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ORIGINAL ARTICLE

Iliocapsularis muscle in human fetuses

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Abstract

Purpose To determine the incidence of the iliocapsularis muscle in fetal period and its relationship with the hip joint capsule.

Methods Twenty-one formalin-fixed fetuses (12 female and 9 male) with a mean gestational age of 29 ± 3.89 weeks (range 25–36) were dissected to reveal morphological properties of iliocapsularis muscle.

Results Iliocapsularis muscle was observed in 39 out of 42 sides (92%). Its proximal attachment was detected either below the proximal attachment of rectus femoris muscle in 21 out of 39 sides (54%), or it was forming a common tendon with rectus femoris on the anterior inferior iliac spine in 10 out of 39 sides (26%), or it was forming an arch along the superior–medial–inferior sides of the proximal attachment of rectus femoris muscle in 8 out of 39 sides (20%). Muscle fibers originating from the anteromedial part of hip joint capsule were also constant in all sides. Distal attachment of iliocapsularis muscle was distal to the lesser trochanter in all specimens. Its form was as a broad muscle in 32 out of 39 sides (82%) and as a thin rectangular muscular slip in 7 out of 39 sides (18%). Iliopsoas and iliocapsularis muscles had their particular fascia in 34 out of 39 sides (87%), and in the other 5 sides, there was no fascia which prominently separated the two muscles. Its length was longer in females than males ($p = 0.031$) and it was wider on the right side ($p = 0.029$). Linear functions were $y = 0.49 + 0.17 \times$ weeks and $y = 6.94 + 0.89 \times$ weeks for width and length, respectively.

Conclusion Data obtained with the present study about iliocapsularis muscle in fetal period revealed that it is an individual and constant muscle. Its dimension, location, and course over the hip joint capsule support the idea that it tightens the hip capsule and stabilizes the femoral head.

Keywords Iliocapsularis muscle · Fetus · Hip joint capsule · Morphology

Introduction

Although the iliocapsularis muscle (IC) has been reported as a constant muscle in adults on the anterior aspect of the hip joint capsule, it has been mentioned as a separate muscle with various names as ilio-capsulo-trochanteric, iliacus minor, iliacus brevis, or ilio-infratrochantericus [1, 23, 25, 27]. However, contemporary anatomy textbooks did not mention the IC as a separate muscle [17, 18, 20, 24]. It came up with the anatomical study of Ward et al. [27], giving detailed information about the muscle as well as emphasizing its essential role in stabilizing the hip joint capsule and highlighting its importance in the exposure of the anteromedial capsule during periacetabular osteotomy surgery [27]. Later then, several researchers have focused on the muscle, particularly on its role in hip joint stabilization.

Iliocapsularis muscle has been reported to originate from the anterior inferior iliac spine (AIIS) along with the anteromedial part of hip joint capsule and insert to the lesser trochanter distal to the attachment of iliopsoas muscle (IP). Its attachment to the anteromedial hip joint capsule has been noted to tighten the hip capsule, help to stabilize head of the femur [1, 5, 12, 21, 26, 27], and prevent synovial impingement during flexion [15]. It has been also stated that the IC is hypertrophied in dysplastic or unstable hips [1, 6, 8, 10, 11]. Moreover, Domb et al. asserted that hypertrophy of the IC may be the cause of repetitive traction injury [6].

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On the other hand, the IC has been used as a key landmark in multiple surgeries including hip arthroplasty, IP tendon tenotomy, and Bernese periacetabular osteotomy [1, 12, 27]. Anterolateral border of the IC has been described as the ideal location for capsulotomy in anterior total hip arthroplasty, while its anteromedial border can be used during modified Smith–Peterson approach to periacetabular osteotomy for joint capsule identification [8]. It has been stated that the IC may be helpful during anterolateral or direct lateral approach to identify the IP tendon [7]. Similarly, an ideal T capsular incision is performed between the fibers of the IC and gluteus minimus muscle to prevent iatrogenic injury to surrounding structures including the vessels to hip joint [2, 3, 13].

