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Hip Range of Motion and Association With Injury in Female Professional Tennis Players

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Background: Adequate hip range of motion is required for the transfer of energy from the lower to the upper extremity along the kinetic chain. Repetitive rotational stresses in the lower extremities during tennis may lead to sport-specific range of motion adaptations, which may increase the risk of injury to other joints along the kinetic chain.

Purpose: To assess whether such range of motion adaptations occur in the hip, and if so, to identify whether they are associated with injury.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 125 female professional tennis players, the majority of whom were ranked in the top 200 World Tennis Association singles rankings, underwent a comprehensive preparticipation physical health status examination. Hip range of motion was assessed using a digital inclinometer and side-to-side differences in rotational parameters calculated, and associations with previous injuries were identified.

Results: A history of an abdominal strain was reported by 10% of players, and there was an association between abdominal strains and the presence of hip flexion contractures (odds ratio, 6.1; P = .006). Hip flexion contractures were bilateral in 85% of those found, affected only the nondominant side in 9%, and affected only the dominant side in 6%. We were unable to identify any specific side-to-side rotational adaptations in the dominant or nondominant hips, and no association between loss of hip range of motion and shoulder, lower back, hip, knee, or ankle injuries was found.

Conclusion: We report an association in female professional tennis players between abdominal strains and flexion contractures of the hip with iliopsoas tightness. We did not find evidence of specific hip adaptations in rotational range of motion. If hip flexion contractures are found on clinical examination, a stretching program may be indicated. Further studies are required to assess whether such a program can reduce the risk of abdominal injury.

Keywords: hip range of motion; abdominal strains; tennis players; hip clinical examination

During overhead sports such as tennis, the lower extremity assists in generating energy, which is transferred along the kinetic chain to the racquet at ball strike. Hip range of motion, and rotation in particular, allows for optimum positioning of the pelvis to provide the effective transfer of this energy along the kinetic chain. Repetitive rotational stresses in the lower extremities are known to occur during general tennis play and may result in overuse injuries.

While a number of studies have reported sport-specific shoulder rotational adaptations (glenohumeral internal rotational deficit [GIRD]) in elite tennis players, there is little information on whether such adaptations occur in the hip. The hip acts as part of a kinetic chain, allowing the generation, summation, and transfer of forces from the legs to the hand and racquet. While it has been shown that shoulder dysfunction (scapular dyskinesis, GIRD) and back pain have been associated with ulnar collateral ligament injuries of the elbow in athletes, thus reaffirming the kinetic chain concept, the role of the hip in injuries elsewhere in the kinetic chain has not been well studied. Hip dysfunction can increase stresses on other joints, and loss of hip internal rotation has been associated with lower back pain in athletes. However, there are little data on how restriction in hip range of motion affects other muscles and joints in the kinetic chain such as abdominal wall musculature, which is commonly strained in elite tennis players. Specifically, it is unknown whether the increased risk of injury that occurs with rotational adaptations in the shoulder (GIRD) also
occurs in the hip and whether there is any relationship between the two.

Such associations are relevant to screening physical examinations, which aim to detect deficiencies in motion or strength that predispose an athlete to injuries. This may enable targeted stretching programs, which can reduce the injury risk.16 During such screening physical examinations, clinical hip range of motion findings are compared firstly for side-to-side differences and secondly against “normal” population data.5 The aims of this study were therefore to establish a descriptive profile of hip rotational range of motion, to assess whether any sport-specific side-to-side adaptations exist, and finally to evaluate whether such adaptations are associated with a history of injury to the hip or other joints along the kinetic chain.

MATERIALS AND METHODS

A total of 125 female professional tennis players underwent a comprehensive physical health status examination in the first quarter of 2012. Of these players, the majority were ranked in the top 200 in the World Tennis Association (WTA) singles rankings at the time of the clinical examination. A questionnaire was administered to the athletes by a trained physical therapist, which included a detailed medical history with site and details of any musculoskeletal complaints, injuries, or surgeries. The study received ethical approval from a local institutional review board.

