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Research article

Association of tensor fascia lata hypertrophy and fatty infiltration in the presence of abductor tendon tears: a radiographic study

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ABSTRACT

Hip abductor tendon tears of the gluteus medius and minimus are becoming a well-recognized source of pain and dysfunction, primarily in middle-age females. Like the rotator cuff, fatty infiltration (FI) can occur after tearing of these tendons. While the association of TFL hypertrophy after abductor tendon tears has been established, its association with FI has not been well studied. Our hypothesis is that hypertrophy of the TFL will be associated with FI of the abductors. All patients >18 years old undergoing primary surgical repair for a confirmed tears on MRI, without a history of prior hip surgery or osteoarthritis, were included. The following measurements were obtained from MRI: TFL cross-sectional area, TFL:sartorius volume ratio, and modified Goutallier grade of gluteus medius and minimus. Seventy patients met inclusion criteria and were divided in two groups, those with ($n = 28$) and those without FI ($n = 42$) of the abductors. The FI group was on average older (65 versus 58 years, $P < 0.00016$). TFL hypertrophy and TFL:sartorius volume ratio were significantly associated with FI ($P = 0.00069$). Following abductor tendon tear and subsequent FI, there exists significant TFL hypertrophy in patients without a prior history of hip surgery in our patient cohort.

INTRODUCTION

Despite the growing recognition of abductor tendon tears and the potential benefit of surgical repair in select patients, there is a paucity of literature describing the clinical implications of more nuanced factors such tensor fascia lata (TFL) hypertrophy and fatty infiltration (FI) [1–4]. Atrophy and weakness of the gluteus medius and minimus have been observed in an osteoarthritic cohort and were correlated with severity of arthritis [3, 5]. Another cohort of patients with abductor tendon pathology exhibited increased TFL hypertrophy, although patients with a history of ipsilateral total hip arthroplasty were included [1]. TFL hypertrophy was not observed in a female cohort of patients with lateral hip pain [6]. The purpose of the current study is to investigate the relationship between TFL hypertrophy and FI in patients with abductor tendon tears. We believe that patients with increased FI of the abductor tendons will have increased TFL size, as measured by cross-sectional area (CSA) and volume ratio on an axial magentic resonance imaging (MRI).

The gluteus medius and gluteus minimus, commonly referred to as the abductor tendons, insert upon the anterosuperior portions of the greater trochanter [7, 8]. Interestingly, a previous anatomical investigation of the gluteus medius and minimus has theorized that they primarily function as dynamic hip stabilizers and pelvic rotators with secondary functions as hip abductors, while the TFL serves as the predominant hip abductor [8]. Abductor tendon pathology typically presents insidiously and is often only diagnosed after failure of conservative measures [1, 6, 9, 10]. Patients with insufficiency of these tendons often describe a long-standing, dull ache that is worsened with weight bearing or laying on the affected side. Physical examination often reveals tenderness over the lateral hip, inability to perform resisted abduction and a Trendelenburg gait [6, 11, 12]. Diagnosis can be confirmed via high-resolution MRI with an emphasis on axial and coronal T2 fat-saturated images and coronal T1 images.

MRI allows not only for identification of tears but also for assessment of the degree of atrophy and FI of the muscles, which can indicate the chronicity of the tears. Additionally, MRI can identify hypertrophy of muscles surrounding the hip such as the tensor fascia lata (TFL). The Goutallier classification is a similar technique that uses MRI to distinguish between muscle and fibrous/fatty tissue following rotator cuff tears [13–15]. The Goutallier grading system ranges from 0 to 4 and is determined by the ratio of normal muscle to FI. Fuchs *et al.* [14]

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Table I. MRI parameters used for each study

	Cor T1 (pelvis)	*Cor T2 FS (pelvis)*	*Cor T2 FS (hip only)*	*Ax T2 FS(hip only)*	*Sag oblique PD FS(hip only)*
TR (ms)	830	4030	3810	4770	3700
TE (ms)	10	60	65	65	30
FOV (mm)	380 × 411	380 × 411	220 × 238	230 × 249	190 × 205
Acquisition time (min:s)	3:31	5:50	3:40	3:20	3:30

Ax = axial, Cor = coronal, Sag = sagittal, PD FS = proton density fat suppressed, FOV = field of view, TR/TE = pulse sequence parameters.

proposed a simplified and more reliable 3-point scale that was aided by the implementation of MRI. This scale combined Goutallier Grades 0 and 1 (consisting of normal to minimal FI), Grade 2 remained unchanged (more muscle than fat) and combined Grades 3 and 4 (more fat than muscle). Limitations of the Goutallier classification include lack of widespread acceptance of one grading system, anatomic disruptions that may distort imaging findings and subjectivity of the grading system. Despite these limitations, most studies show moderate or good agreement [13, 16].

