Received: 16 November 2022 | Accepted: 1 December 2022
DOI: 10.1002/ca.23988

COMMUNICATION

CLINICAL ANATOMY WILEY

Gross anatomical study of the subcutaneous structures that create the three-dimensional shape of the buttocks

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Abstract

The purpose of this study was to clarify the subcutaneous structures involved in the morphology of the gluteal region for clinical application. Thirty-seven formalin-fixed cadavers and one soft-fixed cadaver were used in this study. Gluteal tissue was removed from five formalin-fixed cadavers. A horizontal section and sections parallel to the long axis of the body were made from the excised tissue, and the subcutaneous fat was removed to observe the fibrous structure within the subcutaneous fat. Two formalin-fixed cadavers and one soft-fixed cadaver were used to perform conventional gross anatomical dissection and histological examination. On 30 formalin-fixed cadavers, the thickness of the subcutaneous fat was measured in various areas of the buttocks. The thickness of subcutaneous fat was thicker in the center of the buttocks and thinner on the lateral buttocks. Superficial fascia (SF) was found only in the upper buttock, being indistinct in the lower buttock. In the sacral and coccygeal areas, the dermis was tightly adhered to the bone as a single mass. Fibers arose from around the iliac crest to the SF. On the medial side of the gluteal fold, a strong fiber arose from the sciatic tubercle and inserted into the gluteus maximus and dermis. By identifying the characteristic subcutaneous structures of the gluteal region, we were able to identify the anatomical structures that shape the three-dimensional morphology of the buttocks. These findings may be useful in surgical treatments such as improving the buttock shape.

KEYWORDS

anatomical, superficial fascia, buttock shape, deep fat, gluteal fascia, gluteal fold, ischio-cutaneous ligament, stretched tissue dissection method, subcutaneous fat, superficial fascia, superficial fat, surgical superficial fascia

1 | INTRODUCTION

The buttock is one of the most complex three-dimensional shapes in the human body, and various factors, including the skin, subcutaneous fat, muscle thickness, and shape of the skeleton, are thought to influence its shape. The buttock is one of the most important areas in terms of body shape, and many studies have investigated the morphology of the ideal buttock (Wong et al., 2016). Furthermore, humans are the only animals that walk bipedally and can perform activities in a standing position. Therefore the skin, subcutaneous tissue, and other surface structures of the buttocks are affected by gravity, which leads to age-related changes in buttock morphology

(Cuenca-Guerra & Lugo-Beltran, 2006; Cuenca-Guerra & Quezada, 2004). However, despite many morphological studies, there have been few anatomical studies of the structure of the subcutaneous tissue of the buttocks, and it is not known how the various structures in this tissue are involved in the shape of the buttocks or gravity-induced and age-related changes. In general, the structure that directly supports the skin and has the most influence on the morphology of the external surface of the buttocks is the subcutaneous fat, and elucidating the structure of the fibers distributed therein would be useful for elucidating the three-dimensional shape of the buttocks.

We have used the stretched tissue dissection (STD) method (Hashiguchi et al., 2022; Watanabe et al., 2022), in addition to conventional gross anatomical dissection and histological examination, to clarify these structures. The advantage of the STD method is that only fibrous structures remain in the subcutaneous fat, allowing observation of fibers running in three dimensions and clarification of the relationship between the deep tissues such as the deep fascia (DF) and periosteum, and the superficial structures including the superficial fascia (SF) and dermis. For this reason, we have applied this technique to the buttocks.

The purpose of this study was to perform an anatomical study of the gluteal region with particular focus on the subcutaneous structures to determine the influence of these structures on the shape of the buttocks and improve the results of cosmetic surgery in the gluteal region.

2 | MATERIALS AND METHODS

A research plan for this study was submitted to and approved by the Kurume University Ethics Committee (approval number 21164).

The gluteal region on one side each of 37 formalin-fixed cadavers (23 male, 14 female; mean age 73.2 years [range 60–90] at the time of death) were used in the study. Two of the specimens were used for conventional gross anatomical dissection, five for the use of STD methods, and 30 for measurement of the thickness of subcutaneous fat in the buttocks. One side of one cadaver (male, aged 73 years at death) that was soft-fixed with *N*-vinylpyrrolidone solution was also used for the conventional gross anatomical dissection (Haizuka et al., 2018).

The buttocks were dissected in two different ways: (1) a gross anatomical dissection using the usual technique of layer-by-layer dissection from the superficial to deep layers; and (2) a dissection performed on sections prepared using the STD method.

2.1 | Gross dissection using the layer-by-layer conventional technique

We performed conventional layer-by-layer gross dissection on the buttocks of two formalin-fixed cadavers and one soft-fixed cadaver. The area of dissection was cephalad to 10 cm cranial to the iliac crest, caudal to 10 cm caudal to the gluteal fold (GF) in the thigh, medial to the midline, and lateral to the mid-axillary line. First, the skin was exfoliated and elevated just below the dermis, where the subcutaneous fat was observed. Next, the relationship between the gluteal fascia and fibrous septa within the subcutaneous fat was assessed while carefully removing the subcutaneous fat over the gluteal fascia. The gluteal fascia was then removed and the gluteus maximus, gluteus medius, and iliotibial ligament were dissected to confirm the relationship between the gluteus maximus muscle and the surrounding fibers. Finally, the gluteus maximus was cut at the center of the muscle to confirm the fibrous tissue extending from the sciatic tubercle to the dermis.

In two formalin-fixed cadavers, the connective tissue extending from the sciatic tuberosity was sampled after the dissection. The tissues were paraffin-embedded after degreasing and decalcification, sectioned at 5 μm, and stained by hematoxylin & eosin and Masson trichrome staining methods for verification of gross anatomical findings.

2.2 | Dissection using the STD method

The following soft tissues, including some of the bones constituting the pelvis, were removed from five sides of five formalin-fixed cadavers: the lumbar region 10 cm cephalad from the iliac crest on the cephalic side, the thigh 10 cm caudal from the GF on the caudal side, the midline on the medial side, and the mid-axillary line on the lateral side. The excised tissue was then frozen in a freezer at 0°C for 24 h and cut with a diamond band saw (ZW-BS type 1; Zek-tech, Osaka, Japan) to create sections 1.5 cm wide.