Two sports fellowship–trained orthopaedic surgeons performed a structured physical examination of the hip in all players. Range of motion of the hip was measured using the Pro 3600 Digital Inclinometer (SPI-Tronic), which allows real-time digital reading of angles in a 360° circle with respect to a horizontal or vertical reference line. The accuracy of the device as reported by the manufacturer is within 0.1°, and its use in hip range of motion measurements has been reported previously.15 Internal and external hip rotation were measured in 90° of flexion (while seated) and in extension (while prone). Seated hip rotation allowed for the pelvis to remain stationary while the hip joint rotates. During seated measurement of hip rotation, the midline of the digital inclinometer was aligned with a line connecting the tibial tubercle to the center of the ankle with the knee flexed to 90°. In the prone position, the pelvis was flat against the examination table and thus fixed, and neutral rotation (0°) was taken as a line perpendicular to the floor. Hip rotation in the flexed position was assessed with the patient sitting, and neutral rotation (0°) was taken again as a line perpendicular to the floor in line with the body axis. Interobserver, and particularly intraobserver, reliability for this method of evaluation is known to be high, with reported intraclass correlation coefficients of 0.8 to 0.9.8,20,25

We investigated side-to-side differences in hip rotational range of motion using multiple parameters. Total rotational arc (Tot) for each hip was calculated by adding the internal rotation and external rotation measurements for both the prone (pTot) and flexed (fTot) positions. The number of athletes with side-to-side differences in Tot of >10° was calculated. Total arc loss (TAL) was calculated by subtracting the Tot in the dominant from the nondominant hip in both prone (pTAL) and flexed (fTAL) positions. Hip internal rotation deficit (HIRD) in the dominant hip was calculated by subtracting the internal rotation measurement of the nondominant hip from the dominant hip in both the prone (pHIRD) and flexed (fHIRD) positions. The presence of a fixed flexion contracture was assessed using the Thomas test.9 The athlete was positioned supine on the examination table with both knees in flexion to bring the lumbar spine to neutral (flat). While one hip was held in flexion at this angle, the limb being examined was lowered to the table. The presence of a flexion contracture was defined as inability to completely lower the tested limb to the table and was recorded as a positive test result. Similarly, the presence or absence of an iliopsoas “snapping” hip was assessed with the method described by Byrd.4

We used the definition of Ellenbecker et al5 for assigning lower extremity dominance in tennis players, defining the lower extremity dominant leg as the ipsilateral side of the forearm ground stroke and the same side as the upper extremity with which the player served. However, as rotational deficits in the hip may also affect the nondominant leg,25,29 we also calculated and examined rotational parameters with the dominance reversed (Rv pHIRD, Rv fHIRD, etc.).

Data from the patient questionnaire were collated with information from a WTA player health database, which records previous health information including radiology results, and diagnoses of shoulder, hip, knee, lower back, or abdominal complaints occurring at any time during their playing history. Data were analyzed to identify associations between these and hip rotational parameters and clinical examination findings.

Statistical Analysis

Differences in range of motion measurements between dominant and nondominant hips were assessed with a paired t test. Associations between dichotomized range of motion parameters and history of injury were analyzed with Fisher exact tests. For all analyses, α was set at .05.

RESULTS

The mean age of athletes at the time of examination was 24.7 years (range, 17-37 years) (Table 1). Fifteen (12%) of the players were left-hand dominant. There was no difference in the mean flexed internal rotation range of motion between the dominant and nondominant hips (38° vs 38°, respectively; P = .9) or in external rotation range of motion (29° vs 27°, respectively; P = .8) (Table 2). Ranges of internal and external rotation motion were also similar in the prone position, with a mean Tot in the dominant hip of 60° when prone compared with 65° in the flexed position. The mean internal rotation was greater than the mean external rotation in both the dominant and nondominant hips in both flexed and prone positions (Table 2).

With regard to side-to-side rotational differences, the mean pHIRD was 7.9°, and the mean fHIRD was 4.3°.
With hip dominance reversed, the mean Rv pHIRD was 5.2°, and the mean Rv fHIRD was 4.8°. Only 8% of players had an Rv pHIRD of \( \geq 10° \) (Table 3). Similarly, 25% of players had a pHIRD of \( \geq 10° \), but only 11% had a pHIRD of \( \geq 15° \). In the flexed position, the mean difference of fTot between the dominant and nondominant hips (fTAL) was 2°. Side-to-side differences of \( >10° \) in fTot were found in 22% of players, and only 8% had differences of \( \geq 15° \). There was no correlation between player age and range of internal rotation, external rotation, or any calculated rotational parameter. We found 25% of players with a positive Thomas test result in their dominant hip and 26% in their nondominant hip. In athletes with a positive Thomas test result, it was bilateral in 85%, affected only the nondominant side in 9%, and affected only the dominant side in 6%. Iliopsoas snapping was present in 1 or both hips in 64% of patients. Of those, it was bilateral in 70%, affected only the nondominant hip in 15%, and affected only the dominant hip in 15%.

