



# Anatomical features of the iliocapsularis muscle: a dissection study

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## Abstract

**Purpose** Iliocapsularis (IC) overlies the anteromedial hip capsule and is an important landmark in anterior approaches to hip arthroplasty. Previously believed to be part of iliacus, few publications describe the prevalence, attachments, fibre direction, blood supply, innervation, and size of IC. This study was aimed to determine these anatomical features using embalmed bodies and whether they vary between sides, sex, and age.

**Methods** Thirty-eight formalin-fixed adult bodies were dissected and the prevalence, presence of a connective tissue raphe, attachments, fibre direction, blood supply, and innervation, were documented. Length and width were measured, and significant differences were investigated with *t* tests.

**Results** Iliocapsularis was present in all bodies examined, originating from the inferior border of the anterior inferior iliac spine, and inserting 20 mm distal to the lesser trochanter in 54 muscles (71%). Iliocapsularis was supplied by a thin branch from the femoral nerve and by branches of the lateral circumflex femoral and deep femoral arteries and veins. Muscle fibre direction was from superolateral to inferomedial. Mean length was  $116.8 \pm 11.2$  mm and width was  $12.8 \pm 3.1$  mm, with no significant differences between sides, sex, and age.

**Conclusion** This was the first study to document the venous drainage and compare the dimensions with sides, sex, and age, using adult bodies. However, the true function of IC is still unknown. Iliocapsularis is a constant muscle, distinct from iliacus, which is relevant to orthopaedic surgeons and physical rehabilitation specialists, particularly for postoperative patient care.

**Keywords** Iliocapsularis muscle · Anatomy · Musculoskeletal · Total hip arthroplasty · Direct anterior approach

## Introduction

In the few studies published on the iliocapsularis (IC), it has been described as a constant, well-defined muscle that overlies the anterior hip capsule deep to rectus femoris and lateral to the inferior part of the iliacus [1, 6, 22, 23]. A recent systematic review and meta-analysis [9] reported only six previous studies describing the anatomical features of IC. The IC originates in part from the inferior border of the anterior inferior iliac spine (AIIS) as well as an elongated attachment along the anteromedial hip capsule and inserts “about 15 mm distal to the lesser trochanter” [14, 22, 23] (Fig. 1). The muscle fibres are said to run from anterolateral proximally to posteromedial distally [22, 23]. A connective tissue raphe separating the lateral main fibres of the inferior part of iliacus from the medial fibres of IC was reported to be consistently present in one study [23]. Previous studies suggest that IC is innervated by the femoral nerve and receives its arterial blood supply from small branches of the

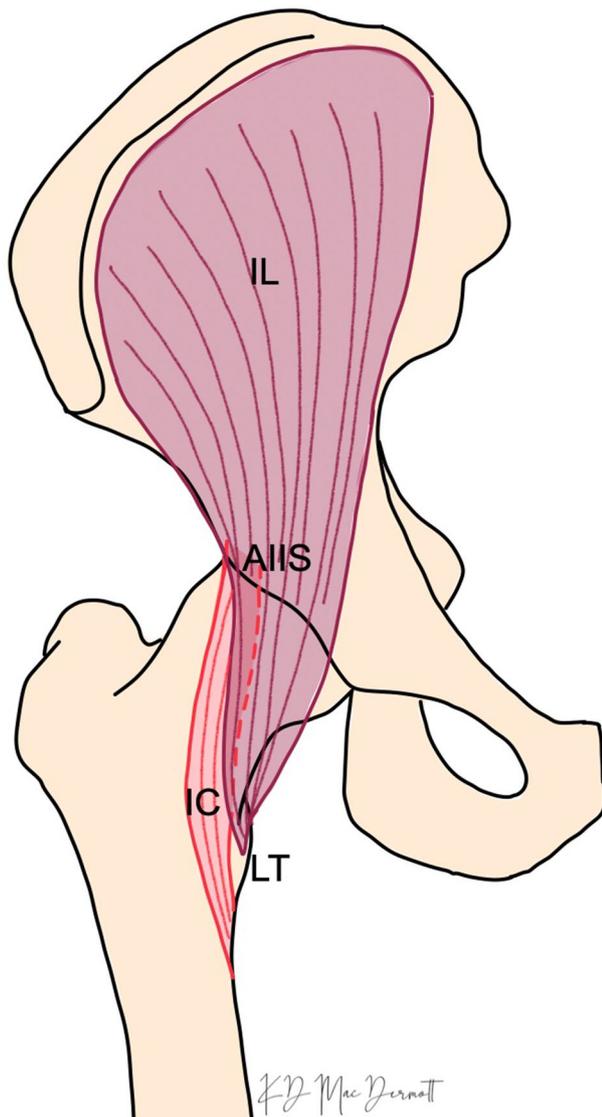
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**Fig. 1** The right iliocapsularis (IC) muscle illustrating its origin from the anterior inferior iliac spine (AIIS) and insertion distal to the lesser trochanter (LT), as well as its relationship to iliacus (IL)

lateral circumflex femoral and deep femoral artery [4, 6, 23]. However, no previous study has described the venous drainage or investigated the muscle fibre type [9].

