Isometric Hip-Rotator Torque Production at Varying Degrees of Hip Flexion

Sam Johnson and Mark Hoffman

Context: Hip torque production is associated with certain knee injuries. The hip rotators change function depending on hip angle.Objective: To compare hip-rotator torque production between 3 angles of hip flexion, limbs, and sexes. Design: Descriptive. Setting: University sports medicine research laboratory. Participants: 15 men and 15 women, 19–39 y. Intervention: Three 6-s maximal isometric contractions of the hip external and internal rotators at 10°, 40°, and 90° of hip flexion on both legs. Main Outcome Measure: Average torque normalized to body mass. Results: Internal-rotation torque was greatest at 90° of hip flexion, followed by 40° of hip flexion and finally 10° of hip flexion. External-rotation torque was not different based on hip flexion. The nondominant leg’s external rotators were stronger than the dominant leg’s, but the reverse was true for internal rotators. Finally, the men had more overall rotator torque. Conclusions: Hip-rotation torque production varies between flexion angle, leg, and sex. Clinicians treating lower extremity problems need to be aware of these differences.

Keywords: hip strength, sex differences, bilateral differences

The primary function of the hip joint is supporting the weight of the head, arms, and trunk during static and dynamic postures. The hip joint also helps control the position of the lower extremity during both weight-bearing and non-weight-bearing movements. Therefore, diminished hip torque production (ie, strength) may lead to the inability to support the head, arms, and trunk and control the leg during movement. In fact, certain lower extremity injuries have been reported to be associated with decreased hip torque production. Therefore, clinicians must be able to correctly assess the hip musculature’s ability to produce torque and subsequently prescribe effective corrective exercises.

An important factor when assessing torque production of the hip musculature is the fact the position of the hip joint strongly influences the action of those muscles. Several authors have reported that the moment arms of the hip musculature change depending on the position of the joint and may in fact reverse their action. For example, Delp et al reported that several muscles in cadavers have external-rotation moment arms when the hip is extended but have internal-rotation moment arms when the hip is flexed. This is potentially important for sports medicine clinicians.
for several reasons. Mainly, athletes often perform movements when the hip is not in the zero or neutral position, such as a water polo player performing the eggbeater motion or an athlete performing a side-step cutting maneuver. In addition, certain hip positions (e.g., hip adduction and internal rotation) potentially put the lower extremity at increased risk of knee injury. Therefore, clinicians need to be aware when assessing hip torque production or when prescribing rehabilitation exercises at the hip that the muscles responsible may depend on the position of the hip.

Although knowledge of changing moment arms is important, this analysis only provides the potential a muscle has for producing torque, not the actual amount of torque production by the muscle. It is probably more important for clinicians to know the latter of the 2 when assessing a patient. Several studies have examined torque production of the hip rotators. However, to our knowledge, only 1 study has examined hip-rotator torques at different hip-flexion angles, which is important considering the changing role of the hip rotators. In that study, Jarvis reported that external-rotator torque production was not influenced by hip-flexion position, but internal-rotator torque production was. Specifically, the internal rotators exerted significantly greater torque when tested in the seated position than when tested in the supine, back-lying, position. However, Jarvis only tested 2 angles of hip flexion, 0° and 90°, and only examined females.

Other researchers have examined hip-rotator torques in both males and females. This is important because there appears to be a discrepancy in the incidence of injury between the sexes that may be associated with hip torque production. Both Cahalan et al and Claiborne et al reported significantly greater mean maximum hip-rotator torques in males than in females. However, they only evaluated hip-rotation torques at 1 position of hip flexion, which as noted is not always appropriate for athletes performing movements in varying angles of hip flexion or in potentially deleterious positions.

In addition, there is evidence suggesting discrepancies in torque production between the legs. For example, several authors have reported differences in hip-abductor torques between the dominant and nondominant leg. Nonetheless, little is known about differences in hip-rotation torque production between the legs. Finally, there are reports of kinematic differences between the dominant and nondominant leg during certain sport-specific tasks, especially in females.

