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Descriptive Profile of Hip Rotation Range of Motion in Elite Tennis Players and Professional Baseball Pitchers

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Background: Repetitive loading to the hip joint in athletes has been reported as a factor in the development of degenerative joint disease and intra-articular injury. Little information is available on the bilateral symmetry of hip rotational measures in unilaterally dominant upper extremity athletes.

Hypothesis: Side-to-side differences in hip joint range of motion may be present because of asymmetrical loading in the lower extremities of elite tennis players and professional baseball pitchers.

Study Design: Cohort (cross-sectional) study (prevalence); Level of evidence, 1.

Methods: Descriptive measures of hip internal and external rotation active range of motion were taken in the prone position of 64 male and 83 female elite tennis players and 101 male professional baseball pitchers using digital photos and computerized angle calculation software. Bilateral differences in active range of motion between the dominant and nondominant hip were compared using paired *t* tests and Bonferroni correction for hip internal, external, and total rotation range of motion. A Pearson correlation test was used to test the relationship between years of competition and hip rotation active range of motion.

Results: No significant bilateral difference ($P > .005$) was measured for mean hip internal or external rotation for the elite tennis players or the professional baseball pitchers. An analysis of the number of subjects in each group with a bilateral difference in hip rotation greater than 10° identified 17% of the professional baseball pitchers with internal rotation differences and 42% with external rotation differences. Differences in the elite male tennis players occurred in only 15% of the players for internal rotation and 9% in external rotation. Female subjects had differences in 8% and 12% of the players for internal and external rotation, respectively. Statistical differences were found between the mean total arc of hip range of internal and external rotation in the elite tennis players with the dominant side being greater by a clinically insignificant mean value of 2.5°. Significantly less ($P < .005$) dominant hip internal rotation and less dominant and nondominant hip total rotation range of motion were found in the professional baseball pitchers compared with the elite male tennis players.

Conclusion: This study established typical range of motion patterns and identified bilaterally symmetric hip active range of motion rotation values in elite tennis players and professional baseball pitchers. Asymmetric hip joint rotational active range of motion encountered during clinical examination and screening may indicate abnormalities and would indicate the application of flexibility training, rehabilitation, and further evaluation.

Keywords: hip; range of motion; baseball; tennis

The repetitive loading of the lower extremities can lead to the development of degenerative joint disease and labral injury in athletes.[5,15,17,24,28] The multidirectional and cutting movements inherent in the sport of tennis as well as the repetitive landing and rotational stresses in the lower extremities inherent in the overhead motions of the tennis serve and pitching in baseball during training to achieve

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elite levels of performance in these sports can result in overuse injury and the development of osteochondral injury.[15] Factors affecting the integrity of the hip joint in athletes include age, hip range of motion, physical loading, and body mass index.[15,19,28]

Restrictions in hip rotational range of motion as well as in flexion have been suggested as clinical indicators of hip joint osteoarthritis and labral injury.[5,13-15,17,21] During clinical examination and preventive screening physical examinations, bilateral measurement of joint range of motion is performed to identify injury and flexibility deficiencies for both injury prevention and performance enhancement. Interpretation of range of motion testing typically involves 2 types of comparisons to facilitate clinical application. The first is the comparison of range of motion to the contralateral extremity. This, however, requires the assumption that bilateral symmetry of the joint being measured has been previously established in the literature. The second comparison involves the application of the data to population-specific normative samples. Because of the asymmetric hip loading patterns inherent in baseball pitching,[12] tennis serving,[10] and tennis ground strokes,[23] one might expect the development of sport-specific and extremity-specific (push-off leg vs landing leg) adaptations in range of motion from the repetitive performance of these activities at elite levels.

Numerous studies have reported the specific rotational adaptations of the glenohumeral joint in elite tennis players[7-9,16,22] and in professional baseball pitchers.[3,6,8] Bilateral descriptive data for lower extremity hip internal, external, and total rotation range of motion are not available for these populations.

