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Fascia glutealis as mediator of musculocutaneous dynamics in the buttocks region

The gluteal region is a pronounced body part at the end of the torso only among humans and primates. It consists of two semi-spherical buttocks (clunes) that are separated by the gluteal cleft. The gluteal muscles surround the hips and hold the pelvis in a precarious balance. A layer of fat lies on the fascia of the gluteus medius; this layer's form is responsible for the size and shape of the gluteal region's sides and top (**Figs. 1 and 2**; [25]).

The buttocks are considered an intimate body part with strong attraction for both sexes. Influencing its form has become especially important in aesthetic medicine [1, 2]. The muscles, the connective tissue structures, and the subcutaneous fat in this region form a functional unit. Dermatomes and myotomes are developed from the mesoderm via the somites [23]. Here, the muscle-fascia structures form connections with the subcutaneous tissue above them and jointly form the torso fascia, so that the entire body is encased in a fascial panniculus [4]. Therefore, the border region between the free extremity and the torso requires a more detailed examination.

The gluteal fascia is connected to the fasciae of its surroundings. Ventrally, it encloses the broad fascia tensor muscles before it merges into the broad fascia. Cranially, it attaches to the iliac crest, thereby creating a compartment; this compartment encloses the gluteal muscles. Ventrally, in the area of the gluteus medius, the fascia is coarse and tight, whereas it is thin over the gluteus maximus. Reinforcements that cover the muscle like reins and reach all the way to the gluteal groove are only found at the caudal edge of the gluteus maximus. Here, the gluteal fascia continues to the broad fascia. Behind the gluteus maximus, the fascia is connected to the sacral bone and coccyx; these connections close the chamber towards the dorsal area. This chamber, which covers all three gluteal muscles, is subdivided by a connective tissue layer, which inserts between the gluteus maximus on the one hand and the gluteus medius and minimus on the other. Numerous connective tissue septa between the rough bundles of the gluteus maximus are located in the area of the gluteus maximus' surface chamber. The deep chamber runs along the gluteus medius and minimus to the greater trochanter [24].

The frontal, coarser portion of the gluteus medius' fascia is essentially an anchor point for the iliotibial tract. The dynamic

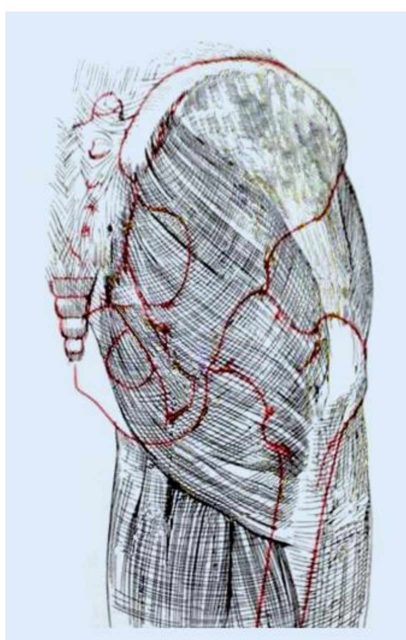

Fig. 1 ▲ Gluteal region with schematic depiction of the bone and muscle structures of the gluteal and thigh region

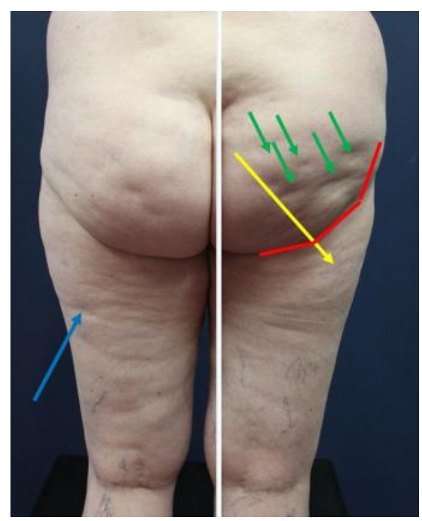

Fig. 2 ▲ Gluteal region without (*left*) and with contraction of the gluteal muscles (*right*). *Yellow arrow* contraction of the bottom third of the gluteus maximus (GM); *green arrows* retraction of the myofascially moved retinacula, *red line* lifting of the gluteal fat pad through the muscle action of the GM; thigh (*blue arrow*), semi-lunar cellulite indentations