Horizontal sections were made on two sides. However, on the lower part of the buttock, the angle was changed gradually so that the section was perpendicular to the skin surface in relation to the roundness of the skin (Figure 1A). On the other three sides, cross-sections were made parallel to the long axis of the trunk. In this way, the

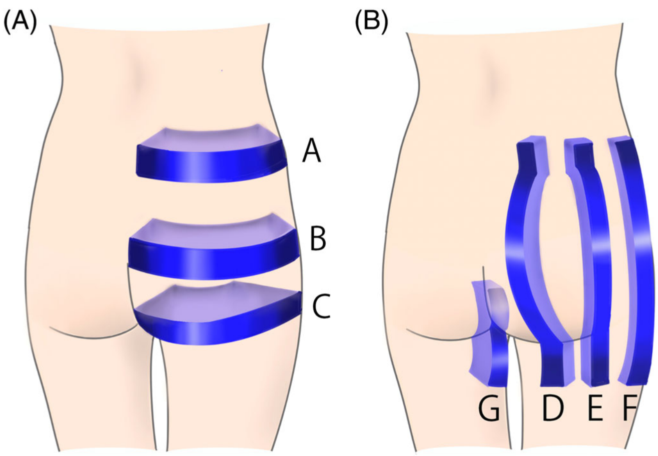


FIGURE 1 Sections of the STD method presented in the figures. a. Horizontal section. A: Section of the lumber region (at the level of L3-4 intervertebral disc). B: Section of the middle of the buttock (at the level of middle of the secrum). C. Section of the gluteal fold. In this region, the section is oblique with the deep part slightly cephalad to be perpendicular to the skin surface. b. Sections parallel to the body axis. D. Sagittal section in the center of the buttock. E. Oblique section of the lateral buttock. F: Frontal section on the mid-axillary line. G. Frontal section of the medial thigh and the perineum.

sections were made so that they were sectioned in the frontal plane on the medial side of the perineum and medial thigh region, sectioned in the sagittal plane on the posterior side and angled so that they were perpendicular to the skin surface as they moved laterally, and sectioned in the frontal plane again on the mid-axillary line (Figure 1B). The prepared sections were first immersed in aqueous eosin solution (about 0.1 g of eosin per 500 ml of distilled water) for approximately 24 h to stain the muscles red, thereby giving contrast to the sections. The sections were then placed on a black rubber board, pinned to the bony parts, and sutured with 4–0 nylon threads applied to the skin at 1.5-cm to 2-cm intervals before being extended and fixed outward. The subcutaneous fat was removed under an operating microscope to observe the subcutaneous fibrous structure.

2.3 | Measurement of the thickness of subcutaneous fat

Using one side each of the 30 cadavers, the thickness of the subcutaneous fat was measured in each area of the buttocks (Figure 2). Thickness measurements of subcutaneous fat at the center of the buttocks were taken on the scapular line (a sagittal line passing through the inferior pole of the scapula), and thickness measurements of subcutaneous fat on the lateral side of the buttocks were taken on the mid-axillary line.

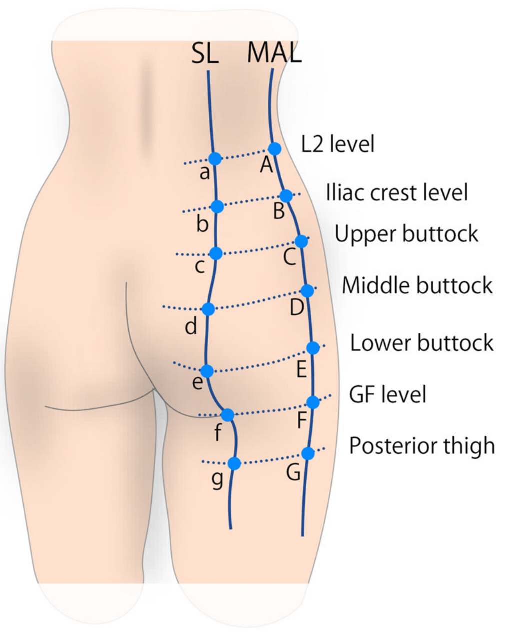


FIGURE 2 Points where the thickness of subcutaneous fat was measured. Subcutaneous fat thickness was measured on the scapular line (SL) and mid-axillary line (MAL). The height of the measurement site was determined at seven points: the second lumbar vertebra (L2 level: a, A), the height where the SL intersects the iliac crest (Iliac crest level: b, B), the height of the upper quarter of the distance between the iliac crest and GF on the SL (Upper buttock: c, C), the midpoint between the iliac crest and GF (Middle buttock: d, D), the height of the lower quarter between the iliac crest and GF (Lower buttock: e, E), the height where the SL and GF meets (GF level: f, F), and the height 5 cm caudal to the GF (Posterior thigh: g, G).

The measurement points were defined as the height of the second lumbar vertebra, the intersection of the scapular line and the iliac crest, the upper one-quarter point between the iliac crest and the GF, the midpoint between the iliac crest and the GF, the lower one-quarter point between the iliac crest and the GF, the intersection of the scapular line and the GF, and the height of the posterior thigh 5 cm caudal to the GF. The points at which the aforementioned seven points intersected the scapular line were designated as points *a–g* from the cephalad side, and the points where they intersected the mid-axillary line were designated as points A to G from the cephalad side. The length from the skin surface to the DF was measured three times with a caliper with an accuracy of 0.05 mm, and the average value was used as the measurement value. Statistical processing of the data was performed for the points on each of the scapular and mid-axillary lines. One-way analysis of variance (ANOVA) was used to compare means among points in each group. Post hoc analyses were performed with the least significant difference test when the F ratio for the ANOVA was significant at $p < 0.05$.

3 | RESULTS

3.1 | Gross anatomical findings using the usual layer-by-layer technique

Very little subcutaneous fat was observed above the sacrum. Although just above the iliac crest the subcutaneous fat was relatively thin, it then increased in thickness toward the GF (Figure 3 A). In the thigh caudal to the GF, the subcutaneous fat over the fascia femoris was thinner than that directly above the GF. The subcutaneous fat also became thinner toward the lateral side of the body. Deeper than the gluteus maximus muscle, connective tissue arising from the sciatic tubercle at the medial part of the GF was attached to the gluteal fascia and inserted into the dermis cephalad of the GF (Figure 3 B). No fibrous structures anchoring the skin to create the groove could be observed except the most medial part of the GF.

