

# Iliopsoas Muscle/Tendon Proportions at Three Levels of Described Arthroscopic Tenotomy: An Anatomic Study in Fresh Cadaveric Specimens



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**Purpose:** To calculate the iliopsoas muscle/tendon ratio at 3 levels of arthroscopic iliopsoas tenotomy sites in fresh cadaveric specimens. **Methods:** An anatomic study design was performed using 16 iliopsoas musculotendinous units from the level of the hip joint to their insertion on the lesser trochanter. All specimens came from 16 fresh cadaveric specimens (10 male, 6 female), with a median age of 41 years (range 31-55.25 years). Circumferential measurements of the composite musculotendinous unit and the iliopsoas tendon were then made at the lesser trochanter insertion, the site of transcapsular tenotomy, and the site of tenotomy at the level of the labrum. Anatomical variance of the iliopsoas tendon at the insertion on the lesser trochanter and muscular extension below the lesser trochanter level also were described. The difference between the median circumference of the iliopsoas musculotendinous units or the isolated tendons at the 3 levels was calculated. **Results:** The median circumference of the iliopsoas musculotendinous unit at the level of the labrum, orbicularis zone (transcapsular tenotomy site), and the lesser trochanter was 140.9 mm (range 137.9-148.9), 136.7 mm (range 132.9-140), and 99.5 mm (range 96.5-104.8), respectively. The median circumference of the iliopsoas tendon at these same levels was 25.6 mm (range 22.7-33.7), 28.9 mm (range 25.1-32.2), and 30.9 mm (range 27.9-36.1), respectively. Accordingly, the proportions of the iliopsoas muscle/tendon at the level of the labrum, the transcapsular tenotomy site, and the lesser trochanter insertion were 18% tendon/82% muscle, 21% tendon/79% muscle, and 31% tendon/69% muscle, respectively. **Conclusions:** The proportions of the iliopsoas muscle/tendon at the level of the labrum, the transcapsular tenotomy site and the lesser trochanter insertion were 18% tendon/82% muscle, 21% tendon/79% muscle, and 31% tendon/69% muscle, respectively. The distal muscular projection below the tendinous insertion on the lesser trochanter may maintain the functional connection of the iliopsoas between origin and insertion even after releasing the tendon. **Clinical relevance:** This finding may have implications for a new understanding of arthroscopic tenotomy of the iliopsoas around the hip, as previously described muscle/tendon proportions were not calculated in fresh cadavers.