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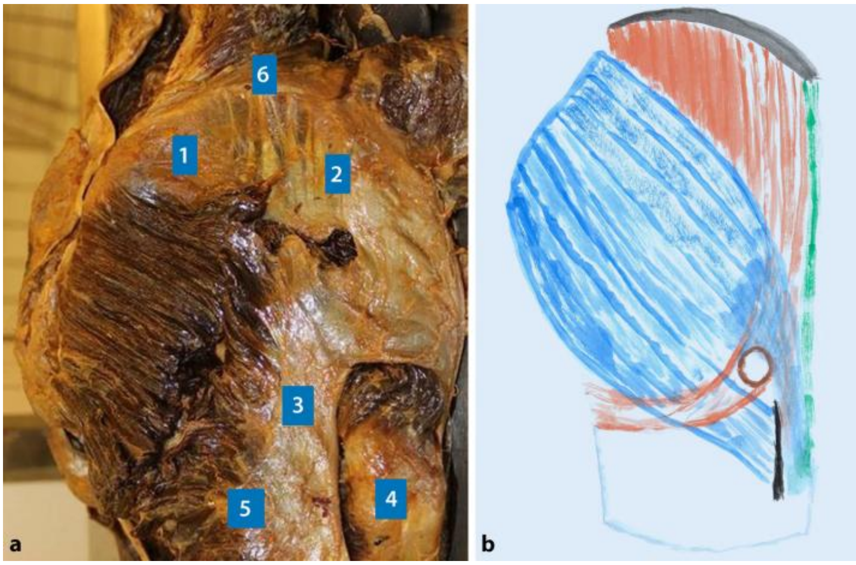

Fig. 3 ▲ **a** *1 + 2* fascia above the gluteus medius, *3* muscle aponeurosis with transition to broad fascia, *4* trochanter after lifting off the fascia and bursa, *5* attachment type of ischiatic holster, *6* iliac crest. **b** *Blue* gluteus maximus with fascial bands, *red* fascial bands of gluteus medius and aberrant fascial bands from the broad fascia; *green* fascial bands of the broad fascia tensor; *gray* iliac crest, gluteal tuberosity (femur); *brown* gluteal foramen

of the fascia group (medius, maximus top 2/3) is mediated via the trochanter with a bursa-type sliding zone. The transition of the gluteus maximus' aponeurosis to the wide tendons of the broad fascia can be easily seen in the surface image ("trochanteric fossa"). The greater trochanter here can be felt through the flat aponeurotic membrane and is often also visible as a slight rise [11].

Thus, the top two-thirds of the gluteus maximus end in an aponeurotic fascia structure, which finally ends in the broad fascia [25]. This is also called the muscle's muscle–tendon power transmission, which is localized in the lateral third of the gluteus maximus [4].

The coarse, non-movable fascia of the gluteus medius is a fascia holster that radiates on the one hand from the iliac crest with fibers to the iliotibial tract, from which fibers in turn radiate; these fibers thus contribute to the morphology of the ischiatic holster (**Fig. 3**). Distal to this, additional fibers radiate to the fasciae of the thigh flexors. The gluteal foramen is formed between these two hammock-like structures, which are attached at the ischial tuberosity.

This arrangement provides a border for the fat pad in the gluteal region, across which the pad cannot descend to the thigh. The bottom third of the gluteus maximus, with its associated fascia, starts at the gluteal tuberosity of the femur. When standing, this part of the muscle covers the ischial tuberosity; when sitting it slides up, so that the compressive stresses during sitting are transferred to the ischial tuberosity (**Fig. 4**).

Materials and methods

The gluteal region was examined in four female and three male cadavers preserved according to Thiel [6, 7]. Firstly, fat was aspirated. Aspiration was performed by tumescence suctioning with H_2O and application of the Microair system in line with liposuction according to J. Klein [8, 9]. During subsequent dissection, an attempt was made to show the relationship of the fasciae to both the muscles and the subcutaneous tissue and skin (retinacula, neurovascular bundles; **Figs. 5, 6 and 7**).

The retinacula that originate in the fascia were easily depicted in our dissections after the fatty tissue close to the fascia had been aspirated. A compact fusion of the connective tissue structures with the fat lobules towards the dermis was found [4, 27]. Otherwise, large fat lobules embedded in multi-layered connective tissue were observed (**Fig. 6**).