There are also studies trying to determine the functions of the IC using electromyography, magnetic resonance imaging, and ultrasonography. Lawrenson et al. found high electromyography amplitude during hip flexion, and indicated the role of the IC to draw the hip joint capsule anteriorly to prevent impingement [15]. Babst et al. noted the importance of the IC to stabilize the head of the femur in a deficient acetabulum in their study with magnetic resonance imaging [1]. Guillin et al. investigated both the psoas major and iliacus muscles with ultrasonography and detected an independent muscle bundle on the most lateral part of the iliacus muscle and defined it as the ilio-infra-trochanteric muscle. However, Guillin et al. did not mention the precise function of this muscle bundle [9]. Pourcho et al. determined the sonographic appearance of the IC and recommended that ultrasonography-assisted rehabilitation of the IC may play a role in rehabilitation programs for the unstable hip [19].

Eventually, the IC has not been mentioned as a constant muscle in classical anatomy textbooks, but has been identified almost constantly in various studies on adult cadavers so far. In this study, we aimed to obtain morphological data about the IC and to determine its precise dimension, location, and course over the hip joint capsule in fetal period.

Materials and methods

Twenty-one formalin-fixed fetuses (12 female and 9 male) without deformities on lower extremity with a mean gestational age of 29 ± 3.89 weeks (range 25–36) present in the collection of Anatomy Department, School of Medicine, Mersin University were evaluated (Table 1). Clinical Research Ethics Committee of Mersin University approved the study (2018/256). Fetuses were placed in a supine position. Skin, subcutaneous tissue, and sartorius, rectus femoris (RF), tensor fasciae latae, and gluteus medius muscles were dissected and retracted under surgical microscope (Zeiss Opmi-Pico, Germany). Detailed dissection was carried out to reveal the IC muscle's proximal attachment deep and inferior to that of RF. To see its distal attachment, lesser trochanter and the IP distal attachment were carefully dissected. Digital caliper (0.01 mm precision) was used for measurements. Following parameters were observed and recorded:

Table 1 Demographic data of fetuses

Gestational age (weeks)	Foot length (mm)	Number of sides	Gender	
			Female	Male
25	43.95	2	–	1
26	45.59	14	4	3
27	50.10	6	2	1
28	51.64	6	1	2
29	53.64	2	–	1
31	58.11	2	1	–
35	62.91	6	2	1
36	67.75	4	2	–

- Proximal and distal attachments of IC.
- The IC position (deep to IP/lateral and deep to IP/lateral to IP).
- The IC form (broad muscle/thin rectangular muscular slip).

Following parameters were measured by digital caliper and recorded:

- The IC length.
- The IC width of its mid-length.

Measurements were repeated twice at different times by the same researcher, and then, intra-observer reproducibility (intra-class correlation coefficients: ICC) was used to assess the reliability of the data. Shapiro–Wilk test was used for normality check. Paired *t* test was used to compare measurements according to sides, whereas independent samples *t* test was used to compare gender. Mann–Whitney *U* test was used to compare the difference between genders according to age distribution. The mean value and standard deviation were calculated as descriptive statistics. The relationship of parameters with gestational age (weeks) was assessed using simple linear regression. Correlation between variables was investigated by the Pearson's correlation coefficient. The statistical significance level was set at $p < 0.05$.

Results

Morphological data related to the IC width and length according to gestational weeks are presented in Table 2. The measurements (ICC = 0.989, $p = 0.001$) proved that reliability of the data was quite excellent. Table 3 demonstrated the

comparison of the IC width and length related to side and gender. No statistically significant difference was found in age distribution between genders ($p = 0.379$).

- The IC was found lateral to the IP, deep to RF, and medial to gluteus minimus muscle and lying over the anteromedial part of the hip joint capsule. Between the IC (medial) and gluteus minimus (lateral), a fat pad was constantly observed. This fat pad was superficial to the joint capsule and deep to the femoral neurovascular bundle (Fig. 1a, b).
- The IC was observed in 39 out of 42 sides; in a single fetus (25 weeks aged), it was bilaterally absent, and in another fetus (26 weeks aged), it was absent on the right side.
- Its proximal attachment was most commonly observed below that of RF and from the anteromedial part of hip joint capsule in 21 out of 39 sides (54%) (Fig. 1a).

