Biol. 2014;217(Pt 12):2139-2149.
4. Kageyama M, Sugiyama T, Takai Y, et al. Kinematic and kinetic profiles of trunk and lower limbs during baseball pitching in collegiate pitchers. J Sports Sci Med. 2014;13(4):742-750.
5. Oyama S, Yu B, Blackburn JT, et al. Improper trunk rotation sequence is associated with increased maximal shoulder external rotation angle and shoulder joint force in high school baseball pitchers. Am J Sports Med. 2014;42(9):2089-2094.
6. Scher S, Anderson K, Weber N, et al. Associations among hip and shoulder range of motion and shoulder injury in professional baseball players. J Athl Train. 2010;45(2):191-197.
7. Verrall GM, Slavotinek JP, Barnes PG, et al. Hip joint range of motion restriction precedes athletic chronic groin injury. J Sci Med Sport. 2007;10(6):463-466.
8. McCulloch PC, Patel JK, Ramkumar PN, et al. Asymmetric hip totation in professional baseball pitchers. Orthop J Sports Med. 2014;2(2).
9. Klingenstein GG, Martin R, Kivlan B, et al. Hip injuries in the overhead athlete. Clin Orthop Relat Res. 2012;470(6):1579-1585.
10. Garvey JF, Hazard H. Sports hernia or groin disruption injury? Chronic athletic groin pain: a retrospective study of 100 patients with long-term follow-up. Hernia. 2014;18(6):815-823.
11. Laudner KG, Moore SD, Sipes RC, et al. Functional hip characteristics of baseball pitchers and position players. Am J Sports Med. 2010;38(2):383-387.
12. Laudner K, Wong R, Onuki T, et al. The relationship between clinically measured hip rotational motion and shoulder biomechanics during the pitching motion. J Sci Med Sport. 2015 ;18(5):581-4.
13. Endo Y, Sakamoto M. Correlation of shoulder and elbow injuries with muscle tightness, core stability, and balance by longitudinal measurements in junior high school baseball players. J Phys Ther Sci. 2014;26(5):689-693.

14. Wainner RS, Whitman JM, Cleland JA, et al. Regional interdependence: a musculoskeletal examination model whose time has come. J Orthop Sports Phys Ther. 2007;37(11):658-660.
15. Ellenbecker TS, Ellenbecker GA, Roetert EP, et al. Descriptive profile of hip rotation range of motion in elite tennis players and professional baseball pitchers. Am J Sports Med. 2007;35(8):1371-1376.
16. 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(12):2487-2493.
17. Sauers EL, Huxel Bliven KC, Johnson MP, et al. Hip and glenohumeral rotational range of motion in healthy professional baseball pitchers and position players. Am J Sports Med. 2014;42(2):430-436.
18. Oliver GD, Weimar W. Hip range of motion and scapula position in youth baseball pitching pre and post simulated game. J Sports Sci. 2015; 33(14): 1447-1453.
19. Oliver GD, Weimar WH. Hip and shoulder range of motion in youth baseball pitchers. J Strength Cond Res. 2014. [Epub ahead of print]
20. Krause DA, Hollman JH, Krych AJ, et al. Reliability of hip internal rotation range of motion measurement using a digital inclinometer. Knee Surg Sports Traumatol Arthrosc. 2015;23(9):2562-2567.
21. Clapis PA, Davis SM, Davis RO. Reliability of inclinometer and goniometric measurements of hip extension flexibility using the modified Thomas test. Physiother Theory Pract. 2008;24(2):135-141.
22. Portney LG, Watkins MP. Foundations of Clinical Research: Applications to Practice. Pearson/Prentice Hall; 2009.
23. Cohen J. A power primer. Psychol Bull. 1992;112(1):155-159.
24. Tippett SR. Lower extremity strength and active range of motion in college baseball pitchers: a comparison between stance leg and kick leg. J Orthop Sports Phys Ther. 1986;8(1):10-14.
25. 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(12):2487-2493.
26. Ellenbecker TS, Ellenbecker GA, Roetert EP, et al. Descriptive profile of hip rotation range of motion in elite tennis players and professional baseball pitchers. Am J Sports Med. 2007;35(8):1371-1376.
27. Beckett M, Hannon M, Ropiak C, et al. Clinical assessment of scapula and hip joint function in preadolescent and adolescent baseball players. Am J Sports Med. 2014;42(10):2502-2509.