Discussion

The fascia of the gluteus maximus is thin and has powerful connections to both the muscle and the fat pad. Strong connective tissue strands separate the muscle bundles from one another and can reach through the entire thickness of the muscle to its base. This fact can also be observed during the difficult removal of the muscle fascia. Carla Stecco [25] calls this type of fascia involving intensive muscle contacts "epimysal fascia"; the central medial and distal portion of the gluteus maximus here is affected particularly in women. The lateral part can be characterized as the aponeurotic fascia type, especially in men, but also to some extent in women (**Fig. 8**). The muscle–fascia power transmission can be derived from the topographic anatomy of the gluteal muscles (**Fig. 6**). This epimuscular, muscle–fascia power transmission takes effect more in the medial and distal part through the close interlacing of the gluteal fascia with the superficial fascia (subcutaneous fascia). This power impact is also transferred to the surface of the buttocks via the retinacula of skin (**Figs. 5, 6 and 9**). The aponeurotic portion is responsible more for the muscle–tendon power transfer to the broad fascia. The gluteal muscles have a variety of functions; here the extension in the hip joints is primarily important for raising the body, e. g., from squatting, when standing up, climbing stairs, mountain climbing, or hiking. These muscles are therefore very important as flight muscles. The cranial portions together with the gluteus medius are also responsible for abduction and exterior rotation of the hip joints, the caudal portion is involved in adduction [26]. In our modern society, many of these muscle functions are no longer adequately used and this system is therefore subject to a rapid degenerative process.

The fasciae are also important as a guiding structure for the blood vessels. The large lymph collectors, in particular, depend on the mobility of the muscle fasciae and the accompanying structures [13]. In addition, Paoletti describes a spiral structure of the fasciae and thus a "wringing out" role in fluid transport dynamics [27]. Congestion in the lymph system causes increased adipogenic reactions and/or hyperplasia and hypertrophy of the fatty tissues [28, 29].

Particularly in the case of lipedema, impaired lymph drainage causes usually painful fat accumulation in the extremities and buttocks area [30]. During procedures and examinations we found cellulite without exception among our patient population of more than 400 lipedema patients, both during rest and even more so during the squeezing test. On the other hand, an accumulation of subcutaneous fatty tissue causes a thinning of the dermal structures, which can also be observed among patients with increased BMI [31, 32]. We found this during our examinations of lipedemous arms [14]. The close interaction of the retinacula originating from the fascia and the peripheral subcutaneous fat compartments through the neurovascular bundles can cause significant damage to the peripheral subcutaneous fat compartments, if there is degeneration (dermal white adipose tissue, dWAT; [33]). Here the adipocyte myofibroblast transition (AMT) in terms of fibrosis takes effect [34]. This process can be reversed if treated properly.

When subjected to normal stress, the great flexibility and elasticity of the gluteal fascia prevents rupture of and damage to the blood vessels that run through it [5]. This phenomenon was already described by Thiel [10]. Lymph drainage is also easily possible in this loose mesh; however, if there is fixed damage to tissue (e.g., scars), a standstill occurs.

In this context, the fascia should not be separated from the muscle during aesthetic procedures (augmentation), since this destroys lymph drainage, sensitive nerves, and blood vessels.

In the area of the gluteal region, the fasciae are formed by three layers: the surface layer (superficial fascia), the actual gluteal fascia, and the epimysium below the fascia [12]. The surface layer includes the subcutaneous (dWAT) and deep pad-like (subcutaneous white adipose tissue, sWAT) fatty tissues, as well as various gender-specific connective tissue strands that run from the deep gluteal fas-

Abstract · Zusammenfassung

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Abstract

Cellulite is a change of the skin and subcutaneous tissue that develops mainly in the thighs and gluteal region of almost all women. Many concepts in the pathological physiology of cellulite are to some extent contradictory and inconclusive; however, some studies point to structural changes in the dermis and subcutaneous tissue. A correlation of cellulite with focal hypertrophic subcutaneous connective tissue strands and lower density of connective tissue septa in subcutaneous tissue also point to changes in the related gluteal fascia and thus in the closely interlaced gluteal muscles. A rapid degenerative development of the muscle dynamics that were originally gained over generations unquestionably occurs in the Caucasian race and its related urbanization. The gender-specific dimorphism in the subcutaneous area must also be investigated further, since almost exclusively women are affected. For this reason we have anatomically examined male and female gluteal zones and demonstrated significant genderspecific changes. In particular, a weakening of the muscle-tendon and muscle-fascia dynamics of the gluteal muscles appears to be responsible for the round, superficially visible dermal changes. The entire embryonic unit of the muscle-fascia-skin structures in the buttocks and thigh area is involved in female cellulite. A transformation of these degenerative changes through regenerative measures, such as active movement and shock wave therapy is, therefore, appropriate and necessary.