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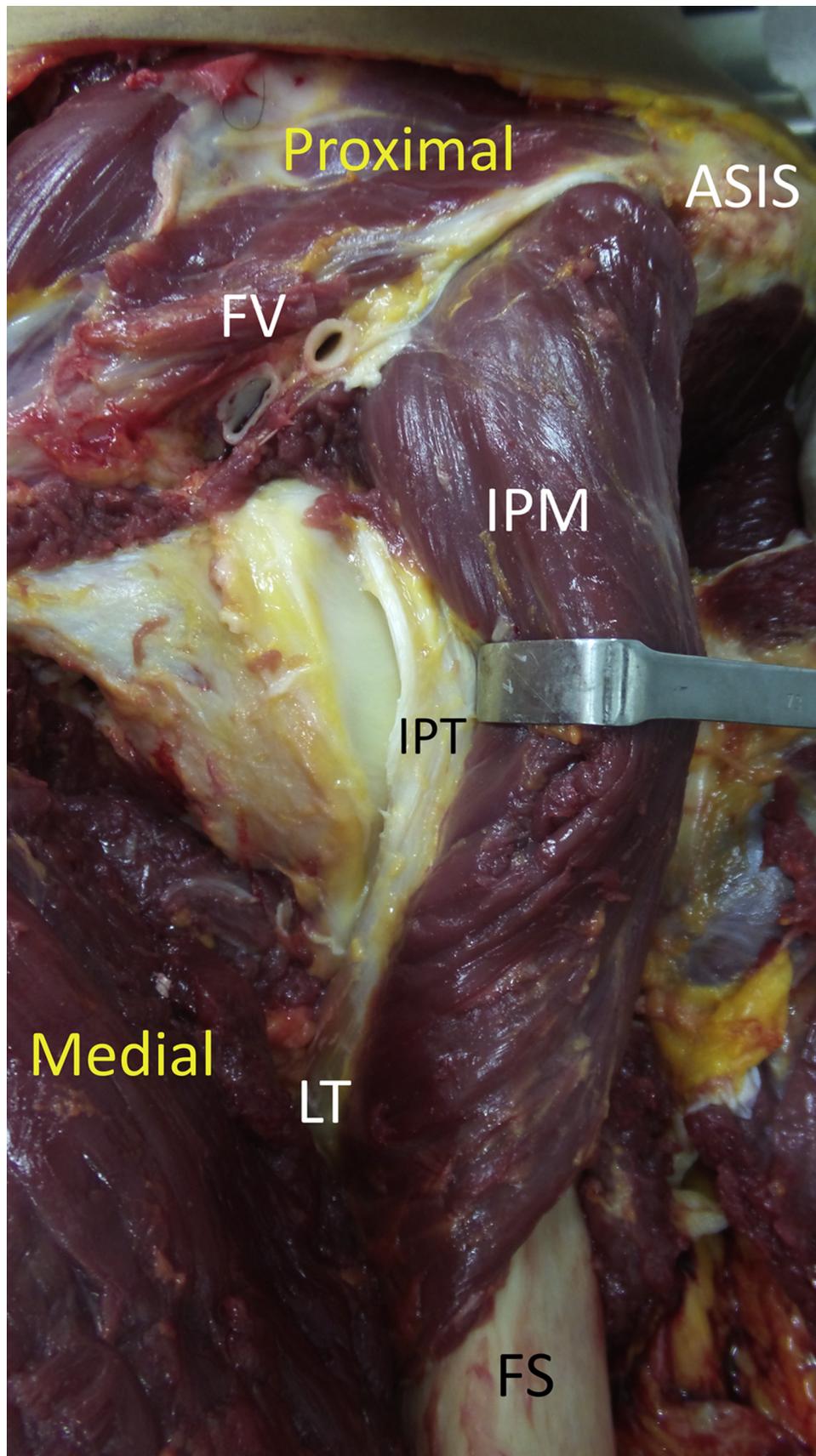
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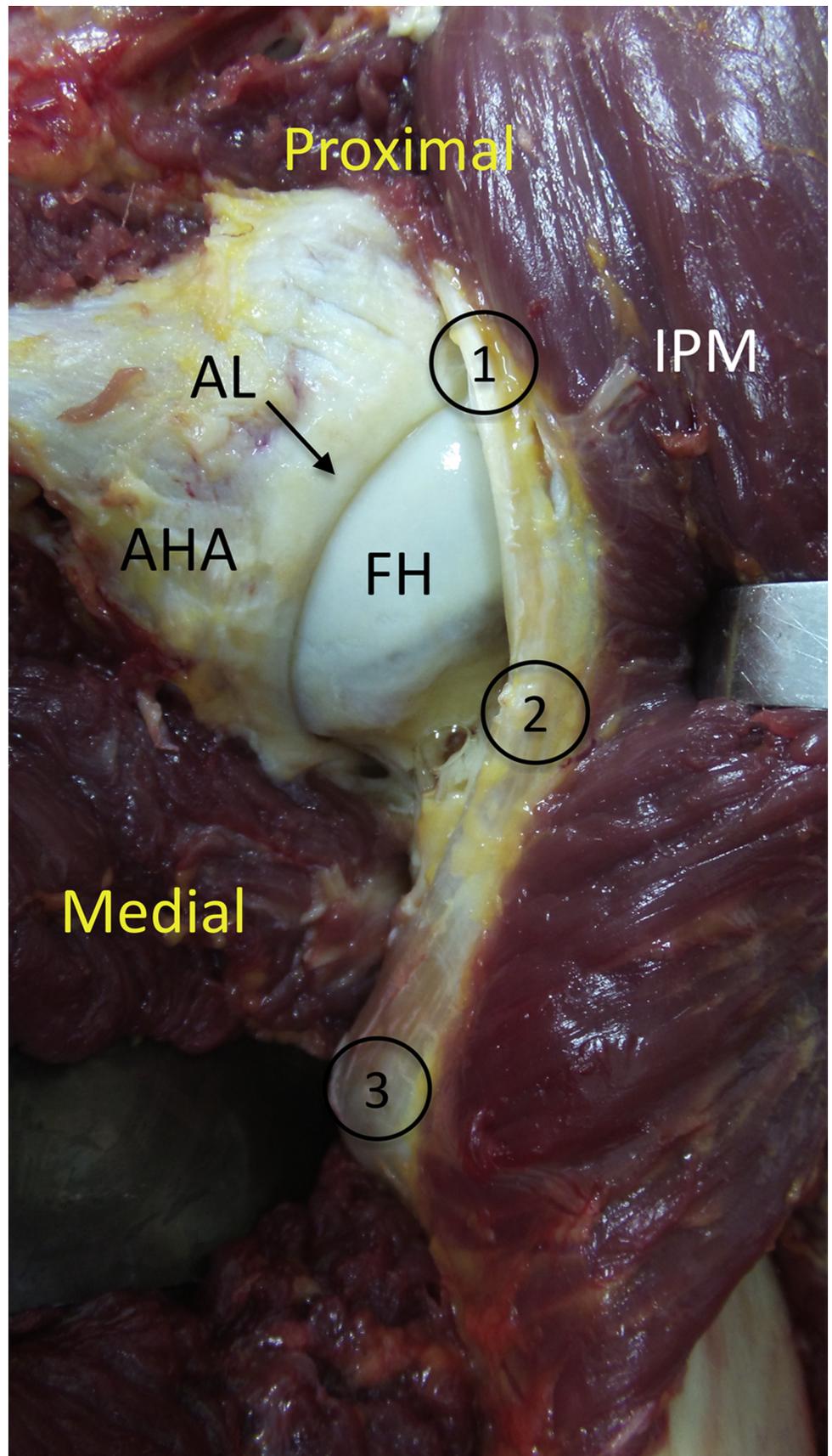
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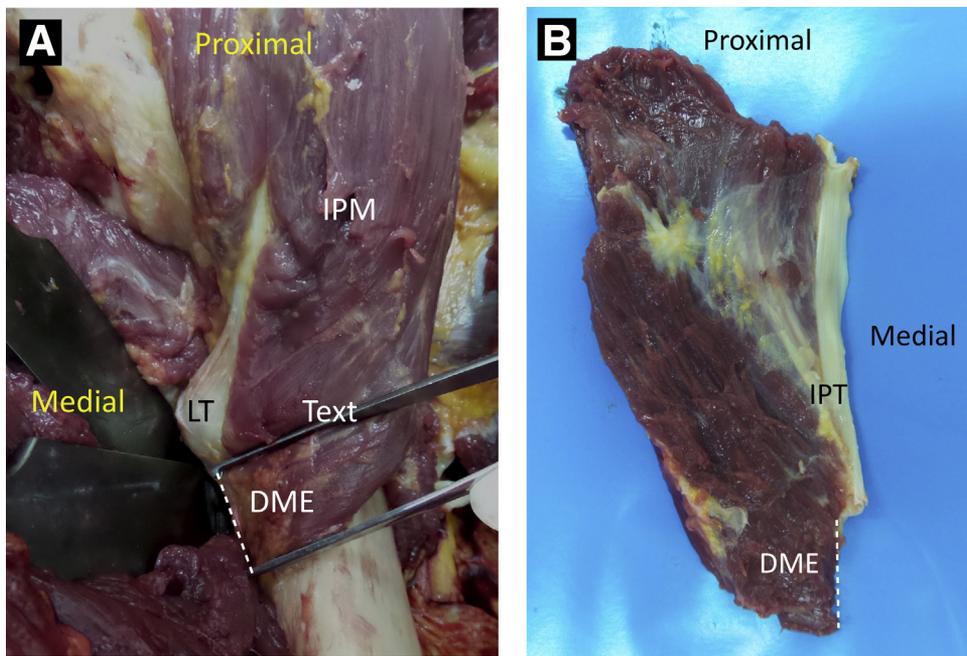
The iliopsoas tendon is formed from a convergence of the psoas and iliacus muscle bellies at the level of the inguinal ligament.<sup>1</sup> This tendon, which is bifid in most cases,<sup>2</sup> runs anterior to the pubis and hip capsule/femoral head and inserts at the lesser trochanter on the posteromedial femur. Hip pain related to an abnormal iliopsoas tendon kinematics is the result of several problems, such as a snapping tendon across the femoral head and/or pectineal eminence.<sup>3-5</sup> Asymptomatic snapping hip occurs in 5% to 10% of the population.<sup>6</sup> However, there may be a greater incidence of snapping hip, especially painful snapping, in those who participate in activities requiring the extremes of hip motion. For example, in a survey of elite ballet dancers, more than 90% reported snaps, cracks, clicks, or dislocations, 80% of which were bilateral.<sup>7</sup> Impingement of hip arthroplasty components on soft tissues may