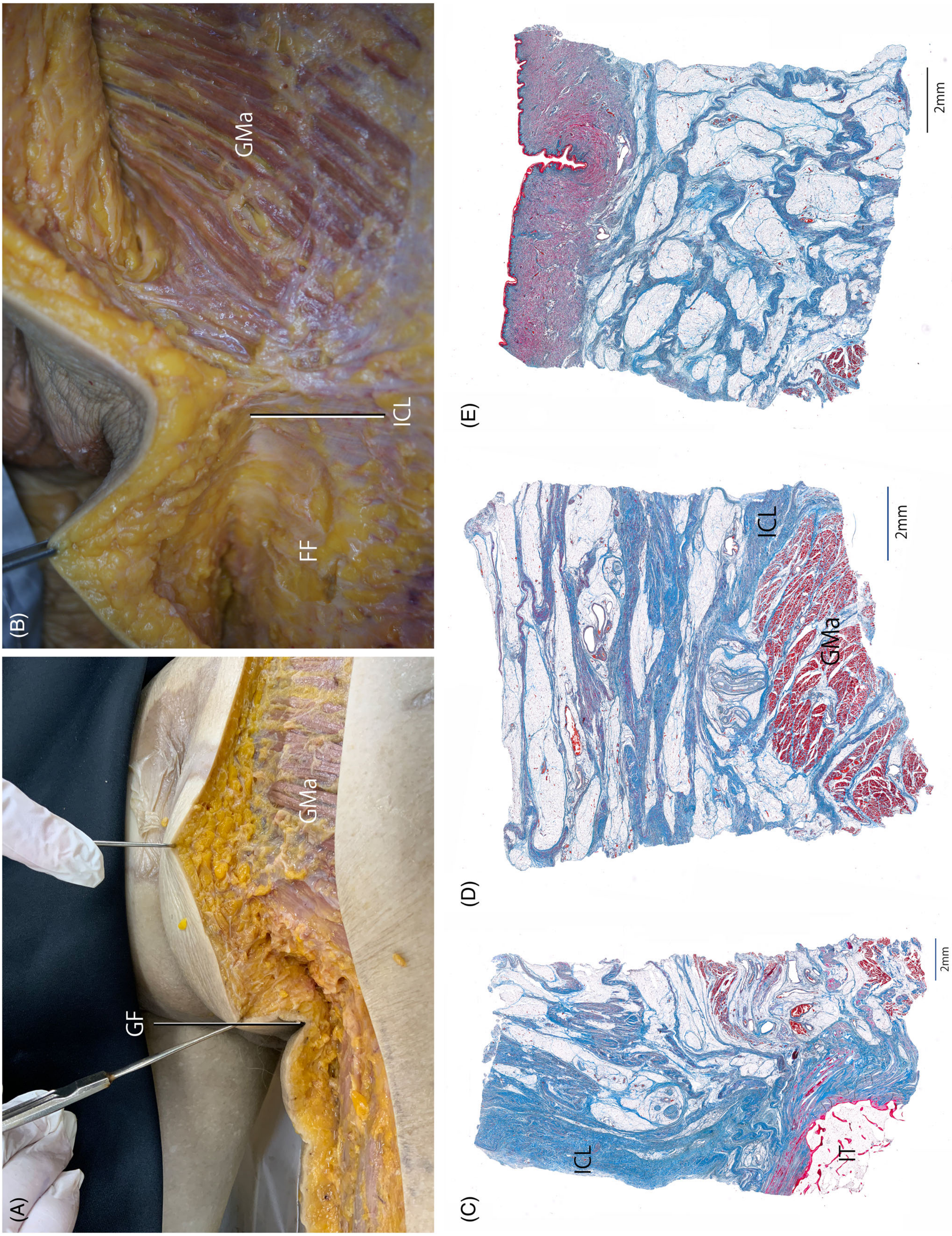
3.2 | Histological examination

Thick connective tissue arose from the bone (ischial tuberosity) (Figure 3 C) and covered the gluteal maximus muscle before continuing to the gluteal fascia (Figure 3 D). The septa surrounding each fat lobule were thick just below the dermis (Figure 3 E).

3.3 | Anatomical findings using the STD method

3.3.1 | Horizontal section of the lumbar region (L3–L4 level)

This is the horizontal section of the lumber region corresponding to section A in Figure 1 (Figure 4A, B). Within the subcutaneous fat,



(A)
GF
GMa
(B)
FF
ICL
GMa
(C)
ICL
IT
2mm
(D)
GMa
ICL
2mm
(E)
2mm

FIGURE 3 Gross anatomical findings and histological findings. FF, fascia femoris; GF, gluteal fold; GMa, gluteal maximus; ICU, ischio-cutaneous ligament. A. Gross anatomy of the right hip. In this dissection, the skin was incised near the middle of the buttock and the subcutaneous fat was excised over the gluteal fascia to show the thickness of the skin. B. Gross anatomical findings near the medial inferior border of the right gluteus maximus muscle. Connective tissue extending from the ischial tuberosity terminates in the fascia of the medial inferior border of the gluteus maximus muscle and dermis. C. Histological finding of ICL (Masson Trichrome stain)(x40). IT: ischial tuberosity; ICL; ischio-cutaneous ligament. Thick connective tissue (ICL) arises from the ischial tuberosity (IT). D. Histological finding of ICL (Masson Trichrome stain) (x40). GMa, gluteus maximus; ICL, ischio-cutaneous ligament. Thick connective tissue (ICL) covers the gluteus maximus (GMa). E. Histological finding of ICL (Masson Trichrome stain) (x40). Mesh-like thick fibers insert the dermis

there was SF extending continuously from the contralateral side to the lateral abdomen beyond the midline, and the shape of the fat was clearly different between the superficial and deep layers separated by SF. Although both layers of fat had septa, the superficial layer was composed of a smaller size of fat lobule surrounded by fibers, while the deep layer was composed of relatively larger fat lobules (Figure 4 A).

The subcutaneous fat layers, both superficial and deep, were thicker and multilayered in the lateral region of the back, and their thickness decreased toward the midline and lateral abdomen. In particular, the full thickness of the subcutaneous fat decreased near the midline of the back. In this region the superficial fat became a single layer, the size of the fat lobules decreased, the dermis and SF came closer together, and the deep fat almost disappeared, with the SF and DF connected by connective tissue. However, the space between the SF and the thoracolumbar fascia was enlarged by skin traction when using the STD method. This indicates that the space between the SF and thoracolumbar fascia is mobile (Figure 4 B).

3.3.2 | Horizontal section of the middle gluteal region

This is the horizontal section of the middle gluteal region corresponding to section B in Figure 1 (Figure 5A, B). In the middle buttock, SF was present just as in the lumbar region, dividing the subcutaneous fat into superficial and deep layers. However, compared with the lumbar region, the deep fat was thin and confined to the lateral part of the buttock. There was almost no deep fat on the medial side of the buttock, and the SF was almost in contact with the gluteal fascia near the origin of the gluteus maximus muscle. The thickness of the superficial fat was also reduced in this area (Figure 5A, B).

In the subcutaneous tissue just over the sacrum and coccyx, there was less subcutaneous fat, and the dermis, SF, and periosteum were firmly attached to the bone in one lumped layer, with no stretch as a result of skin traction (Figure 5B).

3.3.3 | Oblique section of the GF area in the lower buttock

This is the oblique section of the GF area in the lower buttock corresponding to section C in Figure 1 (Figure 6A, B). This section is an oblique cross-section slightly cephalic toward deep to the horizontal. In contrast to the subcutaneous fat of the lumbar region and the middle buttock, there was no clear SF within the subcutaneous fat, which consisted entirely of a superficial layer of fat with honeycomb-like septa. Medially, fibers originating from the ischial tuberosity, namely the ischio-cutaneous ligament (ICL), passed through the medial inferior end of the gluteal muscle and inserted into the gluteal fascia and dermis just cranial to the GF (Figure 6 A, B).