Table 2 Morphological data according to gestational weeks

Weeks	IC length (mm)			IC width (mm)		
	Minimum	Mean ± SD	Maximum	Minimum	Mean ± SD	Maximum
26	12.74	16.30 ± 2.83	23.93	2.72	4.68 ± 1.39	7.02
27	15.82	17.56 ± 1.31	18.91	3.27	5.34 ± 1.83	7.43
28	14.52	16.94 ± 2.11	19.34	4.20	5.48 ± 1.06	6.60
29	19.18	20.76 ± 2.24	22.35	3.82	5.86 ± 2.88	7.90
31	20.62	21.15 ± 0.76	21.69	2.43	4.18 ± 2.47	5.93
35	20.00	23.95 ± 4.54	32.51	7.80	8.09 ± 0.42	8.58
36	26.38	26.55 ± 0.24	26.72	3.86	5.24 ± 1.95	6.62
Total	12.74	19.20 ± 4.31	32.51	2.43	5.42 ± 1.69	8.58

IC iliocapsularis muscle, *SD* standard deviation

Table 3 Comparison of the IC length and width according to side and gender

Parameters	Side		*p*	Gender		*p*
	Right	Left		Female	Male	
IC length (mm)	19.85 ± 3.86	18.80 ± 4.74	0.188	20.10 ± 4.89	17.75 ± 2.72	**0.031**
IC width (mm)	5.93 ± 1.62	5.07 ± 1.66	**0.029**	5.39 ± 1.75	5.48 ± 1.65	0.837

Bold numbers indicate that IC width is statistically wider in right side than left side

IC iliocapsularis muscle, *p* significance level

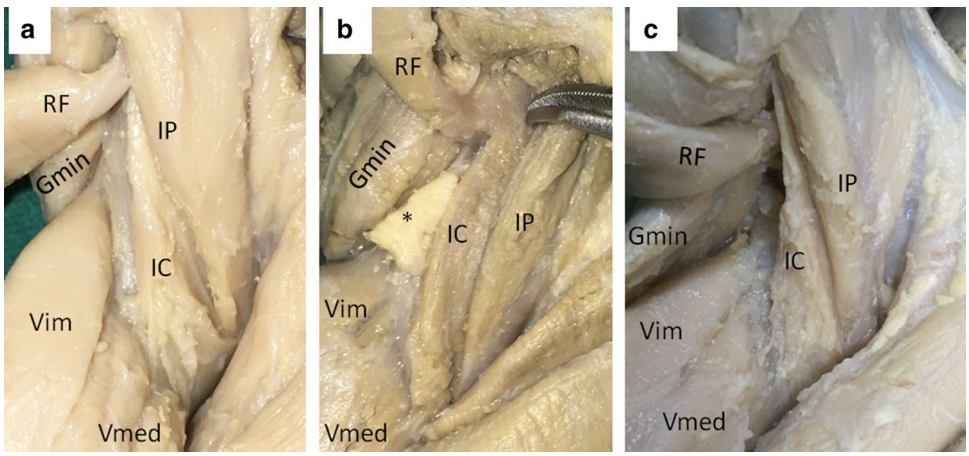

Fig. 1 Photos showing the various proximal attachment sites of the IC (all were on the right side). **a** Below the proximal attachment of RF, **b** as a common tendon with RF on AIIS, *fat pad located between the IC and Gmin, **c** as an arch along the superior–medial–inferior side of the proximal attachment of RF below AIIS. Note the fat pad between IC and gluteus minimus muscle. *IC* iliocapsularis muscle, *IP* iliopsoas muscle, *RF* rectus femoris muscle, *Gmin* gluteus minimus muscle, *Vim* vastus intermedius muscle, *Vmed* vastus medialis muscle, *AIIS* anterior inferior iliac spine

Second frequent type was as a common tendon with RF on AIIS and from the anteromedial part of hip joint capsule in 10 out of 39 sides (26%) (Fig. 1b). In 8 out of 39 sides (20%), its proximal attachment was forming an arch along the superior–medial–inferior side of the proximal attachment of RF below AIIS and from the anteromedial part of hip joint capsule (Fig. 1c). Fibers originating from the anteromedial part of the hip joint capsule were constant in all specimens (Fig. 2).