Therefore, the purpose of this was study was to evaluate hip external-rotation and internal-rotation torque production in both sexes and both legs at 3 different flexion angles: 10°, 40°, and 90°. To our knowledge no other study has examined these variables in combination.

Methods

Thirty participants (15 men and 15 women) free of lower extremity injury during the preceding year were enrolled (See Table 1 for participant demographics). Participants read and signed an informed-consent form approved by the university’s institutional review board.

Participant’s height (cm), mass (kg), and leg dominance were all ascertained. Height was determined by a wall-mounted stadiometer. Mass was determined by weighing the participant on a scale and converting the weight in pounds to kilograms.
Finally, leg dominance was determined by observing which leg the participant preferred to use during 3 functional tasks: kicking a ball, stepping up onto a step, and regaining balance after a perturbation from behind (ie, a small push). Whichever leg was used for at least 2 of the 3 tasks was considered the dominant leg.

After the collection of demographic information, participants performed a 5-minute submaximal warm-up on a Monark GIH cycle ergometer (Monark, Stockholm, Sweden). At the conclusion of the warm-up participants were seated on a Biodex System 3 dynamometer (Biodex Medical Systems, Shirley, NY). Each participant’s leg was secured with the hip in neutral position in the frontal and transverse planes and the knee in 90° of flexion. The rotational axis of the dynamometer was aligned with the estimated axis of rotation of the hip joint. The arm of the dynamometer was placed in a position of comfort above the malleoli but below the belly of the gastrocnemius. The distal thigh was secured with a strap to prevent hip flexion, extension, abduction, and adduction motions. After proper positioning, the participant was instructed to perform a 6-second maximal isometric contraction of either the external or internal rotators of the hip.

Internal- and external-rotation torques were collected for both legs at 3 different angles of hip flexion: 10°, 40°, and 90°. The angles of hip flexion were chosen to represent near extension of the hip, midrange position, and near end range of flexion. It should be noted that 10° and 90° were selected because the Biodex dynamometer does not move beyond those positions. The testing order was determined by drawing from choices for each decision in the following order: dominant versus nondominant, internal versus external rotation, and 10°, 40°, and 90°. At each testing position the participant was asked to perform a 6-second maximal isometric contraction followed by a 60-second rest. At each position, 3 repetitions were performed; the first was a familiarization repetition, followed by 2 test repetitions. Halfway through the testing the participants were given a 5-minute rest period. This was done for 2 reasons. First, the dynamometer arm needed to be changed. Second, it allowed the participant to move off the dynamometer chair and stand, preventing a static posture for the entire testing procedure. Subjects were then repositioned on the dynamometer as previously described, and testing was completed.

The dynamometer was interfaced with a BIOPAC data-collection system using AcqKnowledge 3.7.3 (BIOPAC Systems Inc, Goleta, CA). Data were collected at 200 Hz. The torque values were smoothed for analysis (average of every 50 samples). The average torque produced during the midportion of the contraction (2.5–4.5 s) for both test repetitions was determined. The torques of the 2 trials were then averaged and normalized to the participant’s body mass (Nm/kg). The middle portion of the torque curve was selected to prevent any overshoot or decay effects of the torque curve.

<table>
<thead>
<tr>
<th>Table 1 Participant Demographics, Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Mass (kg)</td>
</tr>
</tbody>
</table>
Data Analysis

A 2 (rotation) × 3 (angle) × 2 (leg) × 2 (sex) mixed-model factorial ANOVA was used to compare normalized average torque (SPSS 15, SPSS Inc, Chicago, IL). The within-subject variables were rotation (internal and external), angle (10°, 40°, and 90°), and leg (dominant and nondominant). The between-subjects independent variable was sex (male and female). The a priori alpha level was set to .05. If interactions were significant, a Tukey HSD follow-up test was used to determine differences between levels.