Historically, IC was regarded as a clinically insignificant muscle in surgical literature and anatomical texts as it was considered to be part of iliacus. However, the development of anterior approaches to the hip joint in orthopaedic procedures has resulted in a new appreciation for IC as a possibly distinct muscle. The IC can be used as a landmark in the direct anterior approach (DAA) for total hip arthroplasty (THA) [1, 8]. Furthermore, IC can be used to supplement the clinical diagnoses of hip dysplasia and femoroacetabular impingement (FAI) by assessing the dimension of IC on

clinical imaging and comparing it to adjacent structures to confirm the presence of a hip pathology [1, 8, 15, 16]. However, only three studies have determined the dimensions of IC in adults, of which one was cadaveric and two were imaging [1, 8, 23]. Thus, the normal range of dimensions for any population is not known. In addition, no previous study has compared the dimensions of IC between sides, sex, and age, using adult bodies. This information could provide insight into any sex-related differences (size) and age-related effects (muscle atrophy) of IC.

To the best of our knowledge, no single study has reported on all of the anatomical features of IC in one cohort, namely prevalence, presence of a connective tissue raphe, muscle origin and insertion, fibre direction, blood supply, and innervation, as well as dimensions. Thus, this study aimed to determine a) the anatomical features and dimensions (length and width) of IC, and b) whether there were any significant differences in features and size between sides, sex, and age in order to investigate whether IC is a distinct muscle from iliacus.

## Materials and methods

### Study subjects

A cross-sectional observational dissection study of 44 adult formalin-fixed embalmed bodies (30 males and 14 females) was conducted at a tertiary institution between July and September 2020. A statistical power analysis to calculate the sample size was unable to be performed due to the limited literature published on IC. A pilot study was planned; however, due to the unforeseen circumstances of the COVID-19 pandemic and the resulting lockdown, the sample size was chosen based on convenience methods and the availability of bodies. Exclusion criteria included damaged IC from previous dissections, dried out and hardened lower limb tissues, hip pathology, or surgical intervention. This study was performed and reported in compliance with the Anatomical Quality Assurance (AQUA) Checklist (Supplement 1) [20].

### Body mass index

The weight and height of each body were recorded by a technical staff member and the body mass index (BMI) calculation was obtained (Supplement 2). The weight was recorded in kilogrammes on intake prior to embalming with a large mortuary scale, while the height was measured after embalming using a modified stadiometer. The body was placed in the supine position, the head positioned facing the ceiling, the lower limbs pressed together and downwards, and the feet positioned upwards. A fixed board was positioned perpendicularly against the feet, while another board was extended along the ruler until contact was made

with the vertex of the head and the height was recorded in centimetres.

## Dissection

The anterior thigh and hip regions were dissected of both the left and right lower limbs of each body using a standard dissection kit. With the body in a supine position, two skin incisions were performed—from the anterior superior iliac spine to the pubic tubercle and from the midpoint of the inguinal ligament towards the patella. The skin was reflected to either side and the subcutaneous fat and connective tissue were removed. The femoral triangle was located, and the contents identified (femoral nerve, artery, vein, and femoral sheath). The tensor fascia latae was retracted laterally, while the sartorius was transected near the apex of the femoral triangle and reflected superiorly. The rectus femoris was exposed and transected near its mid-length and reflected superiorly. A fat pad and connective tissue layer situated between the rectus femoris and IC were removed to expose the proximal portion of IC lateral to the inferior part of iliacus. The origin of IC was determined by reflecting and releasing rectus femoris from its origin. Next, the lateral circumflex femoral artery and vein were cleared of fascia, exposed, and reflected laterally through an incision near their origins from the deep femoral artery and the femoral vein, respectively, to expose the distal portion of IC and the deep femoral artery and vein.

## Data collection

The primary outcomes investigated in this study were the anatomical features and dimensions of IC. Secondary outcomes included determining any significant differences in features and size of IC between sides, sex, and age. The anatomical features examined and documented included the prevalence of IC on each side of the body, presence of a connective tissue raphe between IC and iliacus, muscle origin and insertion (including the insertion distance distal to the lesser trochanter), fibre direction, blood supply, and innervation. The dimensions (length and width) of IC were measured using a ribbon, two pins and an ORIGIN (0–150 mm) electronic digital calliper. The length of IC was measured from its origin to its insertion points, while the width was measured 40 mm inferior to the AIIS to allow comparison with results reported by Ward et al. [23] and Babst et al. [1], who both used this reference point. The measurements were performed three times to determine an average which was utilised in subsequent statistical analysis. Intra- and inter-observer reliability was assessed by the principal researcher and an independent colleague, respectively, repeating the measurements of IC for the entire cohort. The measurements were then compared with the average measurements taken primarily using Bland–Altman plots in Microsoft Excel.

