A MECHANISM FOR LIGAMENTUM TERES INJURIES IN FEMOROACETABULAR IMPINGEMENT: AN ANATOMICAL STUDY

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ABSTRACT

Background: Femoroacetabular impingement can produce abnormal biomechanics that lead to compensatory injuries around the hip and pelvis. Ligamentum teres pathologies are commonly associated with these bony deformities but a mechanism for injury has not been described in the literature.

Purpose: The purpose of this study was to describe a potential mechanism behind ligamentum teres injury and impingement between the femoral neck and acetabulum.

Study Design: Laboratory controlled cadaveric study.

Methods: Twenty-six hips from 15 embalmed cadavers (8 male; 7 female) with lifespans between 55-93 years were skeletonized. The hip was placed in 90° flexion and 0° abduction/adduction and internally rotated until the femoral head neck contacted the acetabulum. This position of impingement with respect to internal rotation was recorded with a goniometer. The hip was then further internally rotated until end range of motion was achieved and again the position of internal rotation recorded with a goniometer.

Results: The positions of internal rotation at which impingement occurred (mean 9°; SD 4.2; Range -2° to 15°) when compared to end range (mean 21°; SD 5.7; Range 5° to 27°) were significantly different ($p < 0.005$; $t = 14.8$). In all the hips, after impingement occurred the site of bony contact between the femoral neck and acetabulum acted as a pivot point. The femoral head was levered inferiorly with a loss of the rotational center within the acetabulum, as internal rotation continued. This movement of the femoral head caused the ligamentum teres to tighten and restricted further movement. Movement into internal rotation beyond this end position caused rupture of the ligamentum teres.

Conclusion: Internal rotation range of motion can occur beyond the position of impingement and resulted in abnormal inferior movement of the femoral head and tightening of the ligament teres. This study provides cadaveric evidence for the mechanism of ligamentum teres injury in those with who engage in activities that required motion beyond the point of impingement.

Keywords: Femoroacetabular impingement, hip internal rotation, ligamentum teres, rotational stabilizer

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INTRODUCTION

Ligamentum teres (LT) pathology, in form of partial tears, are commonly seen in hip arthroscopy and can be associated with the bony deformities seen with developmental dysplasia and femoroacetabular impingement (FAI).^{1,2} Because the LT is described as a rotational hip stabilizer, instability occurring with dysplasia and the potential mechanism behind LT tears have been defined.³ Femoroacetabular impingement has been described as a dynamic disorder in which contact between the femoral neck and acetabulum produce abnormal biomechanics and damaging forces across the hip joint.^{4,5} These abnormal biomechanics may lead to compensatory injuries around the hip and pelvis, particularly in athletes.⁶ The mechanism behind LT pathology occurring with the abnormal biomechanics associated with impingement between the femoral neck and acetabulum has not been described.

Published reports on the prevalence of LT pathology in those undergoing hip arthroscopy have varied greatly, describing prevalence from 4% to 93%.^{1,7-13} Studies that include athletes with FAI reported some of the highest prevalence of LT pathology.^{7-10,12,13} The results of these studies support theories that the LT could be injured in sports that require positions that cause impingement between the femoral neck and acetabulum near end range of motion. In fact one study that included professional hockey players undergoing hip arthroscopy for FAI noted a 93% prevalence of LT pathology.¹³ End range of hip internal rotation range of motion is felt to be the primary source of impingement and has been documented to occur in athletes who participate in a number of sports, such as hockey,^{14,15} golf,¹⁶ ballet,¹⁷ and taekwondo.¹⁸ The amount of internal rotation available at 90° of flexion was found to correlate with the amount of space between the femoral neck and acetabular rim.¹⁹ Once contact occurs, the acetabular rim is thought to induce a levering of the femoral head to cause posterior contra-coup lesions in the posterior wall of the acetabulum.²⁰ The effect of this femoral head levering on the LT is unknown.

Once thought of as being only a vestigial structure, the purpose of the LT is becoming better understood. The function of the LT has been described using a ball and string model, with the LT acting as a

sling, as it wraps around and pulls the femoral head into the acetabulum with rotational movements.^{1,21,22} This model is supported by studies that found the LT to add stability at the end range of hip motion in the frontal and transverse planes.^{21,22} In fact Martin et al³ found the LT to be the primary stabilizer of internal rotation when the hip was in 90° of flexion. Therefore, activities that require end range of internal rotation range in a position of hip flexion may contribute to LT injury, particularly if there are abnormal biomechanics occurring because of contact between the acetabular rim and femoral neck.