**Fig 1.** Left hip, anterior view. Dissection of an iliopsoas musculotendinous unit before measurement. Hip joint capsule is still intact. (ASIS, anterior superior iliac spine; FS, femoral shaft; FV, femoral vessels; IPM, iliopsoas muscle; IPT, iliopsoas tendon; LT, lesser trochanter.)



**Fig 2.** Left hip, anterior view. Levels of measurement of the iliopsoas muscle/tendon circumferences. (1) Labrum level, (2) transcapsular release site level, (3) lesser trochanter level. (AHA, anterior horn of the acetabulum; AL, acetabular labrum; FH, femoral head; IPM, iliopsoas muscle.)



**Fig 3.** (A) Left hip, anterior view. (B) Left iliopsoas (removed from the same specimen), posterior view. Observe the distal muscular insertion below the lesser trochanter tendinous insertion. (DME, distal muscular extension; IPM, iliopsoas muscle; IPT, iliopsoas tendon; LT, lesser trochanter.)

adversely affect outcomes. An example is impingement of the cup on the iliopsoas tendon, which has been reported in 0.4% to 8.3% of patients.<sup>8,9</sup>

Open or arthroscopic iliopsoas tenotomy for the management of internal snapping hip is suggested to be effective operative techniques with endoscopic minimal invasive tenotomy, yielding lower complication rates in comparison with open tenotomy.<sup>10,11</sup> Arthroscopic tenotomies of the iliopsoas tendon are performed at 3 different levels: labrum, orbicularis zone, and lesser trochanter.

Concerns when performing arthroscopic tenotomies include releasing the entire muscle unit and/or damaging neurovascular structures nearby. Knowledge of the muscle/tendon proportions at each tenotomy level is crucial to achieve a complete and safe arthroscopic tenotomy. A previous study investigating the average circumference ratio of the iliopsoas muscle and tendon at the 3 levels revealed 60% muscle/40% tendon, 47% muscle/53% tendon, and 40% muscle/60% tendon at the level of the labrum, orbicularis zone, and lesser trochanter, respectively.<sup>12</sup> A significant limitation of Blomberg et al.'s investigation was the use of embalmed cadaveric specimens. The embalming procedure preserves soft tissue and is ideal for extended anatomical observation; however, the process may negatively impact measurements. The purpose of this study was to calculate the iliopsoas muscle/tendon ratio at 3 levels of arthroscopic iliopsoas tenotomy sites in fresh cadaveric specimens. The authors hypothesized the tendinous contribution of the iliopsoas musculotendinous unit at the 3 levels of arthroscopic

tenotomy would be significantly smaller than previously reported, in fresh cadaveric specimens.

## Methods

This study was performed using 16 hips from 16 fresh cadaveric specimens (10 male, 6 female), with a median age of 41 years (range 31-55.25). The median estimated height, weight, and body mass index were 1.69 m (range 1.65-1.71), 70 kg (range 65-75), and 24.4 (range, 22.5-25.5).

The specimens were taken from full bodies; thus, the origin and insertion of the psoas and iliacus muscles were preserved. There was no evidence of degenerative joint disease, previous trauma, neoplastic infiltration, or previous surgery. Hip dissection was performed by 2 hip surgeons according to Blomberg et al.'s description<sup>12</sup> to obtain data in a similar manner. The inguinal ligament, neurovascular structures, and muscles were carefully removed, preserving the iliopsoas musculotendinous unit (Fig 1). Three different psoas tendon levels were labeled before its extraction: (1) lesser trochanter insertion, (2) the Wettstein et al.<sup>13</sup> site of transcapsular tenotomy, and (3) the Alpert et al.<sup>11</sup> site of release site at the level of the labrum (Fig 2). Then, circumferential measurements of the muscle and tendon were performed at the 3 described levels.

Similar to Blomberg et al.,<sup>12</sup> a single-suture technique was used to measure all circumferences. The suture was wrapped around the musculotendinous unit, and the point of overlap of the suture was grasped with a mosquito hemostat curved forceps. The suture was then measured with a digital caliper (accuracy 0.001) and

**Table 1.** General Information of the Included Hip Specimens (n = 16)

Variable	Median	p25	p75
Age, y	41	31	55.2
Height, m	1.69	1.65	1.71
Weight, kg	70	65	75
BMI	24.4	22.5	25.5
MTU circumference at the level of the labrum, mm	140.9	137.9	148.9
MTU circumference at the level of the TTS, mm	136.7	132.9	140
MTU circumference at the level of the LT, mm	99.5	96.5	104.8
Tendon circumference at the level of the labrum, mm	25.6	22.7	33.7
Tendon circumference at the level of the TTS, mm	28.9	25.1	32.2
Tendon circumference at the level of the LT, mm	30.9	27.9	36.1
Percentage of tendon at the level of the labrum, %	18	16	22.5
Percentage of tendon at the level of the TTS, %	21	19	23
Percentage of tendon at the level of the LT, %	31	29	34.5
Iliopsoas muscular extension distal to the LT, mm	20.3	19.6	22.3