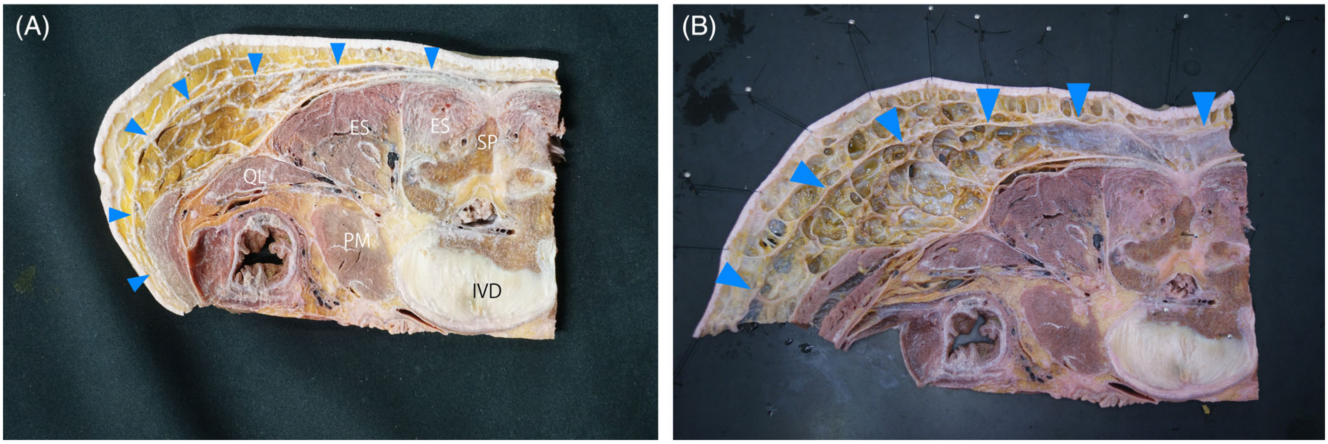


FIGURE 4 L3-4 horizontal section of the lumber region (at the level of L3-4 intervertebral disc). ES, erector spinae; IVD, intervertebral disc; PM, psoas major; QL, quadratus lumborum; SP, spinous process. SF is indicated by blue arrow heads. A. Before STD method. In the lumber region, the subcutaneous fat has a two-layer structure consisting of different size of fat lobules divided by SF. The subcutaneous fat is thin on medial and lateral sidest. B. After STD method. Around the midline, the deep fat disappears, and SF and thoracolumbar fascia are connected by the connective tissue. However these connection is stretched by STD method, indicating that the connection is mobile.

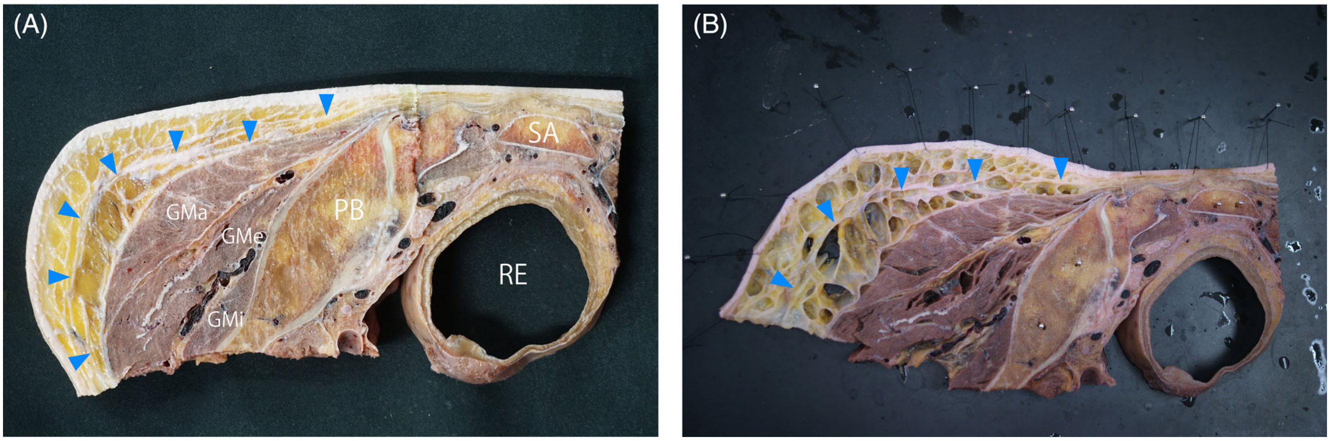


FIGURE 5 Section of the middle of the buttock (at the level of middle of the secrum). GMa, gluteus maximus; GMe, gluteus medius; GMi, gluteus minimus; PB, pelvic bone; RE, rectum; SA, sactum. SF is indicated by blue arrowheads. A. Before STD method. The deep fat is thinner than in the lumber region and localized to the lateral buttock. B. After STD method. On the sacrum, the dermis is rigidly adhered to the periosteum, and no extension is seen by traction.

3.3.4 | Sagittal section of the center of the gluteal region

A sagittal section of the center of the gluteal region is shown in section D of Figure 1 (Figure 7A, B). Although SF was clearly observed in the lumbar region to the upper buttock, it became obscured toward the lower buttock. Deep fat was well developed in the lumbar region over the iliac crest and the gluteus medius muscle, whereas little was seen over the gluteus maximus muscle (Figure 7A). Unlike in the abdomen and other regions, the deep fat had septal walls. In the region from the iliac crest to the gluteus medius muscle, fibers extended from the periosteum of the iliac crest and gluteal fascia to the SF, and large fat lobules were observed.

From the lower buttock to the posterior thigh, the subcutaneous fat had honeycomb-like fibrous septa, and no fibrous structure anchoring the skin from the deep layer to form a groove was observed in this section (Figure 7 B).

3.3.5 | Oblique section of the lateral aspect of the buttock

This is the oblique section of the lateral aspect of the buttock indicated as section E in Figure 1 (Figure 8 A, B). SF was attached to the iliac crest and was clearly observed in the upper buttock on the gluteus medius and upper part of the gluteus maximus, but became indistinct toward the lower buttock (Figure 8A). The deep fat on the gluteus medius and upper part of the gluteus maximus was a lump of fat without fibrous septa. As in section D, no tissue was found just under the GF that pulled the skin from the deep fat (Figure 8 B).