Results

There was no 4-way interaction effect ($F_{2,27} = 1.045$, $P = .366$). In addition, there were no significant 3-way interactions. As illustrated in Figure 1, there was a significant interaction between direction of torque production and flexion angle ($F_{2,27} = 30.119$, $P < .001$). Tukey HSD post hoc testing revealed differences in internal-rotation torque between the 3 hip-flexion angles. Specifically, torque values increased by 33.7% as hip flexion changed from 10° to 90° and by 20.1% from 40° to 90°. Torque values also increased 17.0% from 10° to 40° of hip flexion. In contrast, external-rotation torque production was not affected by hip-flexion angle, with less than 2.0% change between any of the hip-flexion positions. In addition, as can be observed in Figure 2, there was a significant interaction between direction of torque production and leg dominance ($F_{2,27} = 4.370$, $P = .046$). Specifically, torque production of the external rotators was 7.8% greater for the nondominant leg.
than the dominant leg, whereas torque production for the internal rotators revealed an opposite pattern, with the dominant leg producing 7.2% more torque than the nondominant. However, Tukey HSD post testing was not significant. Finally, men produced 25.7% more torque than women ($F_{1,28} = 6.038, P = .020$) across all testing positions (Table 2).

![Figure 2](image)

**Figure 2** — Hip external- and internal-rotation torque as a function of leg dominance, mean ± SD. Significant rotation-by-leg interaction effect.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Men</th>
<th>Women</th>
<th>Sex difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nondominant external, 10°</td>
<td>0.48 ± 0.17</td>
<td>0.36 ± 0.11</td>
<td>24.3%</td>
</tr>
<tr>
<td>Nondominant external, 40°</td>
<td>0.50 ± 0.15</td>
<td>0.35 ± 0.12</td>
<td>30.5%</td>
</tr>
<tr>
<td>Nondominant external, 90°</td>
<td>0.50 ± 0.14</td>
<td>0.37 ± 0.11</td>
<td>26.2%</td>
</tr>
<tr>
<td>Dominant external, 10°</td>
<td>0.56 ± 0.19</td>
<td>0.35 ± 0.12</td>
<td>37.7%</td>
</tr>
<tr>
<td>Dominant external, 40°</td>
<td>0.57 ± 0.19</td>
<td>0.37 ± 0.12</td>
<td>35.5%</td>
</tr>
<tr>
<td>Dominant external, 90°</td>
<td>0.50 ± 0.19</td>
<td>0.37 ± 0.12</td>
<td>33.0%</td>
</tr>
<tr>
<td>Nondominant internal, 10°</td>
<td>0.41 ± 0.19</td>
<td>0.32 ± 0.12</td>
<td>20.7%</td>
</tr>
<tr>
<td>Nondominant internal, 40°</td>
<td>0.49 ± 0.23</td>
<td>0.38 ± 0.18</td>
<td>22.0%</td>
</tr>
<tr>
<td>Nondominant internal, 90°</td>
<td>0.60 ± 0.29</td>
<td>0.47 ± 0.20</td>
<td>22.3%</td>
</tr>
<tr>
<td>Dominant internal, 10°</td>
<td>0.36 ± 0.13</td>
<td>0.30 ± 0.11</td>
<td>14.4%</td>
</tr>
<tr>
<td>Dominant internal, 40°</td>
<td>0.45 ± 0.20</td>
<td>0.35 ± 0.13</td>
<td>22.0%</td>
</tr>
<tr>
<td>Dominant internal, 90°</td>
<td>0.57 ± 0.23</td>
<td>0.46 ± 0.16</td>
<td>19.6%</td>
</tr>
</tbody>
</table>

*Note*. Sex difference = 1 – (women/men).
Discussion

Recently, increased attention has been directed to the role of the hip musculature in lower extremity injury risk, prevention, and treatment. The hip rotators have been the focus of some of that attention because of their role in controlling the position of the femur. For example, a study by Ireland et al\(^3\) reported that a group of females with patellofemoral pain demonstrated a 36\% external-rotation torque production deficit compared with a group of asymptomatic females. Therefore, it is important for clinicians to be able to fully understand the role of these muscles to effectively evaluate and treat such weakness.