BMI, body mass index; LT, lesser trochanter; MTU, musculotendinous unit; p25, 25th percentile; p75, 75th percentile; TTS, transcapsular tenotomy site.

the length of the suture (circumference) was recorded in millimeters. All measurements were performed by a hip fellowship-trained orthopaedic surgeon.

After the circumferential measurements were completed, the muscle belly of the musculotendinous unit was removed, leaving only the tendon intact. Circumferential measurements were made with the same suture technique at the 3 levels described previously. The number of tendinous bands (single, double, and triple) and the length of the iliopsoas muscle belly insertion distal to the lesser trochanter also were measured and registered in all specimens (Fig 3 A and B). The difference between the median circumference of the iliopsoas musculotendinous units or the isolated tendons at the three levels was calculated. To compare the

circumference of the musculotendinous unit and the percentage of tendinous tissue at 3 different levels, the Friedman test was used. In addition, the Wilcoxon test was used to compare the difference between segments, and the Mann–Whitney *U* test was used to compare the percentages of tendinous tissue according to sex and race. General characteristics of the specimens were described by using medians and ranges. SPSS software (version 18; IBM Corp., Armonk, NY) was used for data analysis, with statistical significance set at *P* < .05.

**Results**

The median circumference of the iliopsoas musculotendinous unit at the level of the labrum, orbicularis zone (transcapsular tenotomy site), and the lesser trochanter was 140.9 mm (range 137.9-148.9), 136.7 mm (range 132.9-140), and 99.5 mm (range 96.5-104.8), respectively (Table 1).

The median circumference of the iliopsoas tendon at these same levels was 25.6 mm (range 22.7-33.7), 28.9 mm (range 25.1-32.2), and 30.9 mm (range 27.9-36.1), respectively. Accordingly, the proportions of the iliopsoas muscle/tendon at the level of the labrum, the transcapsular tenotomy site, and the lesser trochanter insertion were 18% tendon/82% muscle, 21% tendon/79% muscle, and 31% tendon/69% muscle, respectively. The tendinous portion of the iliopsoas musculotendinous unit was never bigger, in terms of area, than the muscular portion at the 3 levels (*P* < .001). As expected, the muscle size decreased from proximal to distal being significantly smaller at the lesser trochanter level (*P* < .05), whereas the tendinous portion was roughly the similar at the 3 levels (Table 2).

In male specimens, the average circumference of the iliopsoas musculotendinous unit at the level of the labrum, transcapsular site, and the lesser trochanter was 141.6 mm (range 137.9-150.2), 136.9 mm (range 132.6-140.4), and 100.6 mm (range 97.3-106.9), respectively, whereas in female specimens was 139.1 mm (range 135.7-143.6), 136.74 mm (range 133.4-138.3), and 98.3 mm (range 95.2-102.3), respectively. The median circumference of the iliopsoas musculotendinous unit at all levels was not significantly different between sexes (*P* > .05).

**Table 2.** Median Circumference of the Iliopsoas Tendon and Muscle at 3 Arthroscopic Tenotomy Described Levels

Level	Median Tendon Circumference, mm (range)*	Median Musculotendinous Circumference, mm (range)†	Median Tendon Percentage, % (range)‡
Labrum	25.6 (22.7-33.7)	140.9 (137.9-148.9)	18 (16-22.5)
Transcapsular	28.9 (25.1-32.2)	136.7 (132.9-140)	21 (19-23)
Lesser trochanter	30.9 (27.9-36.1)	99.5 (96.5-104.8)	31 (29-34.5)

\*The median circumferences of the tendon at all 3 levels were significantly different (*P* < .05) from each other except when comparing transcapsular tenotomy site and lesser trochanter levels (*P* = .2).

†The median circumferences of the musculotendinous unit at all 3 levels were significantly different (*P* < .001) from each other.

‡The median tendon percentage at all 3 levels were significantly different (*P* < .001) from each other; however, this proportion was never predominant at any level.

The distal projection of muscle belly insertion into the femur below the lesser trochanter was present in all specimens with a median of 20.36 mm (range 19.6–22.3).