There was a history of hip injuries or complaints in 18% of players; the most common diagnosis was groin strain (6% of players) (Table 4). Four players had been diagnosed with femoroacetabular impingement (FAI), and 2 of them had undergone hip arthroscopic surgery for FAI and labral tears. There were shoulder complaints, the majority of which were of minor pain without magnetic resonance imaging diagnoses, in 28% of players. Twelve players (10%) had suffered abdominal strains in the past, the majority of which (11/12 players) affected the nondominant side. There was an association between a positive Thomas test result and a history of abdominal strain (odds ratio [OR], 6.1; 95% CI, 1.7-25.4; \( P = .006 \)). Abdominal strain was also associated with iliopsoas tightness as assessed by the presence of iliopsoas snapping; all 12 patients with a history of abdominal strain had iliopsoas snapping in their dominant hip and 11 of 12 in their nondominant hip (OR, >10; \( P = .0004 \)). There was a weak association between a history of abdominal strain and pHIRD of \( <10° \) (OR, 3.5; 95% CI, 0.8-14; \( P = .07 \)) and pTot of \( <50° \) (OR, 2.8; 95% CI, 0.6-12; \( P = .1 \)).
and we found no correlation between any rotational parameter and age. General tennis play requires positioning the body for both backhand and forehand strokes, and rotational stresses may be more balanced across the hip than in the shoulder, where the kinetic chain involves only 1 upper limb. It may also be that bony rather than soft tissue constraints to range of motion are more relevant in the hip joint, which in turn would be less prone to adaptations such as capsular tightness than in the shoulder.

The abdominal musculature plays a significant role in trunk and core stability, providing the mechanical link between the lower and upper limbs in the kinetic chain, particularly during the overhead serve. A history of abdominal strain was reported in 10% of players in this study, and we found a strong association between injuries and both a positive Thomas test result and iliopsoas snapping sign. An abdominal strain in tennis players is a debilitating injury, and as in nearly all players in this study, it usually involves the rectus abdominis on the nondominant side. It typically requires 4 to 8 weeks for recovery before returning to competition, and it has a tendency to recur if a player returns to play too early. Asymmetric iliopsoas hypertrophy is known to occur in tennis players, based on our data, if iliopsoas tightness is found on clinical examination, a stretching program should be recommended with the goal of reducing the risk of abdominal injury.

Adequate hip range of motion is required for the transfer of energy from the lower to the upper extremity along the kinetic chain. In particular, sufficient internal rotation is required for optimum mechanics of the overhead motion. Burkhart et al suggested that disruption of the kinetic chain at the hip could lead to shoulder injuries, postulating that if less force was transferred from the lower extremity, this would place greater stress on the upper extremity, thereby increasing the risk of injury. There are some data to support this theory, with Scher et al reporting that baseball players with a history of shoulder lesions had less internal rotation in the nondominant hip than those without. However, the mean loss was only 5°, and the authors questioned its clinical significance. Our data did not support this hypothesis; while 28% of patients in this study had a history of shoulder problems, we were unable to find any associations with restricted hip range of motion.

Other joints along the kinetic chain may also be affected by the loss of hip motion, and a number of previous studies in male athletes have associated loss of internal rotation in the nondominant hip with lower back pain. Vad et al and Murray et al reported independently that golfers with lower back pain had between 8° and 9° less internal rotation in their nondominant hip. Despite extensive analysis of a number of hip rotational parameters, we were unable to demonstrate any such associations with lower back pain. This may be explained by the fact that previous studies largely involved male athletes, and the association may not apply to female athletes. Ellenbecker et al reported that male tennis players had a mean of 10° less internal rotation than external rotation in the hip, whereas no such difference occurred in female players. In our study, professional female tennis players actually