The purpose of this study was to generate a descriptive profile of hip internal, external, and total rotation active range of motion (AROM) and determine whether bilateral differences in range of motion exist in elite tennis players and professional baseball pitchers. A secondary purpose was to determine whether hip rotation range of motion is correlated with years of competitive performance in both of these sports.

MATERIALS AND METHODS

Sixty-four male and 83 female elite tennis players and 101 professional baseball pitchers consented to participate in this investigation. The elite tennis players were recruited from developmental training camps, and the professional baseball pitchers were tested during spring training physical examinations. To qualify as an elite tennis player for the purpose of this study, subjects held national rankings or played professional tennis. Subjects were free from lower extremity injury for 1 year before hip joint AROM measurement and had no history of surgical procedures at any time in either hip. Demographic information was recorded from the subjects before data collection for variables including years of competitive sport performance and injury history (Table 1). The research protocol was approved by the Institutional Review Board of Physiotherapy Associates (Memphis, Tenn).

TABLE 1
Demographic Variables for the Elite Tennis Players and Professional Baseball Pitchers[a]

	Elite Tennis Players		
	Male	Female	Baseball Pitchers
Age, y	18.9 ± 2.4	17.2 ± 2.8	23.7 ± 4.4
Height, in	70.7 ± 4.3	67.5 ± 3.0	74.6 ± 2.1
Weight, lb	162.4 ± 28.3	136.5 ± 17.2	204.1 ± 25.1
Years competing	8.7 ± 2.5	8.7 ± 3.6	13.7 ± 5.6

[a]All values are mean ± standard deviation.

Operational Definitions

Lower extremity dominance for the elite tennis players involved the assignment of the dominant lower extremity to the ipsilateral side of the forehand ground stroke and the same side as the upper extremity with which the player served. The dominant extremity in the professional baseball pitchers was assigned to the same side as the upper extremity used in throwing. In baseball pitching, the dominant extremity has also been referred to as the push-off leg with the nondominant extremity commonly referred to as the landing leg.[12]

Measurement Technique

Subjects were positioned in a prone position on a treatment table with the hip in 0° of extension, with neutral abduction/adduction, and with 90° of knee flexion during measurement. This position was chosen because of its close approximation to the extended hip position inherent in the upright positions incurred when athletes throw a baseball or play tennis. Colored, nonreflective adhesive markers were then applied to the tibial tubercles of both lower extremities to provide a proximal tibial landmark, and a second marker was applied to the midline of each lower extremity 1 body inch proximal to the medial malleolus to provide a distal landmark. A stabilization strap was placed across the lumbar spine of the subject to provide stabilization during testing. Subjects then performed bilateral hip AROM into the movement of internal rotation (Figure 1). During the motion, the examiner manually stabilized the pelvis to minimize substitution during the motion. Subjects were asked to hold the end range position of bilateral hip internal rotation while a standard digital photograph was taken. An Olympus Camedia C-5050 (Olympus Inc, Melville, NY) digital camera was used with a filming distance of 6 ft (1.83 m) while mounted on a tripod at a height identical to that of the treatment table on which the patient was positioned. A vertical reference marker was visible in the photograph to allow for the determination of neutral rotation (0°) for each subject and served as an accurate vertical reference for 1 arm of the computer angle measurement. This vertical reference was used in all subjects. No adjustment or measurement for the inherent

Figure 1. Positioning used for active range of motion measurement of hip internal rotation.

degree of femoral anteversion or retroversion was used in this experiment. The visual external movements of active hip internal and external rotation served as the only measurements for this investigation, in a manner similar to the measures available and commonly used in clinical practice and in musculoskeletal evaluations for injury rehabilitation and injury prevention.

After the internal rotation measurement, each extremity in randomized order was individually measured for hip external rotation while the pelvis was manually stabilized by the examiner. Digital photographs were taken to document end range of AROM of each hip for external rotation. Active range of motion was measured for both internal and external hip rotation bilaterally. The use of AROM measures was purposely targeted to prevent error introduction inherent in the use of passive range of motion measures without objective measurement of end-point overpressure. Difficulty in the consistent application and determination of passive end points with passive range of rotational movement led to the use of AROM to enhance accuracy in this investigation.