Keywords

Thoracolumbar fascia · Gluteal groove · Retinacula of skin · Epimysium · Myofascial power transmission

Die Fascia glutealis als Mittler der muskulokutanen Dynamik der Gesäßregion

Zusammenfassung

Cellulite ist eine sich bevorzugt an den Oberschenkeln und Glutealregion beinahe bei fast allen Frauen entwickelnde Veränderung von Haut und Subkutangewebe. Viele Konzepte zur Pathophysiologie der Cellulite sind teilweise widersprüchlich und unschlüssig. Einige Studien weisen jedoch auf strukturelle Veränderungen an Dermis und Subkutangewebe hin. Eine Korrelation von Cellulite mit fokalen hypertrophen subkutanen Bindegewebssträngen und verringerter Dichte der Bindegewebssepten im Subkutangewebe weist auch auf Veränderungen der damit verbundenen Fascia glutealis und mit der dabei eng verwobenen Glutealmuskulatur hin. Fraglos besteht bei der kaukasischen Rasse und der mit ihr verbundenen Urbanisierung eine rapide degenerative Entwicklung der ursprünglich über Generationen erworbenen Muskeldynamik. Auch ist der geschlechtsspezifische Dimorphismus im subkutanen Bereich genauer zu untersuchen, zumal fast ausschließlich Frauen betroffen sind. Aus diesem Grund haben wir männliche und weibliche Gesäßzonen anatomisch untersucht und hierbei deutliche geschlechtsspezifische Veränderungen aufzeigen können. Vor allem eine Abschwächung der myotendinösen und myofaszialen Dynamik der Glutealmuskulatur scheint für die runden, oberflächlich sichtbaren dermalen Veränderungen verantwortlich zu sein. Die embryologische Einheit der muskulofasziokutanen Strukturen im Gesäß und Oberschenkelbereich ist als Gesamtes bei der weiblichen Cellulite involviert. Daher ist eine Transformation dieser degenerativen Veränderungen durch regenerative Maßnahmen wie aktive Bewegung und Stoßwelle sinnvoll und notwendig.

Schlüsselwörter

Fascia thoracolumbalis · Sulcus glutealis · Retinacula cutis · Epimysium · Myofasziale Kraftübertragung

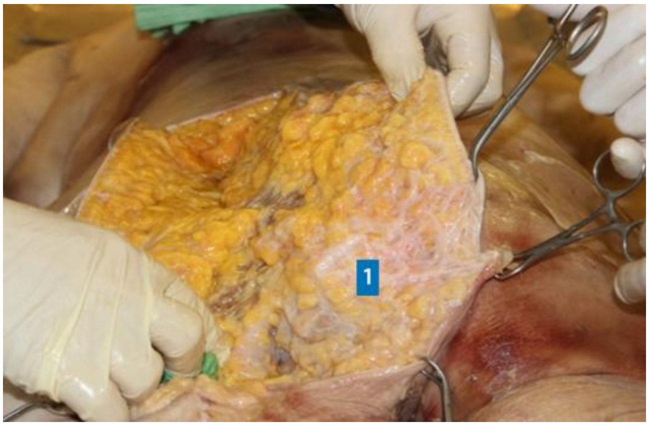

Fig. 4 ▲ There is a massive thickening of the connective tissue septa in the distal medial edge of the gluteal fascia; these show a pressure pad-like aspect, similar to palmar and plantar fat pads. When sitting the bottom muscle edge slides towards the cranium, thus this fat structure protects the ischial tuberosity. *1* Pressure pad-like connective tissue fat pads above the ischial tuberosity