MATERIALS AND METHODS

Patient selection

Institutional review board approval was obtained prior to the onset of the study. This study was a retrospective review of patients presenting to a single fellowship-trained sports medicine orthopedic surgeon that had been diagnosed with a hip abductor tear from 1 January 2015 to 4 January 2020. Inclusion criteria were as follows: patients >18 years old, MRI-confirmed gluteus medius and minimus tear, and confirmation of tear at time of surgery.

Definitions of radiologic diagnosis included the following:

(i) Tendinopathy is defined as increased tendon diameter or hyperintensity on T1-weighted sequences but without intratendinous hyperintensity on the T2-weighted or fluid-sensitive sequences.
(ii) A partial tear is defined as focal hyperintensity on T2-weighted or fluid sequences that did not involve the whole diameter of the tendon.
(iii) A complete tear is defined as hyperintensity on T2-weighted or fluid-sensitive sequence that involved the whole diameter of the tendon. Exclusion criteria were incomplete or inadequate MR images and history of any prior ipsilateral hip surgery.

MRI assessment

For all patients, a 3-Tesla MRI of the affected hip was obtained preoperatively at the same imaging institution using the parameters listed in Table I. Images were then assessed by a single fellowship-trained musculoskeletal radiologist. Using T2 fat-saturated axial sequence, the TFL and sartorius CSA and anterior-posterior (AP) diameter were measured for each slice, extending from the superior aspect of the femoral head to the level of the lesser trochanter. Subsequently, TFL to sartorius volume ratio was calculated using the sum of the CSAs multiplied by the slice thickness from the superior aspect of the femoral head to the level of the lesser trochanter. Additionally, CSA and AP diameter at the mid and inferior aspects of the femoral head were measured and recorded separately (Fig. 1).

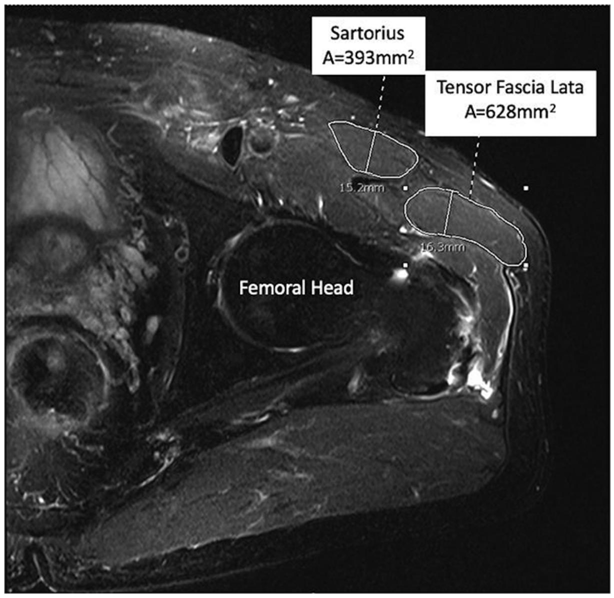

Fig. 1. Axial T2 image at the level of the center of the femoral head, showing CSA and anteroposterior diameter of the TFL and sartorius muscle bellies.

A modified Goutallier classification of FI for the gluteus medius and minimus muscles of the affected hip was then assessed. Using coronal T1 sequence, a classification of normal, mild, moderate and severe was assigned based on the Goutallier classification [1]. The normal classification corresponds with completely normal muscle, without any fatty streaking (Goutallier Grade 0). The mild classification corresponds with muscle with minimal fatty streaks (Goutallier Grade 1) or increased fatty streaking with more muscle than fat (Goutallier Grade 2). The moderate classification corresponds with equal amounts of fat and muscle (Goutallier Grade 3). The severe classification corresponds with more fat than muscle present (Goutallier Grade 4). The classification utilized in the current study combined Goutallier Grades 3 and 4 into a single Grade 3. Figure 2a–d shows patients with normal (Grade 0), mild (Grade 1), moderate (Grade 2) and severe (Grade 3), respectively. The grading of normal (no FI), mild, moderate and severe FI was graded on a 0-, 1-, 2- and 3-point scale for each muscle and then summed giving a maximum of 6 points (medius plus minimus).