Hip range of motion from the digital images was determined using a PC and Pegasus (Performance Evaluation Group, Tempe, Ariz) computerized angle calculation software. Each photographic image was imported into Microsoft Excel while the computer program was used to align 2 lines to calculate the angle of internal and external rotation. The vertical reference marker in each photograph was used to determine the 0° reference point with the end point of the lower limb rotation being aligned via the exact center of the distal and proximal reference markers. The exact angle from the vertical reference line to the end point of active range of internal and external rotation was used for data analysis of each subject.

Data Analysis

The SPSS software package (SPSS Inc, Chicago, Ill) was used to generate descriptive statistics for hip internal and external rotation as well as total rotation range of motion,

TABLE 2
Hip Rotation Active Range of Motion (in Degrees) in Elite Tennis Players[a]

Parameter	Dominant Hip[a]	Nondominant Hip[a]	*t* Value	Significance
Men (n = 64)				
Internal rotation	27 ± 9.8	26 ± 8.2	–1.48	.143
External rotation	37 ± 9.3	36 ± 9.3	–1.40	.165
Total rotation	64 ± 14.1	62 ± 14.2	–2.09	.005[b]
Women (n = 83)				
Internal rotation	37 ± 10.1	35 ± 10.5	–2.11	.037
External rotation	36 ± 8.9	35 ± 8.5	–1.37	.173
Total rotation	73 ± 13.6	71 ± 13.1	–2.75	.007[b]

[a]Mean ± standard deviation.
[b]Significant at the .005 level.

TABLE 3
Hip Rotation Active Range of Motion (in Degrees) in Professional Baseball Pitchers[a]

Parameter	Dominant Hip[b]	Nondominant Hip[b]	*t* Value	Significance
Internal rotation	23 ± 8.3	22 ± 8.9	.485	.629
External rotation	35 ± 9.1	34 ± 10.6	.427	.670
Total rotation	58 ± 10.6	57 ± 10.7	1.25	.211

[a]N = 101.
[b]Mean ± standard deviation.

which was obtained by summing the internal and external rotation measures from each limb. Nine paired *t* tests were used for the 3 specific populations tested with $\alpha = .005$. This level was determined using a Bonferroni correction.[18] A Pearson correlation test was used to examine the relationship between hip rotation range of motion and years of competitive sport performance. Additionally, a subset of randomly determined subjects (11 elite tennis players and 11 professional baseball pitchers) was chosen to be retested using the digital measuring software. This produced test-retest measurements on 44 extremities for internal and external rotation. An intraclass correlation coefficient (ICC) (1,k) was used to determine test-retest reliability.

RESULTS

Intraclass correlation coefficients were calculated for the method of angular measurement of hip internal and external rotation and were found to be .99.

Tables 2 and 3 show the descriptive values for hip internal, external, and total rotation from the elite tennis players and professional baseball pitchers, respectively. No significant side-to-side differences ($P > .005$) were found between the dominant and nondominant hip in internal or external rotation in the elite tennis players or professional baseball pitchers. Additionally, total rotation range of motion did not differ between extremities in the professional baseball pitchers. A statistically significant ($P < .005$) difference between extremities in total rotation range of motion was measured in the elite tennis players. Significantly less ($P < .005$) dominant hip internal rotation was measured in the professional baseball pitchers compared with the elite male tennis players. Significantly less ($P < .005$) dominant and nondominant hip total rotation range of motion was also measured in the professional baseball pitchers compared with the elite male tennis players.

The range of bilateral differences between the dominant and nondominant hip for external rotation in the elite male tennis players was –13° to 12° (ie, 13° less rotation on the dominant limb to 12° more rotation on the dominant limb) and –16° to 13° for internal rotation. Ranges of difference in the elite female tennis players were –22° to 14° for external rotation and –41° to 13° for internal rotation. The baseball pitchers had ranges of differences of –26° to 29° for external and –18° to 24° for internal rotation. Further analysis of the number of subjects in each group with a bilateral difference in hip rotation greater than 10° identified 17% of the professional baseball pitchers with internal rotation differences and 42% with external rotation differences. Differences in the elite male tennis players occurred in only 15% of the players in internal rotation and 9% in external rotation. The women had differences of 10° or more in 8% and 12% of the players for internal and external rotation, respectively.