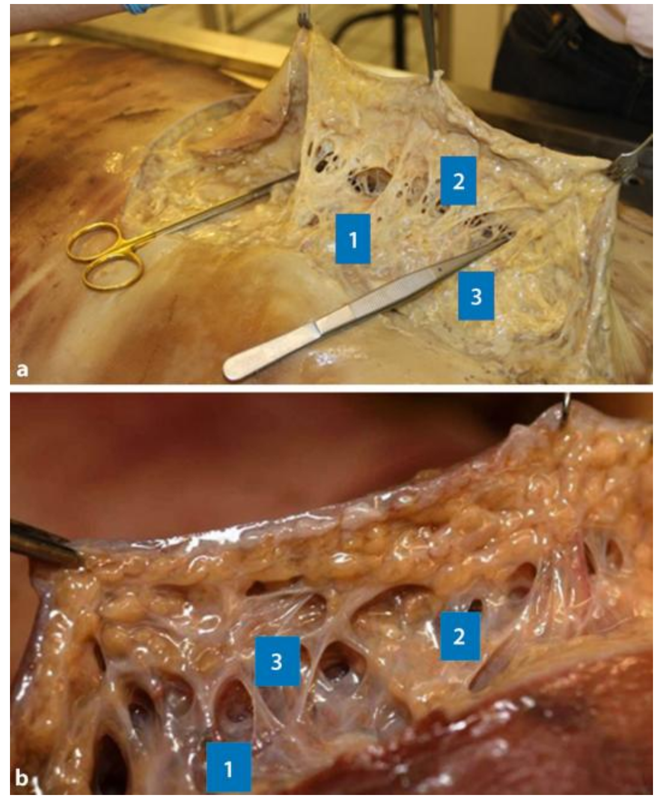

Fig. 5 ▲ There is a coarse, fixed gluteal fascia above the point of attachment for the gluteus maximus from the posterior iliac crest downward to the sacrotuberal ligament; that fascia connects to some extent with the surface thoracolumbar fascia towards the cranium. Originating from these fixed fascial structures, comparatively coarse retinacula stream through the fat pad into the dermis. Coarseness and thickness here differ substantially between women and men; women's connective tissue structures are significantly thinner and more delicate (**a**, **b**). **a** Female dissection, dorsomedial view: *1* gluteal fascia, *2* retinacula of skin, *3* fascia of the coccyx. **b** Male dissection, dorsomedial view: *1* sacral gluteal fascia, *2* retinacula of skin, *3* intermediate fascia (Camper's)

cia to the surface and serve as a guiding structure for the neurovascular bundles, as already described by Thiel [10]. The multi-layered, centrally loosened gluteal fascia is in close contact with the gluteus maximus, with perimysial and epimysal connecting tissue structures that can penetrate the muscle all the way to the inner fascia sleeve. The functional three-layered structure (skin, fascia, muscle) found here is not as pronounced anywhere else in the human body, except for the proximal portion of the upper arms [14]. Thus, the retinacula that run from the profound fascia cannot be viewed in isolation from the fascia. They thus also transmit the pull of the muscle via the fascia to the nates (clunes), which can cause a dimple-shaped indentation of cellulite [20] when muscles are weakened; this takes effect especially in women.

Coordination between torso and legs occurs via coordination of the muscles and their fasciae with the powerful thoracolumbar fascia (TL), whereby the surface sleeve of this fascia transitions into the fascia of the gluteus maximus [15]. The fasciae of the gluteus maximus and latissimus dorsi form a cross-grid pattern in the surface sleeve of this system. This fascia system of the torso and gluteal region with its self-contained arrangement is responsible for the control of homo erectus (servo system according to Schleip [4]). This system is crucially involved in the coordination of the power transmission between spine, pelvis and legs; important neurological functions of nociception, mechanoreception, proprioception, and interoception are also tied into this area; there are specific results with regard to the thoracolumbar fascia here ([4, 5, 18, 19]; ◘ **Fig. 10**). The sensations of pain and lust have been described by Krafft-Ebing [16] in *Vita sexualis*. With regard to interoception, there are also specific results in the neighboring region ([17]; ◘ **Fig. 11**).