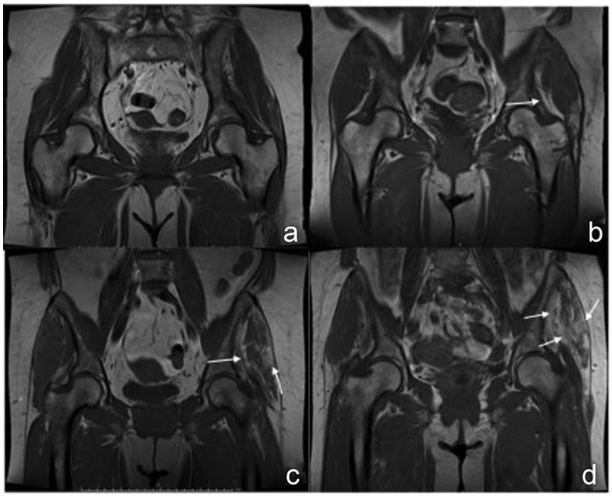

Fig. 2. Coronal T1 images of the left hip, showing Grade 0 (normal/no) FI (a), Grade 1 (mild, b), Grade 2 (moderate, c) and Grade 3 (severe, d).

Table II. Average patient age, BMI, sex, laterality and presence of FI for 70 patients with abductor tendon tears

	Normal Goutallier	*Abnormal Goutallier*	*Total*
Age (years)	54.4	64.7	60.7
BMI	28.6	29.2	28.6
Sex (M/F)	5/37	5/23	10/60

Data analysis

Unpaired Student's t-tests were performed for continuous variables using SPSS (IBM Corp. 2017, Version 25). Regression analysis was performed using TFL/sartorius volume ratio (TFL hypertrophy) as the dependent variable with age, body mass index (BMI) and total Goutallier score (severity of fatty atrophy) as independent variables. Significance level was set to $P < 0.05$.

RESULTS

Eighty-seven patients undergoing surgery for an abductor tear were initially identified. Seventeen patients were excluded due to a history of ipsilateral hip surgery, consisting of prior gluteus medius repair (11), arthroplasty (2), cephalomedullary femoral nail (3) or pelvic osteotomy (1). A total of 70 patients were included in this study, with an average age of 60.7 years (SD 8.9) and an average body mass index of 28.6 kg/m^2 (SD 4.5). There were 60 females and 10 males, with the left hip involved in 43 patients and the right in 27 patients. When stratifying by FI grading system, the cohort was divided into two groups: those with no FI ($n = 42$) and those with any evidence (mild, moderate or severe) of FI of either the gluteus medius or minimus ($n = 28$) (Table II).

All patients' grading of FI is shown in Table III. There was no difference in BMI between the FI and normal muscle groups, but the group with FI group was older (average age: FI 65.4 versus normal 57.6 years, $P = 0.00016$) (Table IV).

The group with evidence of FI had greater TFL CSA and diameter at both the center of the femoral head (694 versus 524 mm^2, $P = 0.0049$) and inferior femoral head (810 versus 593 mm^2, $P = 0.0021$), but the sartorius CSA and diameter did not differ between the groups. The TFL:sartorius volume ratio of was increased in the group with FI (2.9 versus 2.1, $P = 0.00069$). The two groups did not differ when comparing BMI ($P = 0.59$) (Table IV). Further regression analysis demonstrated a statistically significant relationship between severity of fatty atrophy and TFL hypertrophy ($P < 0.001$), while both age and BMI failed to reach statistical significance (Table V).

Table III. Number of patients with corresponding grading of FI of the gluteus medius and minimus muscle bellies broken down by individual score (Muscles were graded as normal (0), mild (1), moderate (2) and severe (3) and then summed giving a maximum of 6)

FI total	*Gluteus minimus FI score*	*Gluteus medius FI score*	*Number of patients (70 total)*
0	0	0	42 (60%)
1	1	0	9 (12.8%)
2	1	1	4 (5.7%)
2	0	2	3(4.2%)
3	1	2	2 (2.8%)
3	2	1	4 (5.7%)
3	3	0	2 (2.8%)
4	2	2	2 (2.8%)
5	3	2	1 (1.5%)
6	3	3	1 (1.5%)

Table IV. Patients grouped by presence or absence of FI of the abductors, and subsequent comparisons made using unpaired t-tests for the following variables: age, BMI, TFL:sartorius muscle belly area ratio calculated at the center and inferior aspect of the femoral head, and TFL:sartorius volume ratio

	No FI	*FI present*	P-*value*
Age	57.60 ± 8.45	65.37 ± 7.53	<0.001
TFL:sartorius area ratio at center of femoral head	2.08 ± 0.54	2.83 ± 1.19	0.004
TFL:sartorius area ratio at inferior of femoral head	2.17 ± 0.54	3.01 ± 1.17	0.001
TFL:sartorius volume ratio	2.10 ± 0.46	2.90 ± 1.07	<0.001

DISCUSSION

The current study is the first of our knowledge to investigate the relationship between TFL hypertrophy and abductor FI in one of the largest cohorts of patients indicated for surgical repair, without any history of prior hip operation. Additionally, the current study provides the added benefit of incorporating TFL and sartorius measurements at multiple radiographic landmarks in order to improve the accuracy of measurement, which has not been done in prior investigations. The results of this design serve to reinforce many aspects of preceding studies that have aimed to explore the impact of FI and TFL hypertrophy on patients with abductor tendon tears.

