Effect of Subspine Decompression on Rectus Femoris Integrity and Iliopsoas Excursion: A Cadaveric Study

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Purpose: To determine the relative influence of anteroinferior iliac spine (AIIS) or subspine decompression on proximal rectus femoris integrity and iliopsoas excursion throughout a physiological range of motion. **Methods:** Nineteen cadaveric hips from 10 specimens were dissected to retain the origin of the rectus femoris direct and indirect heads. The anatomic footprints of the origins were measured with calipers. Serial 5-mm resections of the AIIS were made to determine the extent of proximal tendon disruption that corresponded to each resection. Iliopsoas tendon tracking was also assessed after sequential AIIS decompression by measuring the excursion of the medial border of the iliopsoas tendon as it traveled from its native resting position to the point where it first encountered bony impingement at the AIIS. **Results:** The mean proximal-distal footprint of the rectus femoris direct head was 17.95 ± 2.99 mm. The mean medial-lateral distance was 11.84 ± 2.34 mm. There was a consistent bare area along the inferior aspect of the AIIS that averaged 4.84 ± 1.42 mm. The average percentage of remaining footprint after each 5-mm resection (5 to 25 mm) was 96%, 65%, 35%, 14%, and 11%, respectively, with statistical significance noted after resections larger than 5 mm ($P < .001$). The native excursion distance of the iliopsoas tendon was 14.05 mm. With each 5-mm resection, the percentage of excursion before impingement on the AIIS increased by 18%, 45%, 72%, 95%, and 100%, respectively, which was statistically significance after all resections ($P < .001$). **Conclusions:** Our study maps the anatomic footprint of the direct head of the rectus femoris tendon and confirms a previously identified bare area along the inferior aspect of the AIIS. Female cadaveric hips had a significantly smaller rectus footprint than male cadavers in our study ($P < .001$). Subspine decompression greater than 10 mm significantly compromises the rectus femoris origin and should be avoided when performing arthroscopic AIIS decompression. In addition, subspine decompression significantly improves tracking of the iliopsoas tendon throughout a physiological range of motion and may be considered a surgical adjunct when treating symptomatic iliopsoas snapping. **Clinical Relevance:** Arthroscopic subspine decompression serves as an important treatment modality for AIIS impingement. With a more thorough understanding of AIIS anatomy, subspine decompression can be used to relieve impingement symptoms and possibly improve iliopsoas tracking while safely maintaining rectus femoris footprint integrity.

Femoroacetabular impingement is described as abnormal contact between the femoral head-neck junction and the anterior acetabular rim that typically manifests in hip pain and places patients at future risk of labral tearing and premature osteoarthritis.[1] The importance of identifying and treating femoroacetabular impingement has led to an increased focus on a subset of hip impingement syndromes described as extra-articular impingement, the most notable being anteroinferior iliac spine (AIIS) impingement.[2]

Pan et al.[3] showed that the femoral neck impinges on the AIIS at extremes of hip flexion. Consequently, there has been an increased focus on analyzing the degree of AIIS dysmorphism and its correlation with clinical impingement, as well as subsequent treatment modalities. In fact, Hetsroni et al.[2] proposed a classification of AIIS types that identifies increasing hip impingement with an increasing prominence, or type, of AIIS over the acetabular rim.

A better understanding of AIIS impingement has led to increasing treatment options, particularly arthroscopic decompression of the AIIS prominence. This procedure has been shown to improve hip function and

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decrease pain in these patients.[4,5] However, there is limited information discussing the extent of AIIS decompression that can be performed without compromising the integrity of the rectus femoris direct head origin. In a recent study the rectus femoris footprint was measured in 11 Turkish male cadaveric hips, in which the mean proximal-distal (P/D) distance of the rectus femoris origin on the AIIS was 2.2 cm and the mean medial-lateral (M/L) distance was 1.6 cm.[6] In contrast, a separate anatomic study of 12 cadaveric hips noted the rectus footprint to be 26.0 mm (P/D) by 13.4 mm (M/L).[7] Despite an increasing awareness of the anatomic footprint of the rectus femoris direct head, there is limited information regarding rectus femoris integrity after subspine decompression.