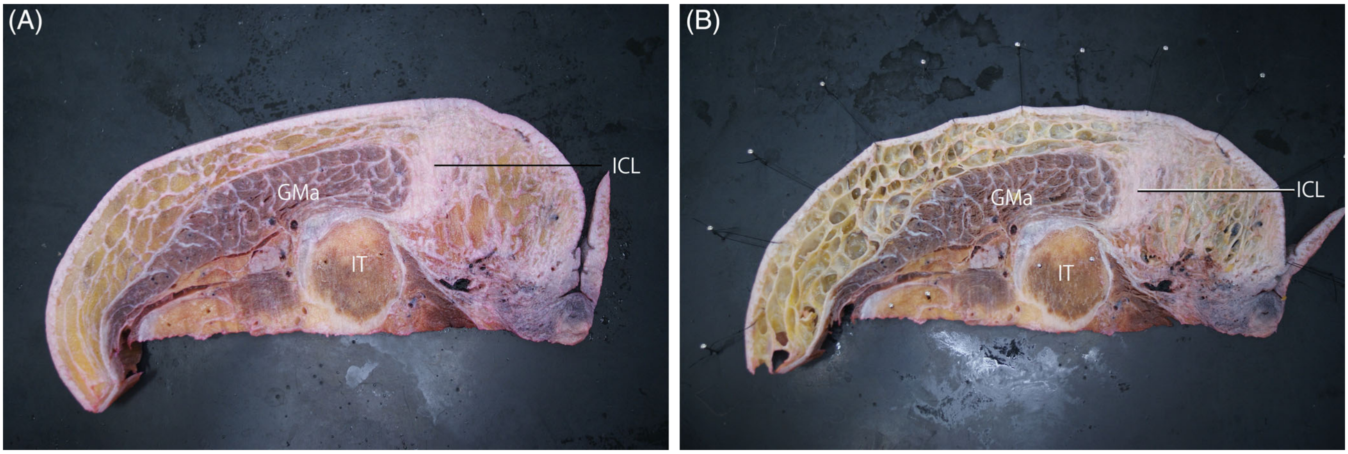


FIGURE 6 Section of the gluteal fold. In this region, the section is oblique with the deep part slightly cephalad to be perpendicular to the skin surface. GMa: gluteus maximus, ICL: ischio-cutaneous ligament, IT: ischial tuberosity. A. Before the STD method, connective tissue arises from the ischial tuberosity (IT) and inserts to the gluteal fascia at inferior-medial border of the gluteus maximus (GMa) and dermis. There is no SF in this region. B. After the STD method, ICL is not stretched by traction, thus gluteal fascia and dermis are anchored strongly by ICL.

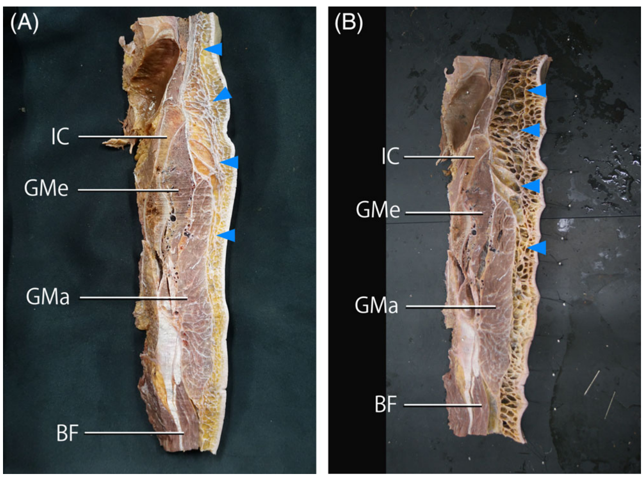


FIGURE 7 Sagittal section of the center of the buttock. BF, biceps femoris; GMa, gluteus maximus; GMe, gluteus medius; IC, iliac crest. SF is indicated by blue arrowheads. A. Before the STD method. SF is present on the iliac crest (IC) and gluteus medius (GMe), but is obscured on the gluteus maximus (GMa). The deep fat on the IC and GMe is single layer and each lobule is big in size. B. After the STD method. Linear septa extending from the iliac crest and gluteus medius to SF is observed.

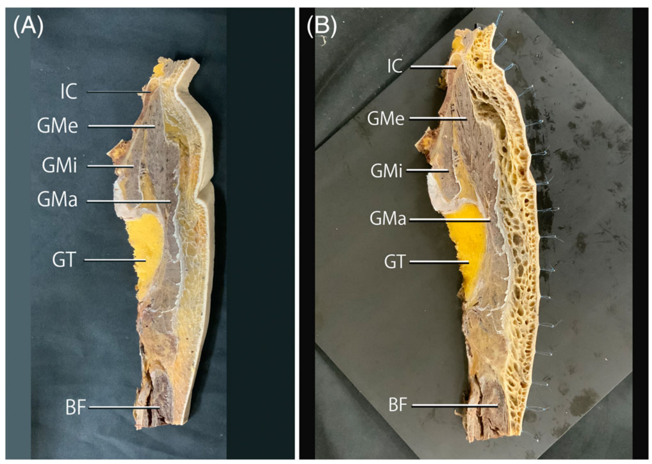


FIGURE 8 Oblique section of the lateral buttock. BF: biceps femoris, GMa: gluteus maximus, GMe: gluteus medius, GMi: gluteus minimus, GT: greater trochanter of the femur, IC: iliac crest. SF is indicated by blue arrowheads. A. Before the STD method. SF is attached to the iliac crest (IC). SF is observed on the gluteus medius (GMe) and upper part of the gluteus maximus (GMa), but is obscured in the lower buttock. B. After the STD method. A space on the gluteus medius (GMe) and upper part of the gluteus maximus (GMa) indicates a single large fat lobule without septa.

3.3.6 | Frontal section on the mid-axillary line of the gluteal region (Figure 9A, B)

This is the frontal section of the gluteal region on the mid-axillary line corresponding to section F in Figure 1. The subcutaneous fat is thin in the entire section. SF was observed from the lateral abdomen to around the greater trochanter of the femur, but was obscured caudally from the point (Figure 9 A). Some fibers arose from the iliac crest and inserted into SF. The subcutaneous fat in the lateral thigh was composed entirely of fat with superficial fat-like septa. The deep fat was composed of large granular fat lobules without septa cephalad to the iliac crest, and from the iliac crest to the greater trochanter was composed of fat with septal walls, with each lobule being larger than that of the superficial fat (Figure 9 B).

3.3.7 | Frontal section of the medial thigh and the perineum

This is a frontal section of the medial thigh and the perineum corresponding to section G of Figure 1 (Figure 10 A, B). The ICL, a thick

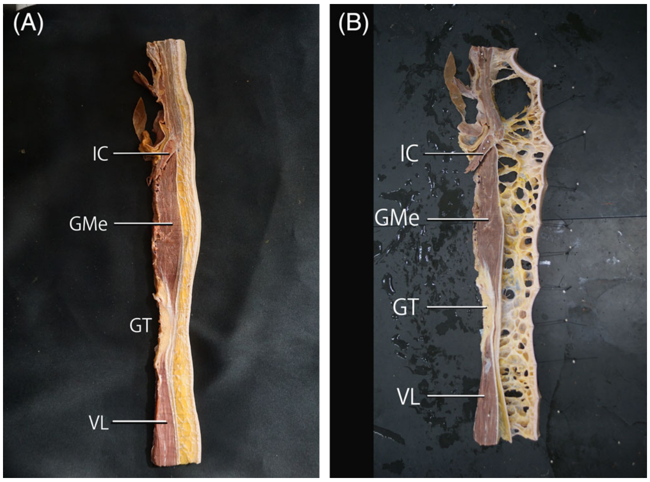


FIGURE 9 Frontal section on the mid-axillary line. GMe, gluteus medius; GT, greater trochanter of the femur; IC, iliac crest; VL, vastus lateralis. SF is indicated by blue arrowheads. A. Before STD method. Subcutaneous fat is generally thin; SF is visible up to near GT, but indistinct caudal to GT. B. After STD method. The subcutaneous fat is generally thin in this section, but the layer is stretched by removal of fat lobules. Fibers extending from the iliac crest (IC) to SF separate the character of the deep fat; the deep fat cephalad to IC is composed of single mass-like fat without septa, whereas that caudal to IC is composed of fat lobules with septa, each lobule of which is larger than that of the superficial layer.