This study was cadaveric based; thus, some bias may have been introduced as the study subjects were not living nor were healthy at the time of death as all had died from natural causes. Furthermore, no medical history of the cohort was available. Often cadaver samples comprise of older individuals; however, this cohort was relatively young. Additionally, selection bias may have been introduced as the current cohort might not represent the population as only 31.8% of the sample was female and 68.2% was male. Methods to eliminate bias involved utilising all bodies available and dissecting both body sides to increase the sample size.

## Statistical analysis

Statistical analyses were performed using Stata version 16 (College Station, Texas, United States). Differences in the measurements (length and width) of IC between sides and sex were investigated by means of a paired *t* test and an independent *t* test, respectively. Correlation analyses measured the association between the measurements with sides and age, while regression analysis compared the measurements adjusted for BMI with sex. For all statistical analyses performed, a *p* value < 0.05 was considered significant.

## Ethical compliance

Consent for the use of the bodies was obtained from the Inspector of Anatomy for the province. Ethical approval was granted by the institution's Undergraduate Research Ethics Committee (reference number U20/02/060, date of approval 08/04/2020) who endorses the Declaration of Helsinki (1964) and its later amendments [5]. The cohort comprised of both willed donors who provided consent and unclaimed bodies for whom the Inspector of Anatomy provided consent, in accordance with the National Health Act 61 of 2003 [17].

## Results

### Subject characteristics

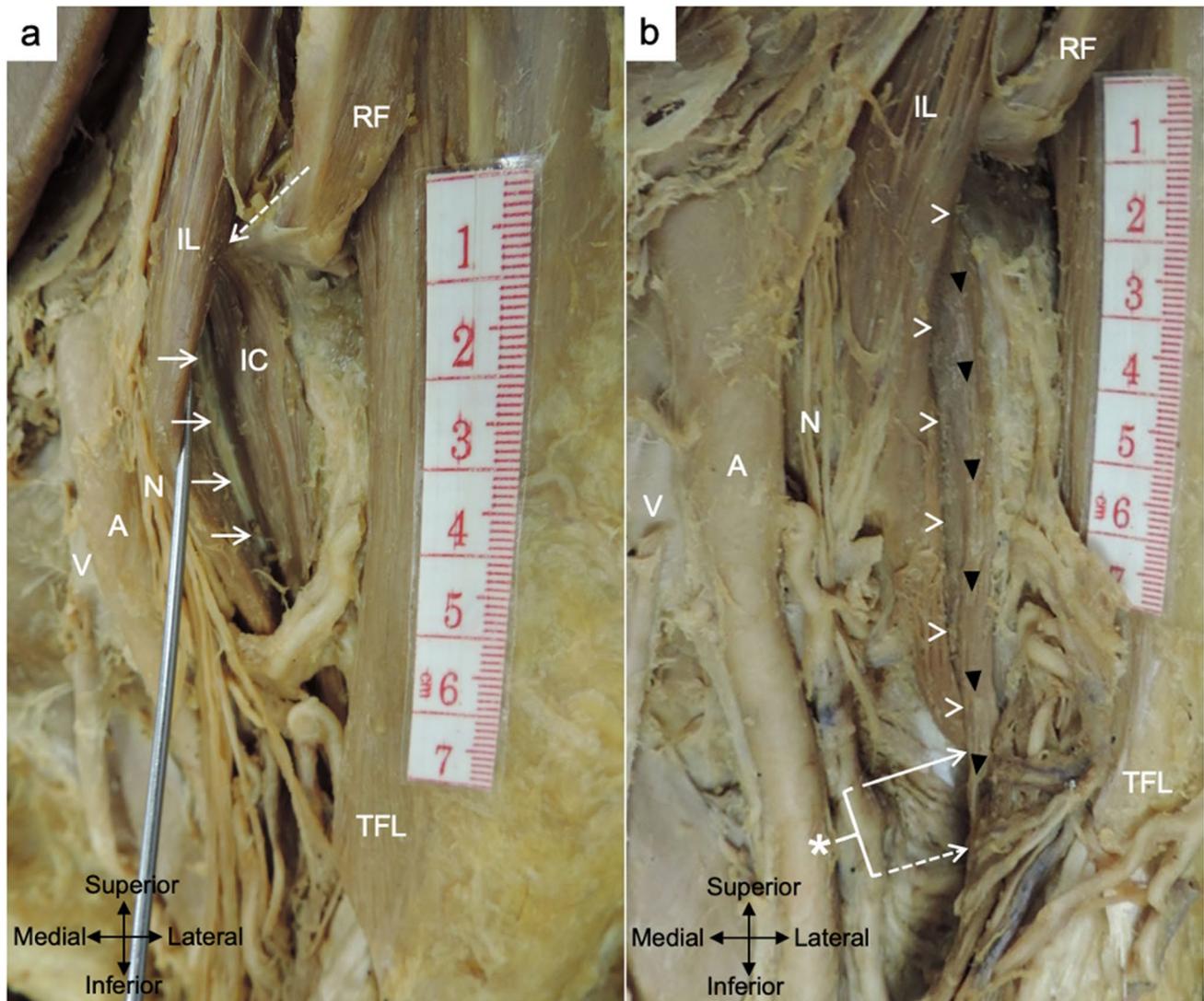
Of the 44 bodies, six were excluded (one female, five males) because of damage from previous dissection, resulting in a final sample size of 38 bodies (76 lower limbs), of which 25 were male (65.8%) and 13 were female (34.2%). The mean age of the cohort was  $45.0 \pm 14.0$  years (range 24–77 years), with majority of the bodies within the 30–39 age range (Table 1). The weight and height were only measured in a subset of bodies ( $n = 19$ ) as the calvaria were removed from the remainder. The mean BMI for the subset of bodies was  $16.9 \pm 4.8$  kg/m<sup>2</sup> (range 11.4–29.9 kg/m<sup>2</sup>) (Supplement 2).