No significant correlation existed between number of years of tennis play or years pitching and hip rotation range of motion.

DISCUSSION

The results of this study clearly indicate that bilateral hip rotation range of motion symmetry should be expected in the uninjured hips of elite tennis players and professional baseball pitchers. Identification of a hip rotation range of motion deficiency during the evaluation of an athlete from these populations might signify an abnormal finding and lead the examiner to conduct further tests to rule out pathologic abnormalities as well as apply specific interventions to address range of motion loss.

The examination and analysis of the mean differences between limbs produced no significant differences in each of the groups tested. However, by calculating the number of players in each group with differences greater than 10° between extremities, we identified an interesting relationship between the groups and between hip rotation directions. In the elite tennis players, fewer than 15% of the players had a difference between limbs in either direction of hip rotation greater than 10°. This finding reflects the lack of an overall mean difference between limbs in the elite tennis players in this study.

In the professional baseball pitchers, we found a similar result in 17% of the players who had a 10° or greater bilateral difference between limbs in internal hip rotation. However, for external rotation, 42% of the players measured had a difference of 10° or greater, despite the finding of no significant differences in overall means. This shows that for the professional baseball pitchers, significant variability in the differences between extremities (dominant vs nondominant) existed. A consistent pattern by which the dominant extremity was greater or less than the nondominant extremity did not occur, yet we found instances in which 10° or more of absolute difference between extremities existed 42% of the time.

Unlike glenohumeral rotation in elite tennis players and baseball pitchers, for which sport-specific alterations of humeral rotation patterning have been consistently measured and identified,[3-9] similar side-to-side variations in hip rotation range of motion patterning do not appear to be produced in tennis play and baseball pitching. In both tennis and baseball, specific repetitive biomechanical patterns are used, which include different push-off and landing activities (tennis serve and throwing) as well as recovery steps (tennis forehand) that produce characteristically different muscle activations and loading patterns. Despite these differences, there does not seem to be a difference in hip active rotation range of motion patterns in elite athletes in these 2 sports. One limitation of this study is the lack of imaging or additional testing to attempt to determine the source of the range of motion patterning in the athletes tested. Subjects with more significant range of motion limitations may have subclinical pathologic changes, such as early osteoarthritis or femoroacetabular impingement that could not be detected with the methods used in this research. Further study on this important topic is clearly warranted.

These data can be used to interpret physical examination findings and make performance evaluations of elite tennis players and baseball pitchers. Specifically, identification of hip rotation range of motion differences between extremities cannot be thought to represent a sport-specific adaptation based on the results of this normative data study. The finding of greater hip lateral rotation compared with medial rotation is consistent with normal hip range of motion values[1,2,11,27] as well as with hip range of motion values reported in studies of team handball, runners, and soccer players.[15] Additionally, our finding of bilateral symmetry of hip rotation range of motion is in agreement with other studies measuring hip rotation in primarily lower extremity elite and recreational athletes.[15,17] Bilateral differences and reduced hip rotation range of motion were identified by L'Hermette et al[17] in populations of athletes with osteoarthritis compared with a control group of similar sport athletes without osteoarthritis or hip injury. This consistent finding of bilateral hip rotation in healthy athletes coupled with the loss of hip rotation range of motion in athletes with hip injury indicates that measuring and carefully interpreting hip rotation range of motion are important parts of the clinical examination and preventive physical examination in athletes.[5,24]