- In all sides, distal attachment of the IC was to the lesser trochanter distal to that of the IP tendon (Fig. 1c).
- The IC form was as a broad muscle in 32 out of 39 (82%) sides (Fig. 3a) and as a thin rectangular muscular slip in 7 out of 39 sides (18%) (Fig. 3b).
- Iliacus muscle and the IC had their particular fascia in 34 out of 39 sides (87%). In 5 other sides, there was no fascia which prominently separated the two muscles. In these 5 sides, the IC was detected as having separate proximal and distal attachments along with the IP, and the muscle was dissected easily from the IP, but its fascia was not that clear as in the others.
- Innervation of the IC was found to be through a thin nerve branch from femoral nerve piercing iliacus first, and then arising on the IC over its superficial surface.
- Almost on all sides, the IC was observed deep to the IP and only its lateral part was exceeding the lateral border of the IP (37 out of 39 sides). It was totally deep to the IP in one side and was impossible to observe it unless the IP was removed. In another side, the IC was found to be totally lateral to the IP (Fig. 4).
- There was a positive statistically significant relationship between the IC width and week parameters ($r = 0.433$, $p = 0.036$). Similar statistically significant relationship was detected between the IC length and week parameters ($r = 0.752$, $p = 0.001$). There was a statistically significant linear relationship between the IC width and length parameters ($r = 0.339$, $p = 0.037$).
- The scatter plot of width and length of the IC with age, regression line, and regression equation is given in Fig. 5. Linear functions were calculated as $0.49 + 0.17 \times$ Age (weeks) for width and $6.94 + 0.89 \times$ Age (weeks) for length.

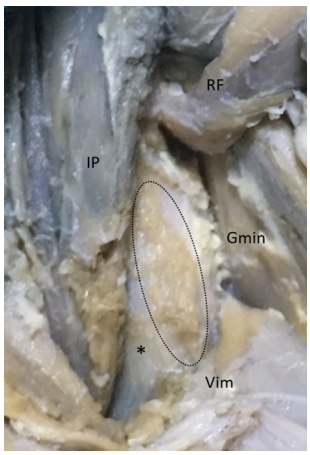

Fig. 2 Photo showing the relation of the IC with hip capsule. The IC was removed inferiorly to show footprints of its capsular proximal attachment on the anteromedial part of the joint capsule (dotted lines). *IC* iliocapsularis muscle, *IP* iliopsoas muscle, *RF* rectus femoris muscle, *Vim* vastus intermedius muscle, *Gmin* gluteus minimus muscle, *hip joint capsule

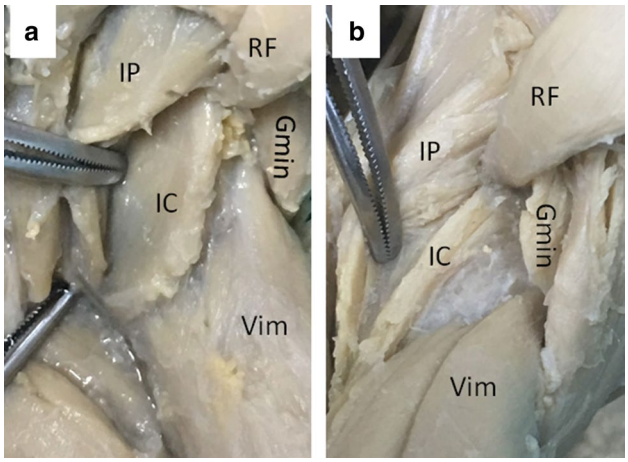

Fig. 3 Photos showing the various forms of the IC. **a** Broad muscle in a 26-week fetus; **b** thin rectangular muscular slip in another 26-week fetus. *IC* iliocapsularis muscle, *IP* iliopsoas muscle, *RF* rectus femoris muscle, *Vim* vastus intermedius muscle, *Gmin* gluteus minimus muscle

Discussion

The present study evaluated the IC muscle incidence in fetuses and provided morphological data for the first time in the literature. Although it has been mentioned not separate but as a part of iliacus muscle in some reports [13, 22] or has been noted only as a variational muscle in some textbooks [25], we determined IC as a separate muscle in 39 out of 42 fetuses (92%). In a single fetus, it was bilaterally absent, and in another fetus, it was absent on the right side; so we consider it as a constant muscle. These two fetuses can be regarded as variational.