**Table 1** Demographic information

Age range	Number of sides	Sex		Age (years): Mean $\pm$ standard deviation (range)
		Female	Male	
20–29	8	1	3	27.3 $\pm$ 2.4 (24–29)
30–39	28	6	8	34.4 $\pm$ 2.9 (30–38)
40–49	10	2	3	45.2 $\pm$ 1.3 (44–47)
50–59	18	3	6	53.7 $\pm$ 3.5 (50–59)
60–69	8	1	3	64.5 $\pm$ 4.7 (60–69)
70–79	4	0	2	75.5 $\pm$ 2.1 (71–77)
Total	76	13	25	45.0 $\pm$ 14.0 (24–77)

### Anatomical features of the iliocapsularis

Iliocapsularis was present on both the left and right sides of all bodies (76 lower limbs) (Fig. 2). In all cases, a distinct fascia separated IC from iliacus medially and from rectus femoris superficially. In addition, a fat pad was located in between IC and rectus femoris. The distinct fascia allowed for the lateral border of iliacus to be separated from the medial border of IC to reveal a connective tissue raphe between the muscles (Fig. 2a). The presence of a distinct fascia, fat pad, and connective tissue raphe, in all bodies, support the hypothesis that IC is a distinct and separate muscle from iliacus.



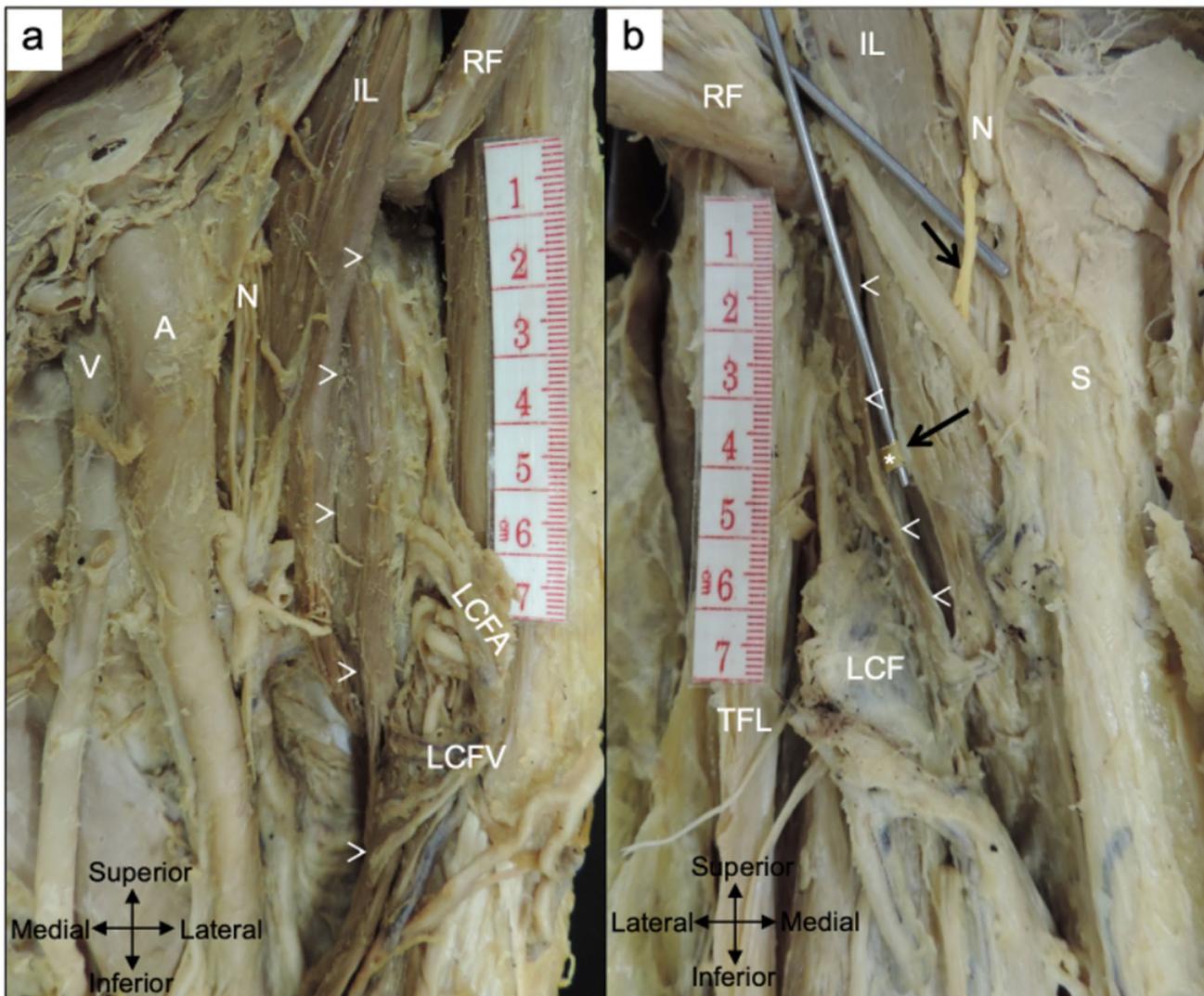
**Fig. 2** Left hip from an **a** anterolateral view illustrating the connective tissue raphe (arrows) separating the iliocapsularis (IC) from iliacus (IL) and the origin (dashed arrow) of iliocapsularis, and **b** anterior view illustrating the insertion (dashed arrow) of the iliocapsularis (white arrowheads), the distance (asterisk) iliocapsularis inserts dis-