Comparison of the hip rotation AROM measures in the elite overhead athletes in this study with those obtained using similar methods in the prone position in normal subjects does show lower overall internal and external rotation range in both the tennis players and the baseball pitchers. Ellison et al[11] reported nearly symmetric internal and external rotation values of 38° and 35°, respectively, and total rotation values of 73° in 100 healthy subjects with a mean age of 26 years. Similarly, Simoneau et al[27] reported 36° of internal rotation and 45° of external rotation in 39 subjects with a mean age of 21 years. Total rotation values of 73° and 81° were reported by Ellison et al[11] and Simoneau et al,[27] respectively. Total rotation values in this study for hip rotation were as low as 58° in the professional baseball pitchers and 62° to 73° in the male and female tennis players. Although we did not directly measure and compare the overhead athletes in our study with a group of normal age-matched controls, it appears from the findings of 2 studies that used identical positional methods on normal subjects that the athletes in our study did have decreases in hip rotation range of motion. Further study and direct comparison may be warranted to more directly examine this finding.

The method of range of motion measurement for this study was chosen because of the compromised reliability reported in the literature for the measurement of rotational range of motion with the universal goniometer.[2,9,11,20,27] Test-retest reliability measured in this study with our methods was ICC = .99. Test-retest reliability in the literature reported by Ellison et al[11] and Simoneau et al[27] ranged from ICC = .79 to ICC = .98. The method that we used allowed for consistent application of the vertical reference position, which can be difficult when using and aligning the stationary arm of the universal goniometer manually. The results of our study are specific to hip rotation in 0° of hip flexion/extension and should not be generalized to testing performed with the hip in 90° of flexion. Ellison et al[11] found no significant difference between hip rotation range of motion measures in normal uninjured subjects between testing in the prone position with 0° of hip extension and a seated position with 90° of hip flexion, whereas Simoneau et al[27] found significant differences in hip external rotation between the prone and seated test positions with no difference reported for hip internal rotation. Despite these findings, it is recommended for comparison purposes that our results be used only for comparison with elite athletes in this specific population using the prone position with 0° of hip extension. Future studies could examine the bilateral relationship of hip rotation range of motion performed in alternative positions and its effect on bilateral symmetry and overall excursion in this population as well as in other specific athletic populations.

Although every attempt was made to use homogeneous subject populations of very elite performers from each sport, the normative data sets in this study cannot be assumed to be totally representative of all athletes from these populations. As with any study, caution should be used when applying the normative data sets to any 1 subject for the purpose of musculoskeletal evaluation.

The lack of a statistical correlation between years of sport performance and hip rotation range of motion is consistent with the findings reported by Kettunen et al[15] in 117 distance runners, soccer players, weight lifters, and shooters aged 45 to 68 years. One possible reason for the lack of a statistical correlation in our study was the use of very young subject populations from these 2 sports. Further research including studies profiling athletes with a greater number of years of competition and training is needed to better understand the relationship between the repetitive effects of sport-specific lower extremity impact loading and measurable physical parameters in aging athletes. Kibler et al[16] identified a loss of shoulder internal rotation range of motion that correlated with years of competitive tennis performance in elite players. A similar correlation was not identified for hip rotation range of motion in the present study.

The use of a clinical method to determine hip active range of motion is recommended in both preventive screening and rehabilitation.[17,24] The concept of femoroacetabular impingement as a source of pain in the athletic hip has been reported,[25,26] and it has been postulated that it may be an early precursor to hip osteoarthritis. Femoroacetabular impingement has been described as abnormal contact and a mechanical conflict between the femoral head/neck junction and the anterior acetabular opening and rim during hip movement.[25,26] Athletes who incur repetitive lower extremity movements and loading patterns and perform aggressive cutting and lateral movements at end ranges of available motion are candidates for musculoskeletal screening using a clinically oriented method to identify range of motion deficiencies. Further study will provide a greater understanding of the role that abnormal range of motion and hip abnormalities, like femoroacetabular impingement, may play in the athletic hip.

CONCLUSION

Bilateral measurement of hip rotation range of motion in elite tennis players and professional baseball pitchers did not identify significant differences between extremities. Additionally, no significant correlation existed between hip rotation range of motion and years of pitching or tennis play. This study provides descriptive data from elite overhead athletes to aid in the interpretation of lower extremity range of motion measurements to identify athletes with possible hip abnormalities for both rehabilitation and preventive screening.

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