AIIS prominence may also play a role in internal hip snapping. Internal snapping is described as an audible click that is heard with hip flexion that may be accompanied by hip pain and is due to tracking of the iliopsoas tendon.[8] Given the extent of soft tissue overlying the anterior aspect of the iliopsoas tendon, the exact mechanism of snapping and associated hip pain is poorly understood. Commonly identified possibilities include the femoral head, the iliopectineal ridge including the AIIS, the iliopsoas bursa, and the iliofemoral ligament.[8]

The purpose of this study was to determine the relative influence of AIIS or subspine decompression on proximal rectus femoris integrity, correlate it with previous findings, and determine iliopsoas excursion throughout a physiological range of motion. We hypothesized that the rectus femoris footprint would be compromised and the iliopsoas excursion distance would increase with more extensive subspine decompressions.

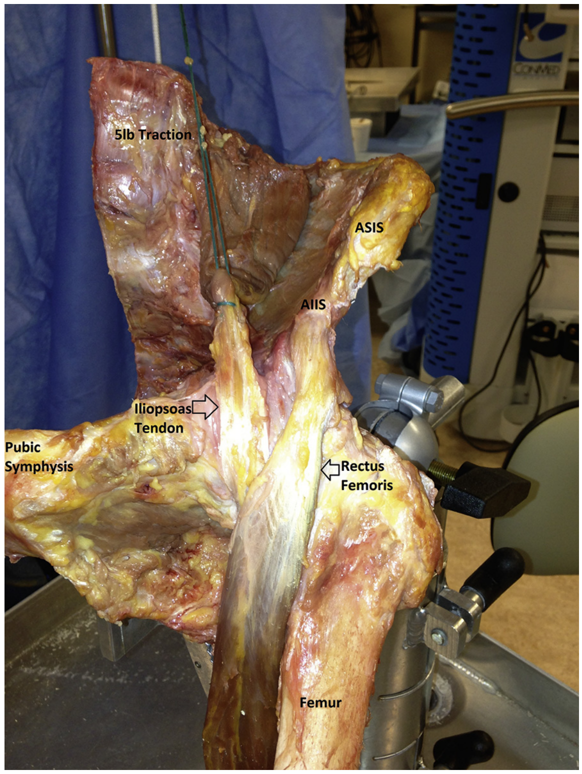

Fig 1. Left cadaveric hip shown in a vice and held at the ischial tuberosity with the pubic ramus level with the table to maintain anatomic continuity between each specimen. (AIIS, anteroinferior iliac spine; ASIS, anterosuperior iliac spine.)

Methods

Ten matched fresh-frozen cadaveric hemipelvis pairs, 4 female and 6 male, were donated by Arthrex (Naples, FL) for this study. All hips were prescreened for AIIS type as described by Hetsroni et al.[2] Only types I and II, as classified by Hetsroni et al., were included in this study because we believe that type III AIIS morphology is rare and would not be a proper representation of the general population. Each hemipelvis was dissected by 1 of 3 authors (R.E., M.S., and one medical student [S.B.]) in an organized, stepwise fashion to ensure standardization. Focus was placed on preserving the origin of the direct head of the rectus femoris on the AIIS and the origin of the reflected head on the exterior surface of the bony ridge, which forms the groove on the iliac portion of the acetabulum. A single hemipelvis was used to determine an accurate method of measuring and performing resection and not included in the final measurement calculations. This left 19 hemipelvis specimens for use in the study. The psoas major insertion was maintained on the lesser trochanter of the femur. Cadaveric hips were placed in a vice and held at the ischial tuberosity with the pubic ramus level with the table to maintain anatomic continuity between each specimen (Fig 1). In addition, a 5-lb weight was tied through a suture to the proximal psoas muscle to standardize a set level of traction throughout our subsequent measurements because the psoas origin was not maintained in these specimens.