The LT is a rotational stabilizer and tightens at the end range of internal rotation in flexion.³ Additionally, it is known that LT injuries are common in FAI^{7-10,12,13} and that impingement between the femoral neck and acetabular rim occurs with hip flexion and internal rotation.²³ The effect the abnormal biomechanics that occur with impingement has on the LT is unknown. The purpose of this study was to describe the potential mechanism behind LT tears and the abnormal biomechanics that occur after the femoral neck contacts the acetabulum.

METHODS

Twenty-six hips from 15 embalmed cadavers (8 male; 7 female) with a lifespan ranging between 55-93 years were included in this study. Each specimen was skeletonized and the hip capsule was vented with a square patch to allow full range of motion and visualization of the LT. The primary investigator positioned the hip in 90° of flexion and 0° of abduction/adduction using a bubble goniometer (Baseline® Bubble Inclinator, Fabrication Enterprises Inc. White Plains, NY). The hip was then internally rotated until the femoral head neck junction contacted the acetabulum. This position of impingement with respect to internal rotation (IR) was recorded with a standard 12-inch goniometer (Baseline® Goniometer, Fabrication Enterprises Inc. White Plains, NY) by the secondary investigator. The hip was then further internally rotated until end range of motion was achieved and again the position of IR recorded with a standard goniometer. Each measure was repeated three times.

The version and inclination angles of the femur were measured by the secondary investigator using

a standard 12-inch goniometer (Baseline® Goniometer, Fabrication Enterprises Inc. White Plains, NY) and the version angles of the acetabulum were measured using a bubble goniometer (Baseline® Bubble Inclinometer, Fabrication Enterprises Inc. White Plains, NY) to describe the orientation of the acetabulum and proximal aspect of the femur. Acetabular version (AV) was determined by the angle formed by the sagittal plane and a line formed by connecting the midpoint of the anterior and the posterior acetabular rim. Femoral version (FV) was determined as the angle formed by a line bisecting the femoral head/neck and a line parallel to the posterior aspect of the femoral condyles. Femoral inclination (AI) was determined as the angle between a line bisecting the femoral neck relative to a line bisecting the femoral shaft. This study was approved by the ethics committee for anatomical studies of Duquesne University.

Statistical Analysis

All data was analyzed using a common statistical software system (SPSS Version 21, Chicago IL). The mean, standard deviation, and range of femoral and acetabular version and inclination angles were computed. A Paired T-test was performed to compare the amount of IR of the hip joint at the position of impingement and end range of motion. Reliability of the measurements were assessed with intra-class correlation coefficients (ICC 2,1) using the first and third measurement of internal of IR of the hip joint at the position of impingement and end range of motion.

RESULTS

The average AV, FV, and AI values are presented in Table 1 and were found to be 18° (SD 6; Range 9-31), 11° (SD 4; Range 3-20), and 37° (SD 6; Range 28-48). It was noted 12/14 cadavers had cam deformities with 17/26 having signs of bony reactive stress associated with FAI. These were determined by visual inspection of each femoral neck and head

for abnormal bone growth and signs of osteoarthritic wear, respectively. No signs of irregular acetabular wear were noted beyond age-related changes to the cartilage.

Impingement occurred at a mean position of 9° IR (SD 4.2; Range -2° to 15°) while end range IR occurred at a mean position of mean position 21° IR (SD 5.7; Range 5° to 27°). The position of IR when impingement occurred compared to the position of end range IR were significantly different ($p < 0.005$; $t = 14.8$). In all 26 hips, after impingement occurred the site of bony contact between the femoral neck and acetabular rim acted as a pivot point, with the femoral head being levered inferiorly. Once this contact occurred (Figure 1), there was a loss of the rotational center within the acetabulum, as IR range of motion continued. This movement of the femoral head being levered inferiorly caused the LT to tighten, until the LT restricted further movement (Figure 2). Movement into IR beyond this end range of motion position caused rupturing of the LT in all hips. Measurements of IR when impingement occurred and position of end range IR were found to be reliable with ICC (2,1) values of 0.87 and 0.97, respectively.