With regard to cellulite, not only the subcutaneous structures, as described by Nürnberger [21], but also the significantly greater connective tissue supply of the gluteal fascia and the associated retinacula in men appear to be responsible for the gender-specific nature of cellulite. The fasciae of gluteus maximus and medius also form the essential fascia holsters for the broad fascia and iliotibial tract. Their radiations form both the ischiatic holster and the flexing fasciae of the thigh that are close to the torso; at the same time, they limit expansion of the buttocks' and thighs' surface fat layer. The hinge-like transitions between the two structures are located in the gluteal groove with the gluteal fossa beneath it. The fossa (◘ **Fig. 12a, b**) and the gluteal groove spread out in a seated position; at the same time the ischiatic holster pulls the bottom edge of the gluteus maximus and its fascia upwards, so that only the ischial tuberosity and the subcutaneous pressure pads of the clunes are stressed during sitting. The distal gluteus maximus, which starts at the femoral

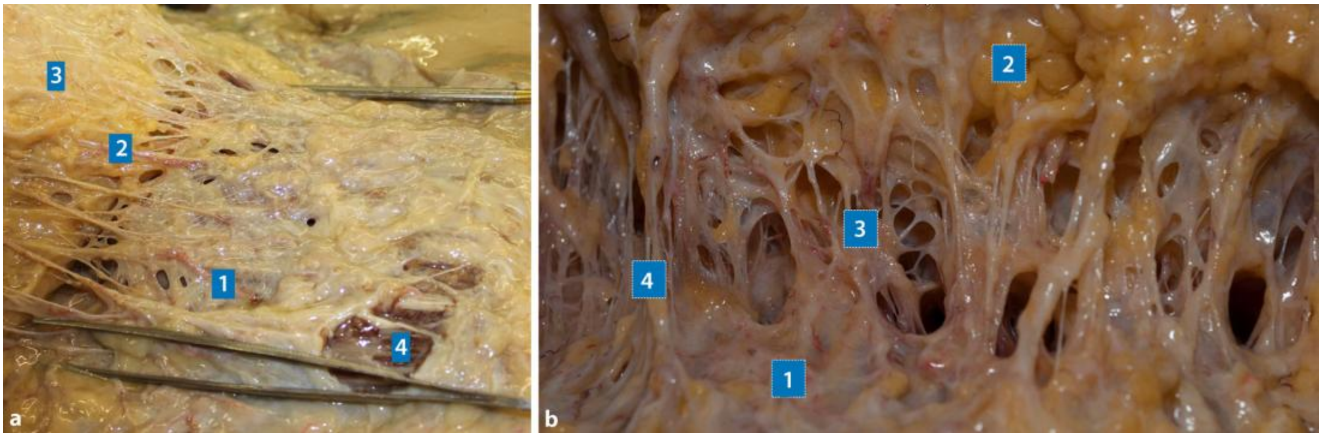

Fig. 6 ▲ From the medial portion of the gluteal fascia, neurovascular bundles with retinacula run in turn from the fascia into the dermis. They thereby supply the subcutaneous dermal fat deposits. Here, too, significant gender differences are observed. **a** Female dissection, from a dorsocranial lateral aspect, retinacula coming from the central part of the gluteal fascia: *1:* vascular bundle in the gluteal fascia, *2* retinaculum with blood vessel, *3* gluteal subdermal/subcutaneous fat pad, *4* gluteus maximus. **b** Male dissection, from a dorsocranial aspect, coarse retinacula coming from the central part of the gluteal fascia: *1* gluteal fascia, *2:* dermal/subcutaneous gluteal fat pad, *3* neurovascular bundle with retinaculum, *4* stretched retinaculum coming from the gluteal fascia