The bony contours of the AIIS and direct head of the rectus tendon were identified in every specimen. The footprints of the direct head of the rectus femoris insertion were measured from the most superior-to-inferior points as well as the most M/L points on each specimen. The superoinferior direction of the rectus footprint was measured in line with the pelvic brim in the direction from the AIIS to the anterosuperior iliac spine. The M/L distance was measured perpendicular to this axis. A total area measurement of the rectus footprint was then estimated by measuring 5-mm-tall rectangles within the footprint, as shown in Figure 2.

With the femur in the neutral position, a mark was made on the iliopectineal ridge at the lateral portion of the iliopsoas tendon and a measurement was made between the psoas and the inferomedial point of the AIIS to determine the distance before possible

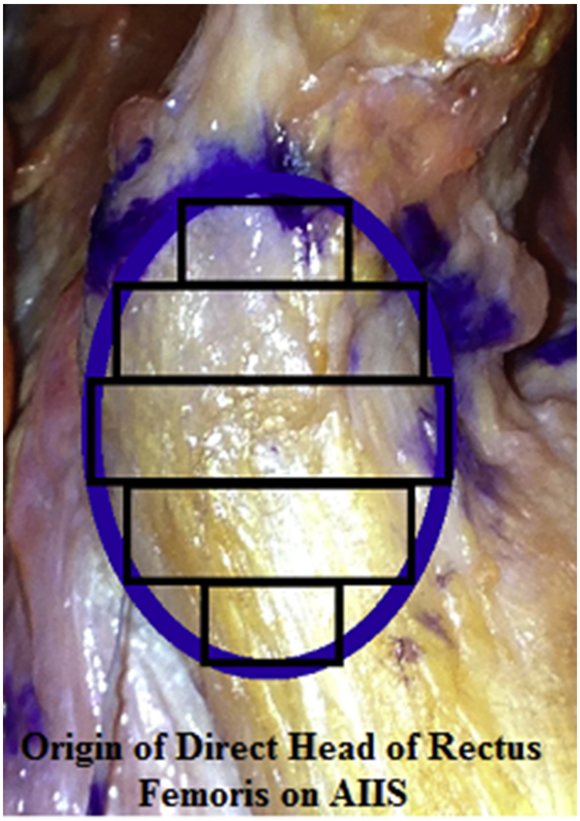

Fig 2. The total area of the rectus femoris direct head footprint was estimated by measuring 5-mm-tall rectangles within the footprint. The total area was, on average, 160.26 mm^2. A left hip model is shown. (AIIS, anteroinferior iliac spine.)

impingement. After neutral measurements of the muscles were obtained, subspine decompression of the AIIS was performed with an osteotome and mallet in 5-mm increments (Fig 3). After each 5-mm increment of decompression, superoinferior and M/L measurements of the direct rectus origin were obtained to assess any intrusion on the direct rectus footprint.

The 5-lb manual tension was maintained at the psoas origin while the hip was placed into flexion and external rotation to the point of the lateral psoas contacting the inferomedial point of the AIIS. By use of a goniometer, the femoral flexion angle was measured when the psoas made contact with the inferomedial point of the AIIS after each 5-mm decompression. The base of the goniometer was aligned with the pubic ramus to maintain standardization of the measurements while the other arm of the goniometer was aligned with the femur while in flexion. Decompression of the AIIS and measurements of the direct rectus femoris insertion point and psoas excursion were continued until there was 5 mm or less of AIIS remaining, at which point a final M/L footprint measurement was obtained. Flexion angles were measured until there was no longer impingement of the psoas on the AIIS with flexion and internal rotation.

Results

The mean age of the 10 matched fresh-frozen cadaveric hips (4 female and 6 male) was 64 years, with a range from 51 to 74 years. One hemipelvis was excluded and used to determine an accurate method of measuring and performing resection; it was not included in the final measurement calculations. The P/D distance of the rectus footprint averaged 17.95 ± 2.99 mm. The M/L distance averaged 11.84 ± 2.34 mm. The total area was, on average, 160.26 ± 55.96 mm^2. Male specimens had a mean P/D distance of 19.73 ± 2.13 mm, mean M/L distance of 12.55 ± 2.06 mm, and mean total area of 193.00 ± 49.11 mm^2. Female specimens had a mean P/D distance of 15.71 ± 1.91 mm, mean M/L distance of 10.57 ± 1.59 mm, and mean total area of 118.86 ± 12.59 mm^2. These 3 measurements of the direct head of the rectus footprint were significantly greater in male patients ($P < .001$).