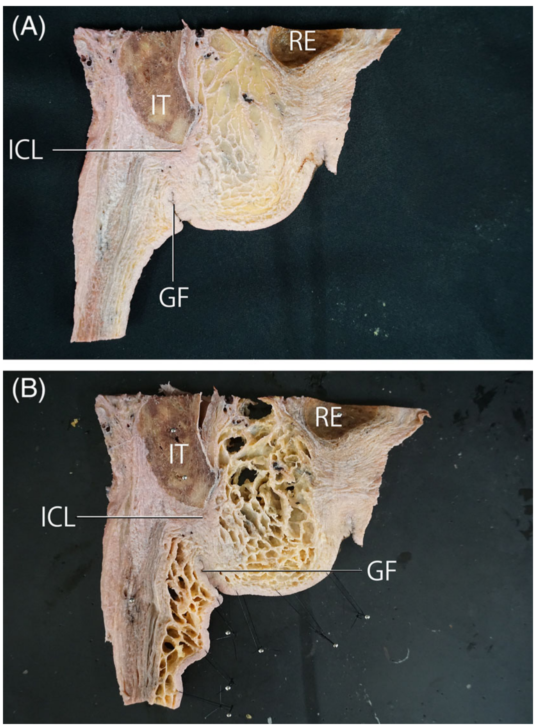


FIGURE 10 Frontal section of the medial thigh and the perineum. GF: gluteal fold, ICL: ischio-cutaneous ligament, IT: ischial tuberosity, RE: rectum. A. Before STD method. ICL connecting the ischial tuberosity (IT) and the skin just cranial to the GF is seen. B. After STD method.

connective tissue arising from the ischial tuberosity and inserting into the dermis just cranial to the GF, was observed. Within this connective tissue there was little fatty tissue, and the skin on the cephalic side of the GF was pulled strongly inward (Figure 10 A). As a result, the skin folded in and the GF was clearly formed (Figure 10 B).

3.4 | Measurement of subcutaneous fat thickness

The following measurements were obtained on the scapular line: a, 6.72 mm; b, 7.88 mm; c, 6.91 mm; d, 8.22 mm; e, 7.95 mm; f, 9.27 mm; g, 7.53 mm. On the mid-axillary line, the measurements were as follows: A, 7.41 mm; B, 7.24 mm; C, 6.81 mm; D, 6.65 mm; E, 6.59 mm; F, 6.72 mm; and G, 5.97 mm. ANOVA for points on each line, namely the scapular ($p = 0.197$) and mid-axillary ($p = 0.929$) lines, showed no significant differences (Figure 11).

4 | DISCUSSION

Subcutaneous fat is generally divided into superficial and deep layers and is bordered by SF, which is a connective tissue membrane. The superficial fat is composed of small fat lobules surrounded by septa, whereas deep fat is composed of large fat lobules without septa. To date, several studies have been performed regarding the morphology of subcutaneous fat (Abu-Hijleh et al., 2006; Illouz, 1990; Markman & Barton, 1987; Nakajima et al., 2004; Nash et al., 2004). Nakajima et al. referred to the superficial layer as the protective adipo-fascial system (PAFS) and the deep layer as the lubricant adipo-fascial system (LAFS). PAFS protects against external forces while LAFS lubricates skeletal muscle movement. However, these authors reported that in the gluteal region, the subcutaneous fat does not consist of two layers separated by PAFS and LAFS but consists of a single layer of fat with septa (Nakajima et al., 2004). Illouz (1990) similarly found no deep adipose tissue in the gluteal region. However, these were studies of whole-body subcutaneous fat morphology, and the details of the morphology of subcutaneous fat in the gluteal region were considered to be inaccurate. Therefore, few details on the subcutaneous tissue morphology of the buttocks have been reported thus far (Ghavami et al., 2018; Porto Da Rocha, 2001).

The definition of SF also differs between the anatomical and clinical fields (mainly plastic surgery), causing confusion in discussion. In the anatomical field, subcutaneous fat itself is considered to be SF (Clemente, 1985; Moore Keith, 2010) (Figure 12). However, in the field of plastic surgery the SF is considered to be the membrane that borders the superficial and deep layers of subcutaneous fat (Fede et al., 2020; Graca Neto & Graf, 2020; Lancerotto et al., 2011). For the sake of convenience in this work, we define SF in the anatomical field as anatomical SF, and SF in the clinical field as surgical SF. In this article, therefore, SF represents the surgical SF (Figure 12).

In this study, SF was clearly observed in the upper gluteal region, but it became more difficult to distinguish from the honeycombed

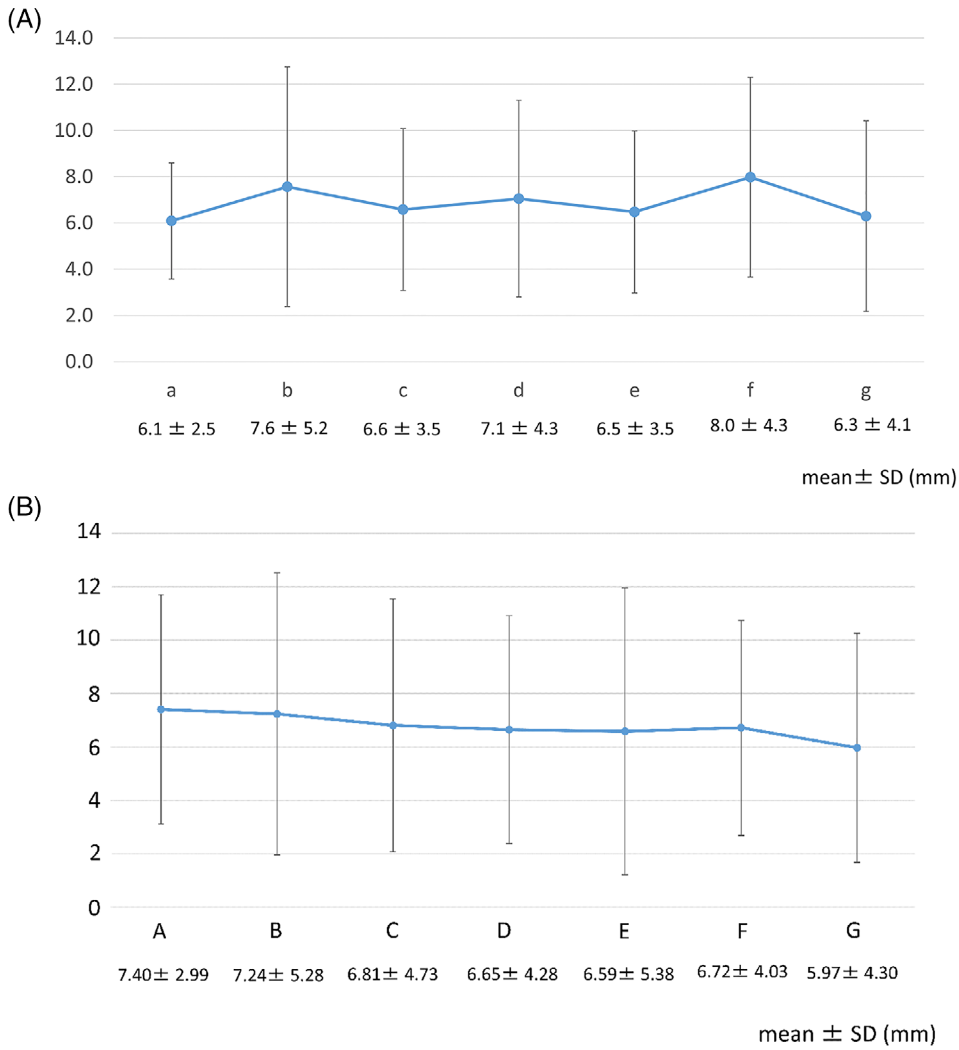


FIGURE 11 The result of the measurement of the subcutaneous thickness of the buttock. A. Measurement data on the SL. B. Measurement data on the mid-axillary line