Previous reports have mentioned this muscle with various names as ilio-capsulo-trochanteric, iliacus minor, iliacus brevis, or ilio-infratrochantericus [1, 23, 25, 27]. "Iliacus minor" or "iliacus brevis" terms do not mention its connection with the hip joint capsule, while" ilio-capsulo-trochanteric" is quite long and distal attachment is not used/necessary most of the times in denomination of muscles. We believe that the term "iliocapsularis" specifies best its

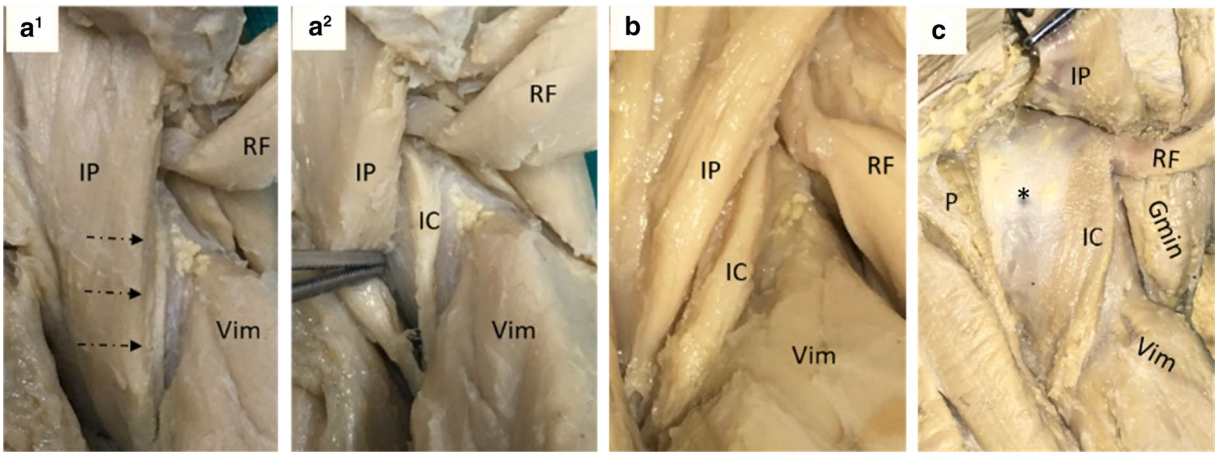

Fig. 4 Photos showing the location of the IC. **a**[1] The IC was located deep to the IP which allows only to observe its lateral border (dashed arrows). **a**[2] The rest of the IC can only be observed by retracting the IP medially; **b** in a single side, the IC was detected as totally lateral to the IP; **c** view of the whole IC after removal of all neighboring muscles. *IC* iliocapsularis muscle, *IP* iliopsoas muscle, *RF* rectus femoris muscle, *Vim* vastus intermedius muscle, *hip joint capsule

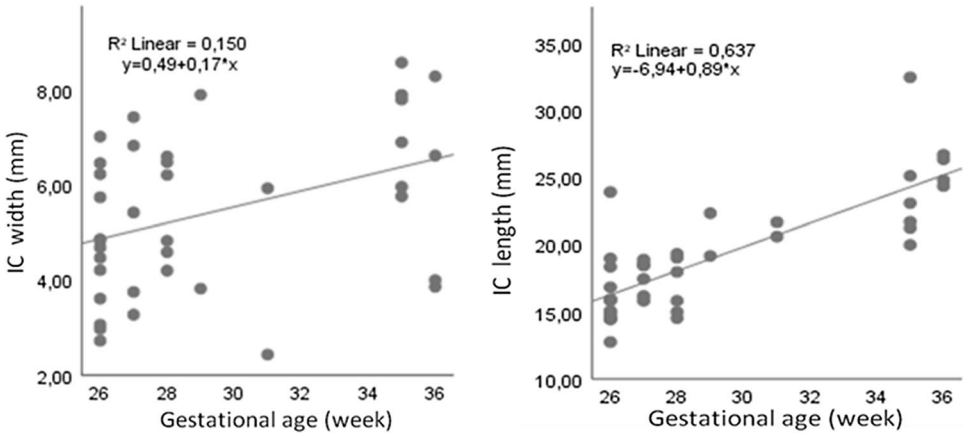

Fig. 5 Scatter plot of width and length of the IC with age, regression line, and regression equation