Although other studies have examined hip-rotator torque production, to our knowledge only 1 has examined rotator torques at differing angles of hip flexion.\(^11\) In addition, others have examined rotator torque production between the sexes, but again only at 1 position.\(^10,12\) Finally, there is some evidence of side-to-side differences in hip-abductor torque production, yet we know of no studies examining hip-rotator torque production between legs.\(^13,14\) Therefore, the purpose of this study was to examine these variables not in isolation but together, to see if a more complete picture of hip-rotator torque production would emerge.

Our results reveal that internal-rotation torque depended on hip-flexion angle, with torque production becoming progressively larger with increasing degrees of hip flexion. As noted, there was a 33.7\% increase in torque production as the hip was flexed from 10° to 90°, a 20.1\% increase from 40° to 90° of hip flexion, and a 17.0\% increase from 10° to 40° of hip flexion. This is in agreement with the study performed by Jarvis,\(^11\) who reported an increase in internal-rotation torque production with increased hip flexion. In addition, the moment-arm analysis performed by Delp et al\(^6\) would support our finding. Again, their study revealed that many of the muscles that have external-rotation moment arms when the hip is near extension have internal-rotation moment arms when the hip is flexed.\(^6\)

Unlike internal rotation, we discovered that external-rotation torque production did not change with increasing hip flexion. Specifically, increasing hip flexion from 10° to 90° only resulted in a 2.1\% increase in torque production, only a 1.8\% increase from 10° to 40°, and a 0.3\% increase from 40° to 90°. Again, this is in agreement with the study performed by Jarvis.\(^11\) However, this may be different than what might be expected based on the moment-arm analysis by Delp et al.\(^6\) In their study, only 3 of the examined muscles did not have a trend toward internal rotation: the obturator externus, quadratus femoris, and iliopsoas.\(^6\) Why external-rotation torque production did not change but the moment arm did cannot be directly explained based on our study. It is possible that more muscles were recruited than what were tested by Delp et al or that there were methodological limitations in using cadavers in that study.

The current results also demonstrate that internal-rotation torque production is greater than external-rotation torque production when the hip is flexed. This concurs with previous studies.\(^10-12\) However, Jarvis\(^11\) found that external-rotation torque production was greater than internal-rotation torque production when the hip was extended. We, too, found that the external rotators produced more torque than the internal rotators with the hip extended, but the difference was not statistically significant. This discrepancy could be partly because we were unable to fully extend the participants’ hips when testing.
As a whole, the concurrence of our results with previous evaluations of torque production, along with the moment-arm analysis in cadavers, gives us confidence that the hip rotators’ function changes significantly based on hip-flexion position. This is important because no muscles have a dedicated function of internally rotating the hip. Therefore, to internally rotate the hip, other muscles must switch or combine their functions to act as internal rotators.

Clinicians may be able to use this combination of results in several ways. Decreased torque production (ie, strength) of the hip musculature can lead to the inability to support the head, arms, and trunk and diminished control of the lower extremity. Therefore, when testing torque production of the hip muscles, particularly the internal rotators, positioning is essential. This is particularly true for athletes who perform with the hip in varying amounts of hip flexion. A salient example is that of a water polo player who performs an eggbeater motion with the legs to keep the trunk upright in the water. The eggbeater motion is when the athlete moves 1 leg clockwise and the other counterclockwise while moving the hip through varying amounts of flexion. Therefore, in water polo players it is important that torque production assessment be performed in the range of motion in which they play. We would also recommend based on results of this study and clinical experience that strengthening exercises for the hip rotators, especially in this population of athletes, include varying amounts of hip flexion.