Table V. Regression analysis comparing effects of age, BMI and Goutallier score (severity of fatty atrophy) on TFL:sartorius volume ratio (TFL hypertrophy)

	TFL:sartorius volume ratio
Age (years)	−0.00520
	(−0.43)
BMI	−0.00695
	(−0.34)
Goutallier score (total)	0.311**
	(4.01)
Constant	2.638*
	(2.50)
n	70

t statistics in parentheses.
*$P < 0.05$, **$P < 0.001$.

In 1989, Gottschalk *et al.* established that the TFL is the muscle primarily responsible for hip abduction, while the gluteus medius and minimus played a secondary role [8]. Given this understanding, several studies have successfully established the nature of this TFL hypertrophy in the absence of a functional gluteus medius and minimus. A systematic review and meta-analysis by Besomi *et al.* found significant increases in EMG activity of the TFL in the presence of gluteal tendinopathy as well as significant hypertrophy of the TFL in the presence of abductor tears [10]. Similar findings have also been documented in patients with GTPS, gluteal tendinitis and femoroacetabular impingement syndrome [17–19]. Sutter *et al.* aimed to quantify these changes by measuring the ratio of the TFL to sartorius CSAs to investigate the relationship between abductor tendon tears and TFL hypertrophy and discovered a statistically significant increase in TFL size in patients with abductor tears relative to the asymptomatic contralateral side. While the relationship between abductor tendon dysfunction and TFL hypertrophy has been well documented, the relationships between abductor tendon dysfunction, TFL hypertrophy and FI are more limited.

The results of the current study build upon the existing body of knowledge by providing a larger cohort and a more robust characterization of the extent of TFL hypertrophy in the setting of fatty atrophy through measurements at numerous anatomic locations. Not only was the TFL:sartorious volume significantly greater in the FI group, but we also found increased TFL area and diameter in the FI group, which has not been found in prior studies. This may be due in part to the more comprehensive analysis obtained by assessing the TFL size at multiple anatomic landmarks in this study. Compensation of abductor FI with TFL hypertrophy may serve as a protective measure of hip abduction in the setting of a deficient gluteus medius and minimus.

Identifying the compensatory changes that may occur to the TFL in the setting of FI can help therapists and surgeons to better understand and address patients' individual pathology. While patients with FI appear to have increased TFL size, their preoperative function may not differ significantly from those without FI possibly due to compensatory measures of the TFL. The presence or absence of FI may also drive surgical decision-making, as patients with severe FI may have worse outcomes relative to those without [2]. When assessing MRI, particular attention should be made to the relative size of the TFL, as an increased diameter and/or area may be indicative of the presence of FI of the gluteal musculature. Patients with severe atrophy may be better served with an augmentation or reconstructive procedure such as a gluteus maximus or TFL transfer; however, the specific indications for this have not been defined with regard to the degree of fatty atrophy [20].

This study is not without limitations. Using the contralateral hip of the same patient as an internal control may have allowed for measuring side-to-side differences in the TFL. It is possible that TFL hypertrophy occurs in both the absence and presence of FI, but we were not able to examine this. Another limiting factor is the binary grouping of the FI classification groups (abnormal and normal). It may have provided additional insight had we been able to further stratify the data according to absolute FI scores. However, the limited number of patients with moderate or severe FI did not allow for further subgroup analysis. Additional information that would have further strengthened this paper include duration of symptoms, presence of hip or knee arthritis and presence of anatomic abnormalities (i.e. hip dysplasia or coxa vara/valga), further detail regarding the extent (partial versus full) and number of tears (single versus both tendons) as these factors may have influenced our findings. Finally, while the data presented in this paper provide a valuable contribution to the current understanding of abductor tendon pathology and muscular adaptations in response to abductor pathology, it would be of greatest use in conjunction with follow-up outcome measures to assess the effect of FI on outcomes. Future studies by our group will aim to correlate long-term functional outcomes with these radiographic parameters.

CONCLUSION

TFL hypertrophy occurs in patients with increased gluteus medius and minimus FI after abductor tear, providing evidence for an increased demand placed upon the TFL in performing hip abduction. Future studies examining the effect of FI and TFL hypertrophy on outcomes after primary repair are indicated and may better direct reconstructive procedures in cases of more severe disease.

DATA AVAILABLILTY

The data underlying this article will be shared on reasonable request to the corresponding author.

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CONFLICT OF INTEREST STATEMENT

None declared.

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