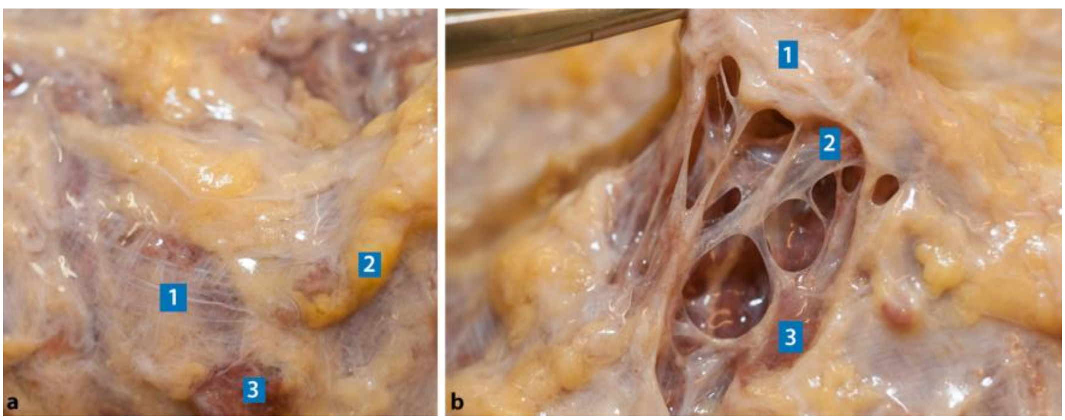

Fig. 7 ▲ **a** In the central area, in particular, there are latticed collagen fibers; however, these mostly run perpendicular to the direction of the muscle fibers. *1* Latticed gluteal fascia fibers; *2* adhesive fat pads; *3* gluteus maximus muscle. **b** The fascia of the gluteus maximus muscle is thin and shows powerful connections to both the muscle and the fat pad. Strong connective tissue strands separate the muscle bundles from one another and can reach through the entire thickness of the muscle to the base. This fact can also be observed during the difficult removal of the muscle fascia. *1* Gluteal fascia; *2* perimysial interlacing; *3* gluteal muscle fiber

gluteal tuberosity, has no uniform fascial structure. With its interlacing towards the subcutaneous tissue and muscle, the gluteal fascia can be considered a large, networked tension transfer system (◘ **Fig. 12**).

The appearance of cellulite is not only due to a surface defect, but is caused by a disorder of the entire unit of muscles, fascia, and subcutaneous tissue. In the same way, these three structures are also closely linked in the face; here, too, complex changes can be seen on the surface [35]. With cellulite in women, the weakening of the extramuscular muscle–fascia power transmission has more of an effect, while in men the significantly stronger connective tissue armoring of the more aponeurotic fasciae with the coarse retinacula, which are attached to it to prevent atrophy of the connective tissue and fat compartments (◘ **Fig. 8**).

The structured fat compartments are well suited to augmentation by using hyaluron or autologous body fat for buttock modeling (◘ **Fig. 9**).

Cellulite should be treated more by subcision of the denting retinacula and reduction of subcutaneous fat [3], but mainly by regenerative methods. For one, activating the gluteal and neighboring muscles through appropriate movement and sport therapy can improve the quality of the cutaneous/subcutaneous connective tissue and fat depots. This can be supported by shock wave therapy [36]. The authors documented the effectiveness of this method in a study: by pretreating subcutaneous fat via radial shock wave, they documented a noticeable induction of mesenchymal and pericytal/endothelial markers in the stromal vascular fraction (SFV; [37]).

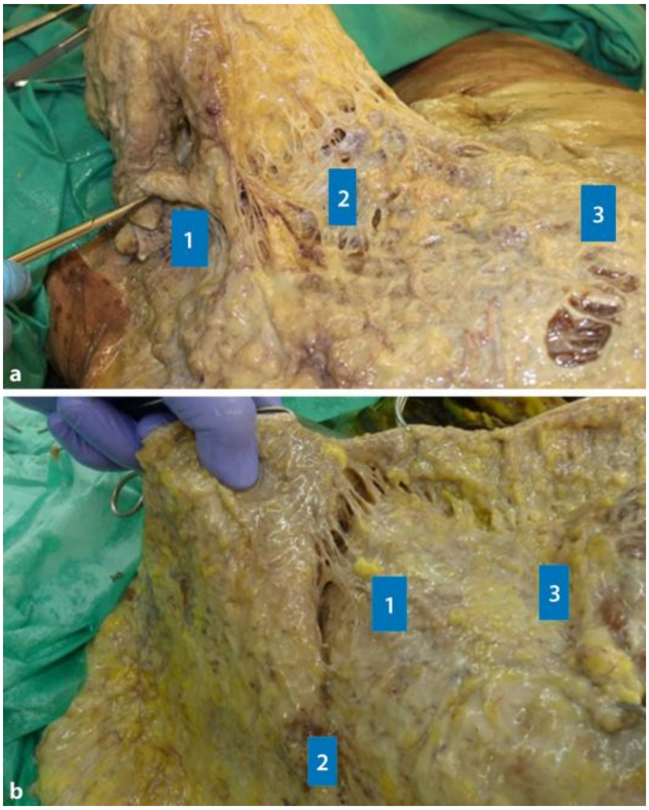

Fig. 8 ▲ The unity of the gluteal fascia is lost in a distal direction with the ischiatic holster (gluteal groove). Here, too, there is a significant gender difference in the macroscopic fascia structure. While a fine lattice structure dominates in women (**a**), a denser aponeurotic fascia structure exists in men (**b**). Thus, there is more of a muscle–tendon dynamic in men, and more of a muscle–fascia one in women. View from cranial lateral: distal fascia dissection above the gluteal groove. **a** *1* delicate latticed fascia structure; *2* gluteal foramen; *3* sacral gluteal fascia. **b** *1* coarse, more aponeurotic gluteal fascia; *2* gluteal foramen; *3* coarse sacral gluteal fascia