In addition, athletes in many other sports need to control hip rotation during positions other than the hip’s neutral joint position. For example, an athlete making a side-step cut may have increased hip flexion and attempt to change directions, which may require the hip rotators to control femur rotation, perhaps preventing potentially injurious positions. Our study did not specifically examine the relationship of hip-rotator torque production to lower extremity mechanics or to an injured population, but further inquiry is warranted.

In this study we also examined differences based on leg dominance. Differences in torque production between the dominant and nondominant legs have previously been suggested but with conflicting results. The results of our study reveal that hip-rotation torque production depends on leg dominance. The external rotators of the nondominant leg produced more torque than those of the dominant leg, 0.46 Nm/kg and 0.43 Nm/kg, respectively. However, with internal rotation the reverse was true. The dominant leg produced more torque than the nondominant leg, 0.45 Nm/kg compared with 0.41 Nm/kg. Why these differences exist is not fully understood and cannot be deduced directly from this study but deserve further study.

Finally, we also examined differences between the sexes. This was done for several reasons. The aforementioned study by Jarvis only examined females. Therefore, to provide a more complete picture of hip-rotator torque production we examined both sexes. In addition, and perhaps more important clinically, there appears to be a discrepancy in the incidence of injury between the sexes that may be associated with hip torque production. We found that men were able produce more torque than women even though torque was normalized for body mass. Men’s overall rotator torque production was 0.50 Nm/kg, whereas women’s was 0.37 Nm/kg. It should be noted that this was for pooled rotator torque; the sex-by-rotation interaction effect was not significant. Table 2 provides a breakdown of sex differences at each of the testing positions. As can be seen, the men had approximately 35.0% more external-rotation torque production in the dominant leg than the women and approximately 27.0% more nondominant external rotation.
The men also produced more torque with the internal rotators than the women, with the dominant leg producing 18.6% more torque and the nondominant leg producing 21.7% more torque. This is in concurrence with previous reports that males produced significantly more torque than females.\textsuperscript{10,12} This potentially has clinical impact because females have a higher incidence of patellofemoral and noncontact ACL injuries, both of which have been suggested to be associated with hip-rotator torque production deficits, particularly of the external rotators.\textsuperscript{3–5}

This study was not without limitations. Most notably, the participants were in a seated or supine open-kinetic-chain position during torque assessments. This could have altered the recruitment of synergist and stabilizing muscles that may be used during functional or sport-specific movements. However, our main goal was to ascertain torque production of the hip rotators in isolation. Future research would be better served to determine whether more functional or sport-specific positions have the same effect. However, testing torque production of the hip rotators in sport-specific positions is very difficult. For example, previous studies have tested hip torques in the standing position, with the exception of the hip rotators, which had to be tested in a seated position to aid in stability.\textsuperscript{10,12} Testing the hip rotators with the hip in extension would also be interesting because the hip is often in extension during sport-specific movements. Finally, we only evaluated healthy, active college students. Although this limits our findings to an uninjured population it is an important step in gaining a more complete picture of hip-rotator torque production, something that has been missing in the literature.

**Conclusions**

In conclusion, the results of this study revealed that hip internal-rotation torque production increased significantly from a position near extension to 90° of hip flexion. This is in concurrence with previous reports on rotator torque production and with recent moment-arm analyses in cadavers.\textsuperscript{6,11} On the contrary, hip external-rotation torque production did not change with differing amounts of hip flexion. Although this concurs with previous reports, it may not be the expected outcome based on moment-arm analysis.\textsuperscript{6,11} In addition, the hip external rotators of the nondominant leg produced more torque than those of the dominant leg, whereas the internal rotators of the dominant leg produced more torque than those of the nondominant leg. Finally, men produced significantly more torque than women for overall hip-rotator torque production even after accounting for body-mass differences. These results have meaningful applications for clinicians in the evaluation, treatment, and rehabilitation of injuries associated with decreased hip-rotator torque production. More research into what muscles are actually active during these movements may further elucidate several common lower extremity conditions.

**References**