tal to the lesser trochanter (solid arrow) and the fibre direction (solid black arrowheads) of the iliocapsularis running from superolateral to inferomedial. *RF* rectus femoris, *TFL* tensor fascia latae, *N* femoral nerve, *A* femoral artery, *V* femoral vein

Iliocapsularis originated from the inferior border of the AIIS (Fig. 2a) and strongly adhered to the anteromedial hip capsule in all cases. The lateral border of IC attached to the intertrochanteric line of the femur, just superior to the proximal attachment of the vastus medialis, before turning medially and inserting distal to the lesser trochanter (Fig. 2b). Iliocapsularis inserted 20 mm distal to the lesser trochanter in 71% of cases (54 muscles), while the remaining 29% (22 muscles) inserted closer to 15 mm (Supplement 3). The muscles that inserted more distal to the lesser trochanter were larger (mean length  $119.7 \pm 11.5$  mm; mean width  $13.5 \pm 3.3$  mm) than those that inserted more proximally (mean length  $109.8 \pm 6.3$  mm; mean width  $11.0 \pm 1.6$  mm).

The fibre direction of IC consistently ran from superolateral to inferomedial in all cases.

The apparent blood supply to IC was from a dual source, namely branches from the lateral circumflex femoral artery and vein which penetrated the lateral border (Fig. 3a), and small branches from the deep femoral artery and vein which transversed iliacus and then penetrated the medial border of the distal portion of IC. The apparent innervation was a thin branch of the femoral nerve which first penetrated iliacus and then emerged between iliacus and IC to supply the muscle (Fig. 3b). In a single case, a branch of the femoral nerve coursed with small branches of the lateral circumflex femoral vessels as a neurovascular bundle and split into



**Fig. 3** **a** Anterior view of the left hip illustrating branches of the lateral circumflex femoral artery and vein penetrating the lateral border of iliocapsularis (arrowheads). **b** Anterior view of the right hip illustrating the innervation from a thin branch of the femoral nerve (black arrows). Probes positioned under the thin branch from the femoral

nerve emerging from iliacus (IL) and penetrating iliocapsularis (asterisk). RF rectus femoris, TFL tensor fascia latae, N femoral nerve, A femoral artery, V femoral vein, LCF lateral circumflex femoral vessels, LCFA lateral circumflex femoral artery, LCFV lateral circumflex femoral vein

smaller nerve branches. These femoral nerve branches then penetrated iliacus and emerged between the two muscles to supply IC.

### Dimensions of the iliocapsularis length and width

The entire cohort ( $n = 76$  muscles, 38 left and 38 right lower limbs) was measured independently by both the principal researcher and an independent colleague to assess intra- and inter-observer reliability, respectively. The Bland–Altman intra- and inter-observer reliability tests revealed a strong agreement between the original measurements and the reliability measurements, concluding the methodology is reliable and reproducible with little error (Supplement 4).

The mean length of IC was  $116.8 \pm 11.2$  mm and the mean width was  $12.8 \pm 3.1$  mm (Table 2). There were no statistically significant differences in length ( $p = 0.53$ ) or width ( $p = 0.71$ ) between the left and right sides. The mean length of IC was  $117.2 \pm 10.3$  mm for the left side and  $116.5 \pm 12.1$  mm for the right side, while the mean width was  $12.8 \pm 2.9$  mm for the left side and  $12.7 \pm 3.3$  mm for the right side.