After 5 mm of resection, 96.28% of the anatomic footprint remained on the AIIS ($P = .08$). After each successive 5-mm resection, the percentage of anatomic footprint that remained was calculated and is shown in Table 1. Of note, there was a consistent area along the inferior margin of the AIIS that appeared to be devoid of rectus footprint. On average, the bare spot measured 4.84 mm, with a range from 3 to 10 mm (Fig 4).

Regarding iliopsoas tracking, the starting excursion distance before impingement from the lateral edge of the iliopsoas tendon to the inferior border of the AIIS was, on average, 14.05 ± 3.73 mm. The starting angle of impingement before any resection of the AIIS of the iliopsoas tendon on the AIIS was measured, corresponding to the superior pubic ramus as described earlier, and was found to be, on average, 70.28° ± 8.9°. The iliopsoas excursion distance and angle of excursion before impingement on the AIIS after each 5-mm resection are shown in Table 2. The percentage of total excursion was calculated for each specimen after each successive 5 mm of resection. On average, the percentage of total excursion increased compared with initial excursion by 18%, 45%, 72%, 95%, and 100% after the 5-, 10-, 15-, 20-, and 25-mm resection increments, respectively.

Discussion

Our study provides a thorough understanding of AIIS anatomy. In this study the average P/D distance among all 19 hips was 17.95 ± 2.99 mm and the M/L distance averaged 11.84 ± 2.34 mm. Hapa et al.[6] performed a similar examination but reported slightly larger footprint measurements, with a P/D distance of 22 ± 1 mm and M/L distance of 16 ± 3 mm. In addition, Ryan et al.[7] noted the rectus footprint to be larger, with mean values of 26.0 mm for P/D and 13.4 mm for M/L. Although this variation