septa surrounding the fat lobule toward the caudal side and disappeared in the lower gluteal region. Furthermore, although in the upper buttock there were septa in both the superficial and deep fat, which differed significantly from typical deep fat without septa, the lower buttock did not contain SF and consisted entirely of fat with septal walls (Figure 12). The fact that the deep fat also has septa and that the lower buttock consists only of fat that is considered to be the superficial fat with septa is attributed to this region being subject to weight bearing in the sitting and lying positions and therefore has a structure that is less mobile. This finding is not significantly different from those of Nakajima et al. and Illouz, and is the first concrete demonstration of the morphological characteristics of the subcutaneous fat of the buttocks and the transitional morphology of SF (Illouz, 1990; Nakajima et al., 2004). Regarding the thickness of the subcutaneous fat, all values were greater at the scapular line than at the mid-axillary line. This is consistent with the findings that the buttocks had thinner subcutaneous fat toward lateral, as confirmed by the horizontal section of the STD method. Comparison of the various points on the scapular line showed no significant difference in the thickness of subcutaneous fat. This was contrary to our expectation that the lower buttock would be thicker, but means that the major factor creating the roundness of the buttocks, especially the lower part, is not the change in thickness of the subcutaneous fat but the thickness of the gluteal muscles. Furthermore, it indicates that the skin depressions that form the GF are already absent on the scapular line. Clinically, our findings that the subcutaneous fat becomes thicker toward lateral and does not change the thickness in height may be useful for harvesting the gluteal flap in plastic surgery, especially in breast reconstruction.

Ghavami et al. (2018) described the skin-supporting structures of the buttocks as being the sacrum, iliac crest, iliotibial ligament area, and ICL extending from the sciatic tubercle to the GF. We found that the soft tissue was firmly attached to the bone as a single lumpy layer of dermis to the periosteum on the sacrum and coccyx. This is in complete contrast with the lumbar region, where the SF and DF are connected by connective tissue but are mobile, suggesting that the skin of the buttock is strongly fixed in this region, as observed by Ghavami et al. The iliac crest in the lumbar region, which according to Ghavami et al. supports the skin of the buttock, is also known to be an area where a protruding bulge is observed in cases of obesity and where subcutaneous fat tends to accumulate. In our study, some fibers were observed to extend from the gluteal fascia over the iliac crest and

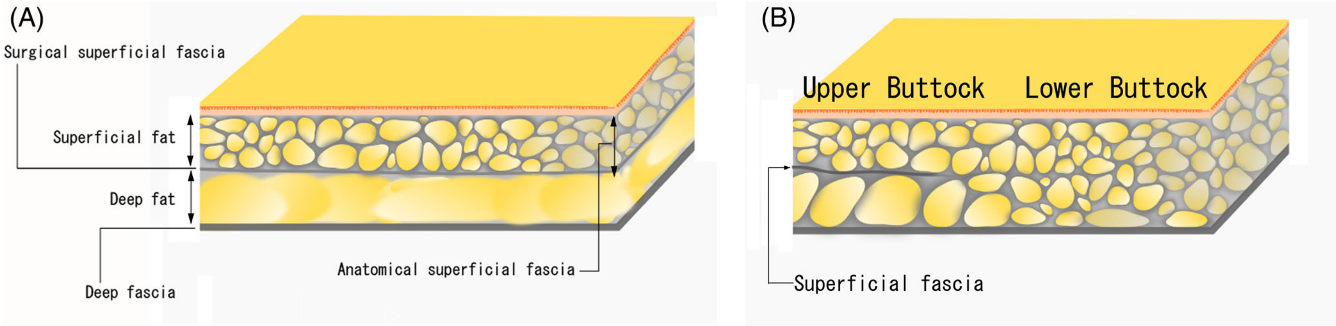


FIGURE 12 Schematic illustration of the subcutaneous fat in the buttock. A. Surgical superficial fascia and Anatomical superficial fascia. B. Difference of the subcutaneous fat in between upper and lower buttock

subsequently from the gluteus medius muscle to the SF, which is thought to support the SF. This structure is thought to cause a groove at the border between the lumbar and gluteal regions in obese individuals. Although the subcutaneous fat over the iliotibial ligament was a two-layered structure divided by the SF into superficial and deep fat, the subcutaneous fat was thinner than that at the middle of the buttock, which was thought to result in relatively less mobility. However, the subcutaneous tissue was not thought to be rigidly fixed, different from the ICL and the sacral and coccygeal regions. In the medial GF, the ICL, a thick connective tissue running from the ischial tuberosity to the gluteal fascia and the dermis cephalic to the GF, was found in the most medial part of the fold. This connective tissue, also called the ligament of Charpy or the ICL of Luschka, is considered to be shaped like a conus extending from the ischial tuberosity to the dermis with the ischial tuberosity at its apex and the dermis at its base. In contrast to the report by Ghavami et al., in our study the ICL stopped at the dermis only just above the ischial tuberosity and did not extend laterally. Above all, the possible origin of the GF arises from this ligament, first pulling the skin and gluteal muscles toward the ischial tuberosity in the medial part of the gluteus maximus, which in turn pulls the lower medial part of the gluteus maximus toward the ischial tuberosity. This causes the lower medial portion of the gluteus maximus to round out and the skin to form an indentation caudal to the ligament. This area was thought to be the most medial part of the GF, and the outer GF was considered to be an extension of this created depression because there is no ligament in the deeper layers (subcutaneous tissue) of the lateral GF to form the GF. Therefore, the fold becomes shallower as it becomes more lateral. The fold overlaps the inferior border of the gluteal muscles, and the contour of the GF is thought to follow the shape of the inferior border of the gluteus maximus. The difference between a deep GF and a shallow GF is thought to lie in whether the ligament extends straight or curves as it travels from the sciatic tubercle to the skin (Figure 13). The ICL is considered to be the most important structure in the three-dimensional morphology of the GF.

From the preceding discussion, the elements of the three-dimensional morphology of the buttocks can be summarized as follows. The subcutaneous fat is almost absent near the midline, thicker in the center of the buttock, and thinner on the lateral side. The thickness does not change with height. Skin fixation is tightly adherent at the sacral and coccygeal regions. Mobility is present in the upper buttock owing to the presence of deep fat, but is less mobile in the lower buttock. Even laterally there is little mobility because of the thin subcutaneous fat. Near the iliac crest, fibers extend from the gluteal fascia and periosteum to the SF to anchor the SF. This also causes nipping due to deep fat gain in obese individuals. In the gluteal groove, the depression is created only by the ICL, and there is no tissue elsewhere in the GF that forms the depression (Figure 13). A major component of the rounding of the lower buttock is bulging of the gluteus maximus muscle.