When the dimensions of IC were compared with sex (Table 2), the length was larger in males ( $119.2 \pm 10.3$  mm) than in females ( $112.4 \pm 11.6$  mm), while the width was similar in both sexes (males,  $13.0 \pm 3.3$  mm; females,  $12.3 \pm 2.5$  mm). A significant difference was found for the left length ( $p = 0.04$ ) only. However, when measurements were adjusted for BMI, no significant difference was found.

When the dimensions were compared with age, a statistically significant low correlation was found between the left length of IC and age ( $r = 0.34$ ,  $p = 0.04$ ), while little to

no correlation was found between the right length ( $r = 0.27$ ,  $p = 0.10$ ), left width ( $r = 0.01$ ,  $p = 0.93$ ) and right width ( $r = 0.17$ ,  $p = 0.32$ ) of IC when compared with age (Supplement 5).

### Discussion

This study's primary outcomes were to investigate the anatomical features and dimensions of IC. Secondary outcomes included determining any significant differences in the features and size of IC between sides, sex, and age. The presence of IC as a constant anatomical structure (100% prevalence) in this study is consistent with the finding of a recent systematic review and meta-analysis [9], except for the foetal study (93% prevalence) by Elvan et al. [6]. A connective tissue raphe (100% prevalence) served as a distinct demarcation between the inferior part of the iliacus medially and IC laterally, similar to Ward et al.'s [23] findings. In the current study, a distinct fascia was consistently present separating IC from iliacus medially and rectus femoris superficially, while Elvan et al. [6] reported an 87% prevalence of this fascia. Similar to previous studies, a pre-capsular fat pad was found between gluteus minimus and IC, extending from the proximal attachment of vastus lateralis to the reflected head of rectus femoris [6, 22]. Previous findings described IC as originating in part from the inferior border of the AIIS and from the anteromedial hip capsule, and inserting "just distal to the lesser trochanter" of the femur [6, 14, 22, 23]. Ward et al. [23] approximated that IC inserted 15 mm distal to the lesser trochanter. In this study's cohort, the origin and insertion points of all IC muscles were likewise found to correspond with those described in the literature. Previous

**Table 2** Morphometry of iliocapsularis according to body sides and sex

	Length (mm): Mean $\pm$ standard deviation (range)			Width (mm): Mean $\pm$ standard deviation (range)		
Left	117.2 $\pm$ 10.3 (98.7–145.1)			12.8 $\pm$ 2.9 (9.1–21.2)		
Right	116.5 $\pm$ 12.1 (95.6–142.3)			12.7 $\pm$ 3.3 (6.9–21.3)		
<i>p</i> Value	0.53			0.71		
Total	116.8 $\pm$ 11.2 (95.6–145.1)			12.8 $\pm$ 3.1 (6.9–21.3)		
	Left	Right	Total	Left	Right	Total
Male	119.6 $\pm$ 9.9 (100.5–145.1)	118.7 $\pm$ 11.0 (99.2–141.5)	119.2 $\pm$ 10.3 (99.2–145.1)	13.0 $\pm$ 3.1 (9.1–21.2)	13.0 $\pm$ 3.6 (6.9–21.3)	13.0 $\pm$ 3.3 (6.9–21.3)
Female	112.4 $\pm$ 9.8 (98.7–131.9)	112.4 $\pm$ 13.6 (95.6–142.3)	112.4 $\pm$ 11.6 (95.6–142.3)	12.4 $\pm$ 2.4 (9.5–16.8)	12.2 $\pm$ 2.8 (8.7–16.7)	12.3 $\pm$ 2.5 (8.7–16.8)
<i>p</i> Value	<b>0.04</b>	0.13	–	0.55	0.47	–
<i>p</i> Value: BMI adjusted	0.18	0.93	–	0.62	0.15	–

BMI body mass index; Bold values indicate statistical significance; –Total measurements were not compared statistically

literature reported the fibre direction of IC to run from “ante-lateral proximally to posteromedial distally just below the lesser trochanter” [23]. However, since IC is located entirely on the anterior aspect of the hip capsule, the present study reported the fibre direction from superolateral to inferomedial ( $n = 76$ ). The arterial supply of IC has been investigated previously in only two hip specimens with latex injection [23], which was reported as being supplied by branches from the lateral circumflex femoral and deep femoral arteries. The present study corroborates this finding and additionally observed the apparent venous drainage from the lateral circumflex femoral and deep femoral veins in all cases. The apparent innervation of IC was from a thin branch of the femoral nerve which penetrated iliacus and emerged between iliacus and IC to supply the muscle. Elvan et al. [6] similarly reported the innervation of IC to be from a thin branch of the femoral nerve which pierced iliacus and coursed on the superficial surface of IC.