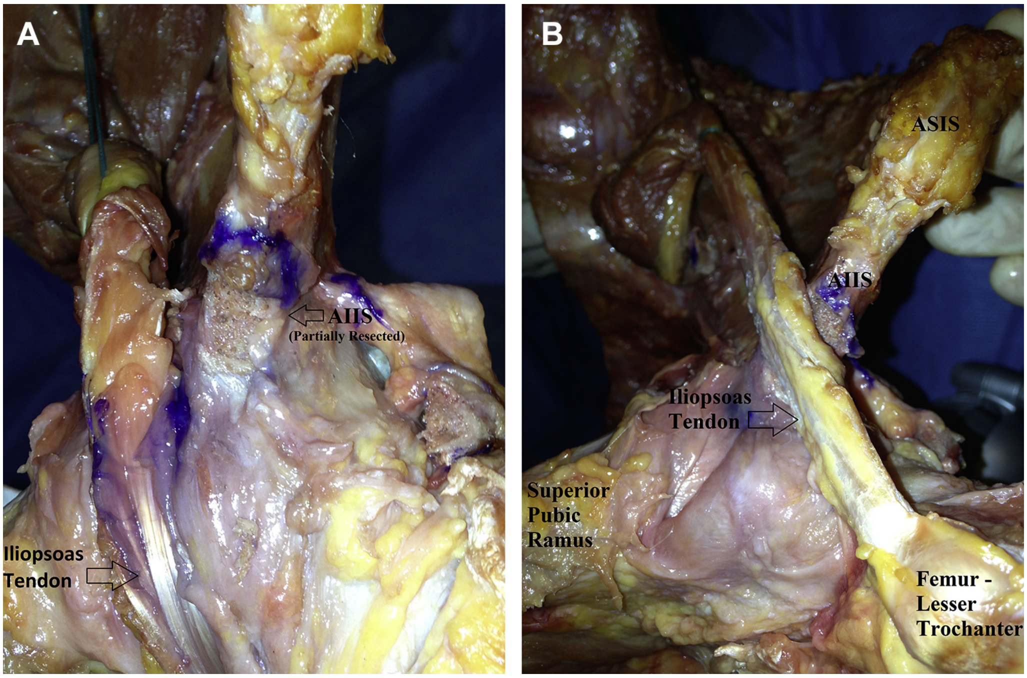

Fig 3. (A) Subspine decompression in a left hip cadaveric model. A 5-mm subspine decompression has been performed; one should note the proximity of the iliopsoas tendon to the anteroinferior iliac spine (AIIS). (B) Iliopsoas tendon impingement on AIIS during physiological range of motion after a 10-mm subspine decompression in a left cadaveric hip model. (ASIS, anterosuperior iliac spine.)

in measurement among studies may be attributable to a greater number of specimens in our study, our smaller measurements are likely because of a higher number of female specimens. A closer comparison of female versus male cadavers in this study indicates that female specimens had significantly smaller initial P/D, M/L, and total footprint area averages, as shown in Table 3. Therefore the rectus femoris footprint average among 11 male-only cadaveric hips, such as in the study of Hapa et al.,[6] would understandably be larger than the average footprint size among an equal distribution of male and female specimens.

As previously shown by Hapa et al.,[6] the direct head of the rectus tendon has a broad insertion over the AIIS with a relatively reproducible bare spot, or "safe zone," on the inferior border of the AIIS. In our study this bare spot measured 4.84 mm on average. Therefore, as suggested by Hapa et al., subspine decompression can safely be performed into this bare area without significantly compromising the rectus femoris footprint.

We have also shown that continuing the resection beyond the bare area can safely be performed without significantly compromising the direct head of the rectus femoris footprint. In fact, 5- and 10-mm resections of the AIIS for subspine impingement can be carried out, leaving approximately 96% and 65% of the anatomic footprint remaining, respectively. We recognize that these values may differ depending on the type of AIIS morphology present in each patient. Nevertheless, these data can be used as a clinical guide during AIIS bony decompression while using standard arthroscopic burr dimensions.

Table 1. Rectus Femoris Direct Head Footprint Measurements After Each Subsequent Anteroinferior Iliac Spine Decompression

	M/L, mm	P/D, mm	Total Area, mm^2	% Remaining	P Value (Total Footprint Remaining)
Initial	11.84 ± 2.34	17.95 ± 2.99	160.26 ± 55.96	NA	NA
5 mm	11.68 ± 2.45	17.47 ± 3.17	155.26 ± 48.4	96.28 ± 4.80	.08
10 mm	10.58 ± 2.32	12.74 ± 2.81	105.79 ± 18.97	64.64 ± 12.28	< .001
15 mm	9.0 ± 2.71	7.68 ± 2.89	59.05 ± 12.69	34.66 ± 11.18	< .001
20 mm	8.25 ± 2.42	4 ± 2.46	25.42 ± 18.4	14.46 ± 7.39	< .001
25 mm	8.5 ± 3.11	2.25 ± 1.26	9 ± 19.41	10.75 ± 5.15	< .001

NOTE. Data are presented as mean ± standard deviation unless otherwise indicated.
M/L, medial-lateral; NA, not applicable; P/D, proximal-distal.