In addition, the prevalence of single-, double-, and triple-banded iliopsoas was registered as 43.7% (7 of 16 specimens), 50% (8 of 16 specimens), and 6.3% (1 of 16 specimens), respectively.

### Discussion

This study demonstrates that iliopsoas muscle contributes a greater proportion than the iliopsoas tendon at any level from the labrum to the lesser trochanter insertion in all hip specimens. Iliopsoas tendon size was similar at all 3 levels, with a median ratio of 140.9 mm, 136.7 mm, and 99.5 mm, respectively. A consistent iliopsoas musculotendinous unit size was observed among the 16 fresh cadaveric specimens with tendinous tissue being 18%, 21%, and 31%, at the level of the labrum, transcapsular tenotomy level, and lesser trochanteric insertion, respectively.

In addition to exploring the iliopsoas muscle/tendon ratio at the described levels, the length of the muscular insertion below the lesser trochanter was recorded. The results demonstrated that there was a projection of muscular insertion below the lesser trochanter in all hips with similar characteristics, with a median length of 20.3 mm. The measurements show the psoas tendon is consistently and significantly smaller than the muscular portion at all levels.

Blomberg et al.<sup>12</sup> evaluated 40 hips from 20 embalmed cadavers and measured the circumferences of the iliopsoas tendon–muscle complex at the level of the labrum, the transcapsular tenotomy site, and the lesser trochanter. The average circumferences of the iliopsoas muscle–tendon complex were 68 mm, 58 mm, and 46 mm, respectively, whereas those measures for the tendinous portion were 27 mm, 31 mm, and 27 mm respectively. Thus, according to Blomberg et al.,<sup>12</sup> the iliopsoas muscle–tendon complex is composed of 40% tendon/60% muscle belly, 53% tendon/47% muscle belly, and 60% tendon/40% muscle belly at the level of the labrum, transcapsular tenotomy site, and lesser trochanter, respectively. This study made an important contribution to the understanding of the functional consequences of iliopsoas tenotomy, as a previous study by Alpert et al.<sup>1</sup> suggested that releasing the iliopsoas tendon at the level of the lesser trochanter could ultimately be equivalent to releasing the entire muscle-belly complex.

Muscle–tendon complex proportions described by Blomberg et al.<sup>12</sup> help to understand its functional anatomy; nevertheless, surgical observations during arthroscopic iliopsoas tenotomy do not correlate with those percentages, probably due to muscle belly size changes and dehydration in embalmed cadavers as used

by Blomberg et al., whereas tendon tissue remains practically constant, thus affecting muscle/tendon ratio.

Iliopsoas tendon is not predominant at any level from the labrum to the lesser trochanter. Variable anatomy was identified, which could contribute to recurrent snapping in the setting of incomplete tenotomy.<sup>14</sup> Philippon et al.<sup>2</sup> used 53 hip specimens to describe anatomical variants of the iliopsoas tendon and reported a bifid tendon being the most common variant (64.2%). A finding that Gómez-Hoyos et al.<sup>15</sup> confirmed and described a divided iliopsoas footprint insertion at the lesser trochanter in 70% of the cadaveric specimens evaluated. In the present study, a double-banded tendon was found in 8 cases (50%).

The inverted teardrop-shaped insertion of the iliopsoas insertion extending to the junction of the inferior lesser trochanter with the femoral shaft also was described by Philippon et al.<sup>16</sup> in a recent anatomical study. They found the iliopsoas insertion footprint being 359.5 mm<sup>2</sup>, with the distal insertion exclusively muscular fibers. This finding suggests releasing the psoas tendon at any level does not completely inhibit the function and explains why the tendon does not retract after tenotomy. This anatomical characteristic also could explain in some level why some studies have found a regenerated tendon few months after tenotomy.<sup>17</sup>

### Limitations

A number of limitations have to be considered when interpreting these results. First, the sample size was small. Second, we relied on circumference, rather than area, which could be more relevant when considering force generation and stress (force/area) through the tendon. Third, the measurements were all made by a single observer. Finally, function was not reported, as this is an anatomic study.

### Conclusions

The proportions of the iliopsoas muscle/tendon at the level of the labrum, the transcapsular tenotomy site, and the lesser trochanter insertion were 18% tendon/82% muscle, 21% tendon/79% muscle, and 31% tendon/69% muscle, respectively. The distal muscular projection below the tendinous insertion on the lesser trochanter may maintain the functional connection of the iliopsoas between origin and insertion even after releasing the tendon.

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