The systematic review and meta-analysis [9] revealed that only three previous adult studies investigated the width [1, 8, 23], while only one measured the length [23]

of IC (Table 3). Ward et al. [23] reported the range of the length (120–130 mm) and width (18–25 mm) of IC in fresh cadaveric hips. Haefeli et al. [8] (magnetic resonance (MR) arthrography imaging) utilised the same pathologic hips as Babst et al. [1] (MR arthrography imaging) as well as a group of non-pathologic hips. The average width of IC in the non-pathologic hips was reported to be  $20.5 \pm 4.8$  mm [8]. In the current study, the mean length ( $116.8 \pm 11.2$  mm; range 95.6–145.1 mm) and width ( $12.8 \pm 3.1$  mm; range 6.9–21.3 mm) of IC (Table 2) was smaller when compared to previous findings [1, 8, 23] (Table 3). Possible reasons for the smaller dimensions of IC may be due to populations differences between geographical and economical regions as this cohort was South African and largely underweight according to the World Health Organisation [24] (mean BMI  $16.9 \pm 4.8$  kg/m<sup>2</sup>), while the previous studies utilised European populations of unknown BMI [1, 8, 23]. Additionally, each study used different modalities, such as fresh adult cadaveric hips [23], MR arthrography images of living patients [1, 8], and formalin-fixed adult bodies (current study). However, as IC was fixed whilst intact on the skeleton,

**Table 3** Dimensions of the iliocapsularis muscle from the current study and previous studies

Author	Current study	Ward et al. [25]	Babst et al. [1]	Haefeli et al. [9]
Type of study; sample size	Cadaveric (formalin fixed); 76 lower limbs	Cadaveric (fresh frozen); 20 hips <sup>†</sup>	Magnetic resonance arthrography; 85 hips (45 dysplastic hips and 40 excessive acetabular coverage hips)	Magnetic resonance arthrography; 115 hips (45 dysplastic hips, 40 excessive acetabular coverage hips and 30 non-pathologic hips)
Demographics: % male, mean age $\pm$ standard deviation (years)	66%, $44.9 \pm 14.0$	25%, <sup>‡</sup>	Dysplastic hips: 45%, $34 \pm 9.7$ Excessive coverage hips: 31%, $33 \pm 11$	Dysplastic hips: 45%, $34 \pm 10$ Excessive coverage hips: 31%, $33 \pm 11$ Non-pathologic hips: 50%, $54 \pm 12$
Landmarks used	Length: from inferior border of AIIS* to 20 mm distal to lesser trochanter Width: 40 mm inferior to AIIS*	Length: from AIIS* to 15 mm distal to lesser trochanter Width: 40 mm inferior to AIIS*	Width: Location A: 40 mm inferior to AIIS* Location B: First section inferior to femoral head	Width: Level of the femoral head centre
Length (mm): Mean $\pm$ standard deviation (range)	$116.8 \pm 11.2$ (95.6–145.1)	# (120–130)	–	–
Width (mm): Mean $\pm$ standard deviation (range)	$12.8 \pm 3.1$ (6.9–21.3)	# (18–25)	Location A: Dysplastic hips: $27 \pm 6$ (17–40) Excessive coverage hips: $20 \pm 5$ (9–39) Location B: Dysplastic hips: $26 \pm 5$ (17–37) Excessive coverage hips: $22 \pm 5$ (11–31)	Dysplastic hips: $23.4 \pm 5.7$ (13.6–34.3) Excessive coverage hips: $18.5 \pm 3.3$ (9.1–24.3) Non-pathologic hips: $20.5 \pm 4.8$ (11.7–32.5)

<sup>†</sup>Unknown medical history; <sup>‡</sup>Age not reported; \* Anterior inferior iliac spine (AIIS); #Mean and standard deviation not reported; –Length not reported

muscle shrinkage can be considered as non-significant [3]. Furthermore, Haefeli et al. [8] measured the width at a different reference point (level of femoral head centre) to the other studies. The previous studies did not compare the dimensions of IC with sides, sex, and age [1, 8, 23]. The present study found that IC was both longer and wider on the left side and in males (Table 2); however, no significant differences were found when the dimensions were adjusted for BMI and compared with sex. Elvan et al. [6] reported IC to be statistically wider on the right side ( $p=0.029$ ) and longer in female ( $p=0.031$ ) fetuses. However, since no cause of death was reported, their findings should be interpreted with caution as it is unknown whether developmental abnormalities were present. No relationship was found when the dimensions were compared with age in the present study (Supplement 5).