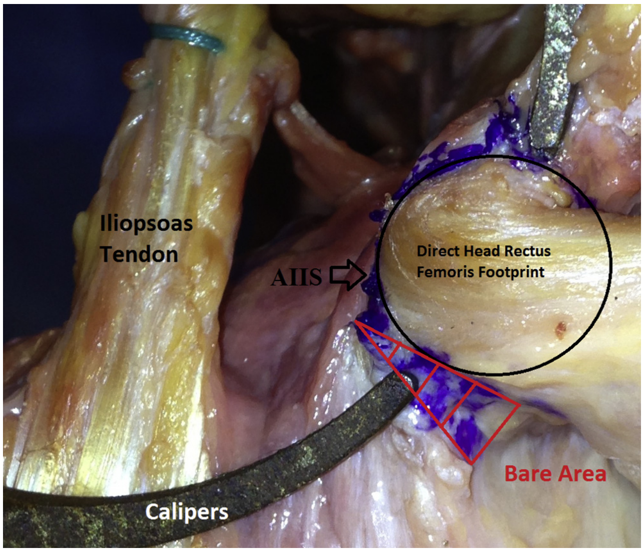

Fig 4. Direct head of the rectus footprint with the bare area on the inferior aspect of the anteroinferior iliac spine (AIIS) in a left cadaveric hip model.

In the second portion of our study, we were able to observe tracking of the iliopsoas tendon as we brought the hip from an extended, internally rotated position to a flexed, externally rotated, and abducted position. We were able to re-create the snapping phenomenon with the iliopsoas over the AIIS. In addition, with each 5-mm resection of the AIIS, the excursion distance of the iliopsoas to contact the AIIS increased. At 5 mm of resection, the iliopsoas tendon increased the excursion distance by 18% of the total, and with 10 mm resected, there was an increase by 45% of the total distance. These data provide a theory to explain how AIIS decompression could decrease symptoms from internal snapping of the hip.

Limitations

There are several limitations to our study. The gender and age of the cadavers were included in this study, but the race and ethnicity of the cadavers were not recorded. The clinical significance of the percentage of rectus footprint remaining on the AIIS after resection is uncertain because no biomechanical testing was completed in this study. Although all specimens were screened at an outside institution for inclusion in this study as having type I or type II AIIS morphology, we were not aware of, and did not clarify, which specimens had type 1 or type II AIIS morphology. Because of the soft-tissue dissection required to identify the rectus tendon origin, as well as the iliopsoas tendon, the tract of the iliopsoas tendon was estimated in all specimens.

Conclusions

Our study maps the anatomic footprint of the direct head of the rectus femoris tendon and confirms a previously identified bare area along the inferior aspect of the AIIS. Female cadaveric hips had a significantly smaller rectus footprint than male cadavers in our study ($P < .001$). Subspine decompression greater than 10 mm significantly compromises the rectus femoris origin and should be avoided when performing arthroscopic AIIS decompression. In addition, subspine decompression significantly improves tracking of the iliopsoas tendon throughout a physiological range of motion and may be considered a surgical adjunct when treating symptomatic iliopsoas snapping.

Table 2. Excursion Angle and Distance of Iliopsoas Tendon Until Impingement on AIIS in Physiological Range of Motion After Subsequent 5-mm Decompression of AIIS

	Excursion Angle Until Impingement		Excursion Distance Until Impingement	
	Mean,°	*P* Value	Mean, mm	*P* Value
Initial	70.28 ± 8.9		14.05 ± 3.73	
5 mm	76.94 ± 8.95	< .001	17.37 ± 3.99	< .001
10 mm	84.2 ± 10.3	< .001	22.21 ± 4.47	< .001
15 mm	86.14 ± 11.8	< .001	26.95 ± 5.76	< .001
20 mm	83 ± 11	< .001	31.06 ± 5.94	< .001
25 mm	No impingement	< .001	36 ± 7.62	< .001

NOTE. Data are presented as mean ± standard deviation unless otherwise indicated.
AIIS, anteroinferior iliac spine.

Table 3. Mean Measurement of Direct Head of Rectus Femoris Footprint on Anteroinferior Iliac Spine

	M/L	P/D	Total Rectus Footprint Area
Male (n = 13)	12.55 ± 2.06 mm	19.73 ± 2.13 mm	193.00 ± 49.11 mm^2
Female (n = 6)	10.57 ± 1.59 mm	15.71 ± 1.91 mm	118.86 ± 12.59 mm^2
P value	< .001	< .001	< .001

NOTE. Data are presented as mean ± standard deviation unless otherwise indicated.
M/L, medial-lateral; P/D, proximal-distal.

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