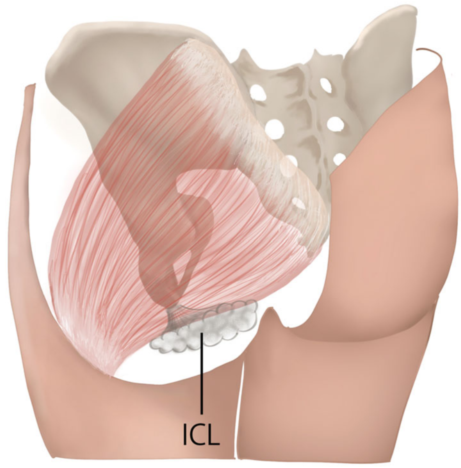


FIGURE 13 Schematic illustration of the ischio-cutaneous ligament (ICL)

The limitation of this study is that it was performed using Japanese cadavers. In general the Japanese do not have large buttocks and few are obese. Therefore, studies in other ethnic groups with more well-developed hips may yield different findings.

5 | CONCLUSIONS

The results of this study may provide useful information for the realization of ideal buttock morphology in buttock lifting, liposuction, and other buttock surgeries. Thorough understanding of the structure of the subcutaneous tissue of the buttock may also be useful for surgical treatment of soft tissue defects such as pressure sores and for improving the morphology of reconstructed breasts with buttock flaps.

ACKNOWLEDGMENTS

The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge and improve patient care. Therefore, these donors and their families deserve our highest gratitude (Iwanaga et al., 2021). We thank Hugh McGonigle, from Edanz (https://jp.edanz.com/ac), for editing a draft of the manuscript.

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REFERENCES

Abu-Hijleh, M. F., Roshier, A. L., Al-Shboul, Q., Dharap, A. S., & Harris, P. F. (2006). The membranous layer of superficial fascia: Evidence for its widespread distribution in the body. *Surgical and Radiologic Anatomy*, *28*, 606–619.

Clemente, C. D. (1985). Fasciae. In C. D. Clemente (Ed.), *Gray's anatomy, 30th American* (Ed ed., pp. 431–434). LEA & Fabiger.

Cuenca-Guerra, R., & Lugo-Beltran, I. (2006). Beautiful buttocks: Characteristics and surgical techniques. *Clinics in Plastic Surgery*, *33*, 321–332.

Cuenca-Guerra, R., & Quezada, J. (2004). What makes buttocks beautiful? A review and classification of the determinants of gluteal beauty and the surgical techniques to achieve them. *Aesthetic Plastic Surgery*, *28*, 340–347.

Fede, C., Porzionato, A., Petrelli, L., Fan, C., Pirri, C., Biz, C., De, C. R., & Stecco, C. (2020). Fascia and soft tissues innervation in the human hip and their possible role in post-surgical pain. *Journal of Orthopaedic Research*, *38*, 1646–1654.

Ghavami, A., Villanueva, N. L., & Amirlak, B. (2018). Gluteal ligamentous anatomy and its implication in safe buttock augmentation. *Plastic and Reconstructive Surgery*, *142*, 363–371.

Graca Neto, L., & Graf, R. M. (2020). Anatomy of the superficial fascia system of the breast. *Plastic and Reconstructive Surgery*, *145*, 193–194.

Haizuka, Y., Nagase, M., Takashino, S., Kobayashi, Y., Fujikura, Y., & Matsumura, G. (2018). A new substitute for formalin: Application to embalming cadavers. *Clinical Anatomy*, *31*, 90–98.

Hashiguchi, S., Hayakawa, K., Inoue, E., Han, A., Iwanaga, J., Tabira, Y., Yamashita, A., Rikimaru, H., Kiyokawa, K., & Watanabe, K. (2022). *An anatomical dissection method for observation of fibrous facial structures*. Plast Reconstr Surg article in press.

Illouz, Y. G. (1990). Study of subcutaneous fat. *Aesthetic Plastic Surgery*, *14*, 165–177.

Iwanaga, J., Singh, V., Ohtsuka, A., Hwang, Y., Kim, H. J., Moryś, J., Ravi, K. S., Ribatti, D., Trainor, P. A., Sañudo, J. R., Apaydin, N., Şengül, G., Albertine, K. H., Walocha, J. A., Loukas, M., Duparc, F., Paulsen, F., del Sol, M., Adds, P., … Tubbs, R. S. (2021). Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. *Clinical Anatomy*, *34*, 2–4.

Lancerotto, L., Stecco, C., MacChi, V., Porzionato, A., Stecco, A., & De, C. R. (2011). Layers of the abdominal wall: Anatomical investigation of subcutaneous tissue and superficial fascia. *Surgical and Radiologic Anatomy*, *33*, 835–842.

Markman, B., & Barton, F. E. (1987). Anatomy of the subcutaneous tissue of the trunk and lower extremity. *Plastic and Reconstructive Surgery*, *80*, 248–254.

Moore Keith, L. D. I. I. A. M. (2010). Integumentary system. In L. Moore Keith, D. F. Arthur II, & M. Agur Anne (Eds.), *Clinically oriented anatomy* (6th ed., pp. 12–16). Wolter Kluwer/Lippincott Williams & Wilkins.

Nakajima, H., Imanishi, N., Minabe, T., Kishi, K., & Aiso, S. (2004). Anatomical study of subcutaneous adipofascial tissue: A concept of the protective adipofascial system (PAFS) and lubricant adipofascial system (LAFS). *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery*, *38*, 261–266.

Nash, L. G., Phillips, M. N., Nicholson, H., Barnett, R., & Zhang, M. (2004). Skin ligaments: Regional distribution and variation in morphology. *Clinical Anatomy*, *17*, 287–293.

Porto Da Rocha, R. (2001). Surgical anatomy of the gluteal region's subcutaneous screen and its use in plastic surgery. *Aesthetic Plastic Surgery*, *25*, 140–144.

Watanabe, K., Aya, H., Inoue, E., Iwanaga, J., Kikuchi, K., & Haikata, Y. (2022). Three sublayers in the SMAS: observations of facial soft tissue using the stretched tissue dissection method focusing on the SMAS. *Clinical Anatomy*, *36*(1), 102–109.

Wong, W. W., Motakef, S., Lin, Y., & Gupta, S. C. (2016). Redefining the ideal buttocks. *Plastic and Reconstructive Surgery*, *137*, 1739–1747.

How to cite this article: Han, A., Inoue, E., Kikuchi, K., Haikata, Y., Tabira, Y., Iwanaga, J., Saga, T., Kiyokawa, K., & Watanabe, K. (2023). Gross anatomical study of the subcutaneous structures that create the three-dimensional shape of the buttocks. *Clinical Anatomy*, *36*(2), 297–307. https://doi.org/10.1002/ca.23988