Previously, IC was termed the ilio-infratrochanteric muscle and was described as the most lateral muscle bundle of iliacus which coursed distally alongside the anterolateral border of iliacus and inserted, without any tendon, onto the anterior surface of the lesser trochanter and infratrochanteric area [7, 18]. Therefore, possibly due to the close proximity of these muscles, IC was considered to be a constant muscle bundle of iliacus [7, 18]. However, the prevalence (100%), the presence of a distinct fascia separating IC from iliacus medially and rectus femoris superficially, a connective tissue raphe serving as a distinct demarcation between IC and iliacus, and the separate muscle origin and insertion points, which were observed in all bodies in this study, may suggest that IC is an anatomically distinct muscle from iliacus. Nevertheless, further studies are required to confirm whether the biomechanical function of IC is different from that of iliacus. The anatomical knowledge and implications of IC as a distinct muscle may be clinically significant in various orthopaedic procedures, the most relevant being the DAA for THA. In this approach, the lateral border of IC is used as a landmark and retracted medially from the capsule to obtain the largest possible area of the anterior articular capsule to perform the procedure [25]. Following the disruption of IC from the hip capsule, the muscle is not sutured or reattached to the capsule. The practice of disrupting IC from the hip capsule likely arose as IC was considered to be an insignificant muscle. However, Lawrenson et al. [10–12] recently suggested that IC functions to reduce capsular impingement during walking and hip flexion. Thus, the effect of IC detachment on the recovery and rehabilitation of hip function after surgery is currently not known. Iliocapsularis can also be visualised using various clinical imaging modalities, although there may be difficulty in distinguishing it from iliacus [9]. Magnetic resonance imaging can supplement the diagnosis of patients with borderline hip dysplasia or FAI by assessing the size of IC and comparing it to adjacent structures. For instance, IC was found to be atrophied in FAI due to excessive acetabular coverage and hypertrophied in dysplastic hips, which was

suggested as compensation to stabilise the hip [1, 8]. Thus, knowledge of the anatomical features of IC may assist orthopaedic surgeons to plan procedures, obtain adequate surgical exposure, and reduce unnecessary tissue trauma.

There are several limitations of this study. The sample comprised an unequal proportion of males ( $n=25$ ) and females ( $n=13$ ) and small unequal sub-sample sizes when divided by age, thus caution should be taken when interpreting results. The blood vessels were not injected with latex which may have further assisted with identifying the blood supply, and there is no data on nerve function. Due to the time constraints imposed by the COVID-19 lockdown, the surrounding musculature of the lower limb could not be dissected to increase the accuracy of the insertion distance measurement. Likewise, only one measurement was taken for the intra- and inter-reliability tests. However, the entire cohort was remeasured to assist in confirming the original measurements' reliability. The height could only be measured in a subset of bodies ( $n=19$ ) as the calvaria were removed. Therefore, the dimensions were only adjusted using the subset BMI calculation. Previous literature has shown discrepancies in the weight and height measurements taken in deceased and living individuals due to various antemortem (wasting diseases) and post-mortem (decomposition process) factors [2, 13, 19, 21]. Currently, there is no consensus on a correction factor has been reported yet; therefore, the exact weight and height measurements were reported in this study. Furthermore, as the height was measured in embalmed cadavers, variability and errors in the measuring may have been introduced due to the rigidity of the bodies from the embalming process. Lastly, the smaller dimensions of IC may have been due to the largely underweight cohort (mean BMI  $16.9 \pm 4.8$  kg/m<sup>2</sup>).

Future studies of unembalmed bodies with a sample of equal male and female proportions and equal age groups should be performed to confirm this study's findings. Additionally, the musculature surrounding IC should be dissected to determine the exact insertion distal to the lesser trochanter. Future research is needed to investigate the true biomechanical and anatomical function of IC to help determine its implication for hip function, which could assist rehabilitation specialists with patient recovery following surgery and determine whether IC is impaired following disruption of the muscle during surgery.

This study confirms previous findings regarding the prevalence, muscular attachments, and arterial blood supply. Iliocapsularis was innervated by a thin branch from the femoral nerve and drained from branches of the lateral circumflex femoral and deep femoral veins. Muscle fibre direction was from superolateral to inferomedial. The presence of a connective tissue raphe, distinct fascia, and separate muscle origin and insertion points strongly suggest IC is a constant, well-defined muscle that is anatomically

distinct from iliacus. Although the mean dimensions of IC in this study were smaller compared to previous findings, the range of the measurements were similar to that previously reported. Thus, this research provides information about this overlooked muscle which is relevant to orthopaedic surgeons in the surgical exposure of the anteromedial hip capsule, to physical rehabilitation specialists for postoperative patient care following surgical intervention, and to anatomists for future research projects.

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**Author contributions** KDMD: Acquisition, analysis, and interpretation of data for the work; manuscript writing and editing; and final approval of the version to be submitted to the journal. RGV: Revising the work critically for important intellectual content; and final approval of the version to be published. BJB: Revising the work critically for important intellectual content; and final approval of the version to be published. PAP: Final approval of the version to be submitted to the journal. BMH: Final approval of the version to be submitted to the journal. KK: Conception and design of the work; manuscript writing and editing; revising it critically for important intellectual content; and final approval of the version to be published.

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**Data availability** Not applicable.

**Code availability** Not applicable.

## Declarations

**Conflict of interest** Authors have no conflicts of interest to declare that are relevant to the content of this article.

**Ethical approval** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Stellenbosch University (U20/02/060, 08/04/2020).

**Consent to participate and for publication** Written consent was obtained from the donors and proxy consent was given by the Inspector of Anatomy for the unclaimed bodies.

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