| TABLE 4 |
| Current or Previous Injuriesa |

<table>
<thead>
<tr>
<th>Injury or Complaint</th>
<th>Players, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder injury/complaint</td>
<td>35 (28)</td>
</tr>
<tr>
<td>Nonspecific pain</td>
<td>20 (16)</td>
</tr>
<tr>
<td>Partial rotator cuff tear</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Subacromial impingement/bursitis</td>
<td>5 (4)</td>
</tr>
<tr>
<td>SLAP tear</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Acromioclavicular joint pain</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Instability</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Hip injury/complaint</td>
<td>23 (18)</td>
</tr>
<tr>
<td>Groin strain</td>
<td>8 (6)</td>
</tr>
<tr>
<td>Flexor strain</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Nonspecific hip pain</td>
<td>5 (4)</td>
</tr>
<tr>
<td>FAI/labral tear</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Abductor strain/trochanteric pain</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Lower back pain</td>
<td>28 (22)</td>
</tr>
<tr>
<td>Nonspecific pain</td>
<td>18 (14)</td>
</tr>
<tr>
<td>Pars stress fracture/spondylolisthesis</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Disc herniation/radiculoapathy</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Knee injury/complaint</td>
<td>36 (29)</td>
</tr>
<tr>
<td>Patellar tendinopathy</td>
<td>8 (6)</td>
</tr>
<tr>
<td>Meniscal tear</td>
<td>8 (6)</td>
</tr>
<tr>
<td>Nonspecific pain</td>
<td>7 (6)</td>
</tr>
<tr>
<td>ACL rupture</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Chondral defect</td>
<td>3 (2)</td>
</tr>
<tr>
<td>MCL strain</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Partial quadriceps tear</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Osgood-Schlatter disease</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Abdominal wall strain</td>
<td>12 (10)</td>
</tr>
<tr>
<td>Lateral ankle ligament sprain</td>
<td>31 (25)</td>
</tr>
</tbody>
</table>

1°, anterior cruciate ligament; FAI, femoroacetabular impingement; MCL, medial collateral ligament; SLAP, superior labrum anterior-posterior.

**DISCUSSION**

In 1996, Kibler et al reported a mean 30° loss of internal rotation in the dominant shoulder of female tennis players and correlated the amount of loss with age and years of tournament play. This “GIRD” adaptation is thought to result from repetitive microtrauma and subsequent capsular tightness, and it has been associated with an increased risk of upper limb injury. In our cohort of professional female tennis players, we did not find evidence of such side-to-side rotational adaptations in the hip. Only 8% of players had a side-to-side difference in fTot of ≥15°, and we found no correlation between any rotational parameter and age. General tennis play requires positioning the body for both backhand and forehand strokes, and rotational stresses may be more balanced across the hip than in the shoulder, where the kinetic chain involves only 1 upper limb. It may also be that bony rather than soft tissue constraints to range of motion are more relevant in the hip joint, which in turn would be less prone to adaptations such as capsular tightness than in the shoulder.

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had between 9° and 16° greater hip internal rotation than external rotation, and therefore, minor loss of internal rotation may have less effect on the overall function of the kinetic chain.

There are a number of limitations to this study. First, we did not assess all players for radiographic evidence of FAI, which has been associated with loss of internal rotation in collegiate football players.\(^{10}\) However, only 4 players in our study had a clinical diagnosis of FAI, and the relevance of arbitrary radiological measurements to clinical symptoms remains unclear. Second, as this was a cross-sectional study, the cause and effect relationship between abdominal strain and hip flexion contracture is uncertain. Additionally, this cohort represents a group between abdominal strain and hip flexion contracture is uncertain. This group, which has been associated with loss of internal rotation may have less effect on the overall function of the kinetic chain.  

Finally, because of the exploratory and hypothesis-generating nature of this study, rather than confirmatory or hypothesis testing, we did not adjust the \(\alpha\) value to mitigate the risk of type I error due to multiple comparisons. However, even if we had adjusted the hypothesis-wide error to .05 for each of the correlates for each injury, our main findings of an association between a positive Thomas test result and iliopsoas tightness with a history of abdominal strain remain significant. These findings, however, require confirmation in future studies.

In conclusion, we report an association in professional female tennis players between abdominal strains and flexion contractures of the hip and iliopsoas tightness. While we did not find evidence of specific hip adaptations in rotational range of motion, if hip flexion contractures are found on clinical examination, then a stretching program may be indicated. Further studies are required to assess whether such a program can reduce the risk of abdominal injury.

**REFERENCES**