attachment over the hip joint capsule along with the iliac bone and reminds its functional role on joint stabilization.

In the present study, iliacus and the IC mostly had their particular fascia which enabled us to perform a clear dissection. However, in some cases, there was no fascia which prominently separated the two muscles; such cases may be the reason for previous studies recognizing the IC as a part of the IL [13, 22].

Previous studies have been reported that the IC, through its course, provides significant support over the anteromedial part of the hip joint capsule [5, 16, 26]. We observed in all fetuses that the IC was also originating from the anteromedial part of the hip joint capsule. There are some reports giving this as supporting the anteromedial part of hip joint, and tightening the capsule to prevent impingement and stabilizing head of the femur in the joint [5, 14]. Moreover, Lawrenson et al. state that "IC provides the most substantial muscular attachment to the anterior hip capsule and has a dynamic role to limit capsular impingement" [15]. Our results confirm the proximal attachment of the IC from the joint capsule in fetuses, as well, and suggest that, as a constant muscle, the IC probably stretches the capsule and stabilizes head of the femur in the joint.

On the other hand, in the study of Carton et al., the proximal attachment of the IC has been given as the inferior facet of AIIS below AIIS ridge [4]. We did not detect a ridge over AIIS; however, we observed several types of the IC proximal attachment regarding its relationship with the head of RF. In the most common type, its proximal attachment was below that of RF, while in the second common type, there was a common proximal attachment for the IC and RF. Interestingly, we detected a third type in which the proximal attachment of the IC was forming arch around that of RF. These various types of proximal attachment may also be the reason to determine the IC not as a separate muscle in previous studies.

A pericapsular fat pad had been reported by researchers between the IC (medial) and gluteus minimus muscle (lateral) beneath RF [2, 26]. The intermuscular plane where this fat pad is located has been used as a landmark for T capsulotomy [12] and allows for precise capsular incision that avoids iatrogenic injury to these muscle–tendon units and the underlying vascular supply to the hip [2]. We also observed this fat pad in all fetuses in the above-mentioned location.

In the report of Babst et al., it was specified that dimensions of the IC vary depending on the morphologic features of the acetabulum [1]. Ward et al. reported that its length was 12–13 cm and its thickness was 0.4–1 cm and its width was 1.8–2.5 cm at the point of 4 cm below AIIS in dissection of 20 fresh adult cadavers [27]. Cooper et al. reported the capsular attachment of the IC as 73.8 mm in length and 16.1 mm in width in 11 fresh-frozen hemipelvic adult cadaveric specimens [5]. In the present study, the IC width was 5.93 ± 1.62 mm and length was 19.85 ± 3.86 mm in the third trimester fetuses. When length and width parameters were compared in terms of gender and side, the IC length was longer in females than males and the IC was wider on the right side (Table 3). Meanwhile, statistically significant relationships were observed between the IC dimensions and fetal development. However, the IC may not have a prominent function unless there is dystrophy. This would be the reason to encounter hypertrophied muscles in developmental dysplasia of the hip.

Conclusion

Our results present detailed morphological data about the IC which was demonstrated as a constant muscle also in the fetal period. Its dimensions, location, and course over the anteromedial part of the hip joint capsule suggest its prominent support to hip joint stability. Linear functions for estimating the fetal morphology of this muscle obtained by our study may be helpful in regional surgical procedures during early postnatal period.

Author Contributions ÖE and MA: project development, data analysis, manuscript writing, and editing; EŞ: data collection and analysis; ZKO and AB: project development and editing.

Compliance with ethical standards

Conflict of interest Authors declared no conflict of interest.

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