DISCUSSION

This study provides cadaveric evidence for the mechanism of LT injury that occurs after the femoral neck contacts the acetabulum with hip internal rotation in flexion. Internal rotation range of motion can occur beyond the position of impingement, with a loss of the rotational center within the acetabulum and inferior movement of the femoral head. This levering mechanism of the femoral head caused tightening and eventual rupture of the LT. These findings can be important in those who engage in athletics that require flexion and IR range of motion beyond the point of impingement, such as butterfly style goal tending.

Many sports have high range of motion demands that include forced hip internal rotation beyond end

Table 1. Average Structural Measurements for Cadaveric Specimens.

	Average	Standard Deviation (Range)
Acetabular Version (AV)	18°	6° (9°-31°)
Femoral Version (FV)	11°	4° (3°-20°)
Femoral Inclination (AI)	37°	6° (28°-48°)

Figure 1. Initial impingement of the femoral neck and acetabular rim, indicated by the black arrow.

Figure 2. Ligamentum teres at the end range of internal rotation, indicated by the black arrow.

range. The results of this study indicate that internal rotation can occur after impingement but the rotation was associated with loss of rotation within the joint. Rotation range of motion beyond the impingement position caused the abnormal femoral head movement outside the acetabulum and tightening of the LT, as the LT attempted to hold the femoral head within the acetabulum. This forced rotation beyond end range of motion has been a proposed mechanism for focal rotational capsular hypermobility²⁴⁻²⁶ but may also be a mechanism for LT pathology. These findings may be particularly important in individuals engaged in activities requiring extreme range of motion, including hockey players and ballet dancers. The result of the current study supports a theory that the LT could be injured in an athlete when internal rotation occurs beyond end range of motion. The results also suggest a potential over-use

injury, with repetitive levering the femoral head out of the acetabulum as a mechanism for LT injury.

This study is the first to describe a potential mechanism behind overuse partial LT tears in those who engage in activities that require repetitive extreme internal rotation in flexion. This overuse mechanism of injury would also correlate with findings that LT pathology in those with FAI that are usually partial tears and not complete ruptures.^{7-10,12,13} Additionally, a systematic review found evidence that LT injury can come from a non-traumatic overuse origin.²⁷ In ballet dancers, injuries to the LT were postulated to occur as the LT attempts to maintain joint stability in movements that require extreme range of motion.²⁸ An overuse mechanism was also supported by findings of only 29-34% with LT pathology reporting an acute mechanism of injury^{2,29}

The role of LT pathology and symptom presentation remains an area of debate. Surgeons who perform open procedures and sacrifice the LT, question its importance as a hip stabilizer. Phillips et al.³⁰ noted that only 24% of patients after surgical excision of the LT during open osteochondroplasty for cam deformities were found to be symptomatic with regard to instability. Martin et al.³ found that subjects complained of instability only when osseous risk factors for instability and a complete LT tear were both present. While individuals with LT pathology may not complain of instability, they do complain of pain. Labral tears and cartilage damage are known to be pain generators, but pain may also be related to partial LT tears. Pain as a symptom in those with partial LT tears are well founded as free nerve endings were identified within the LT.²⁷ Additionally, individuals who underwent arthroscopic LT debridement in the presence of an isolated LT tear commonly reported a decrease in pain.^{31,32}

This biomechanical cadaveric study presents a number of limitations. An electronic tracking system could assist in positioning and measuring hip motion. All soft tissue superficial to the hip capsular ligaments was removed from the specimens. These structures offer stability to the hip joint and influence range of motion, particularly in an in vivo scenario with dynamic muscular action. The IR range of motion values obtained in this study were lower than normal values reported in the literature. However, given the age of the cadavers these values might not be that unusual. The results of the study were validated as those with the lower IR values at the position of impingement had bony findings that would be associated with these values, including decreased femoral version, decrease acetabular version, and fibrocystic lesions indicative of impingement. The effect of embalmed tissue on range of motion must also be considered. However, the capsule was vented to allow full free range of motion to prevent the capsule from restricting motion.

CONCLUSION

The results of the current study indicate that IR range of motion can occur beyond the position of impingement and resulted in abnormal inferior movement of the femoral head and tightening of

the LT. End range of motion of hip IR at 90° of flexion and 0° of abduction/adduction was limited by the LT. This study provides cadaveric evidence for a mechanism of LT injury after the femoral neck contacts the acetabulum. This is of importance in those who engage in sports that require IR motion beyond the point of impingement.

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