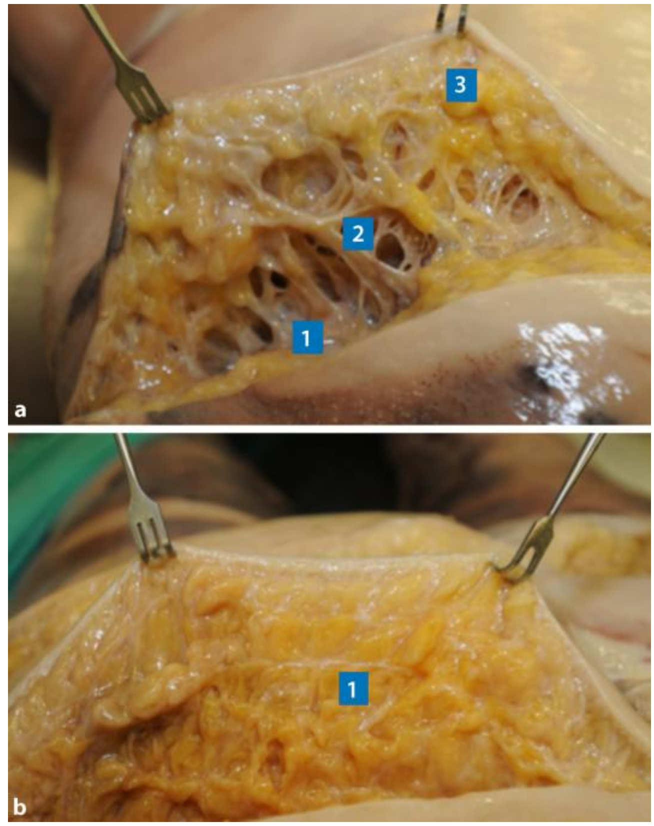

Fig. 9 ▲ Female dissection. During our dissection, the retinacula originating from the fascia could be easily shown by aspirating the deep fat pads; towards the dermis, a compact fusion of the connective tissue structures with the fat lobules was found, which indicates the compactness of the subcutaneous layers. Otherwise, large fat lobules embedded in several intermediate fasciae were observed. **a** Distal gluteal fat pad after aspiration: *1* gluteal fascia, *2* retinacula of skin (branching in several layers), *3* spherical sub-dermal fat pad. **b** Fat pad without aspiration: *1* large, pressure pad-like fat lobules with several intermediate fasciae

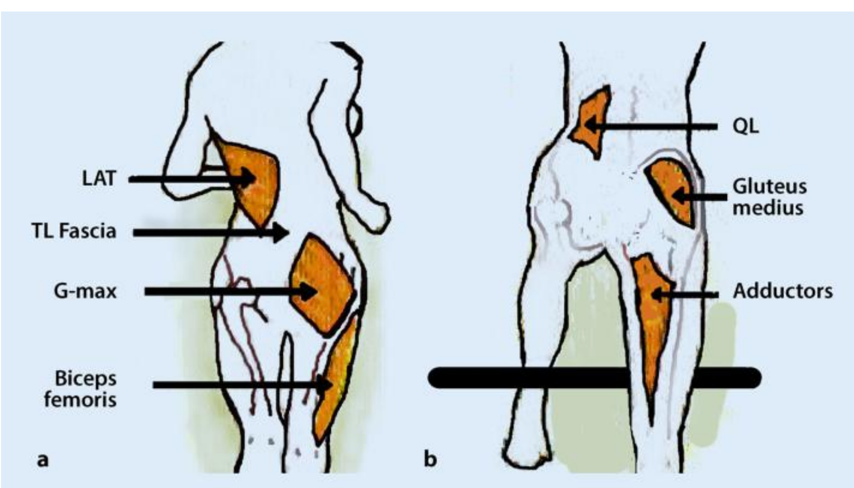

Fig. 10 ▲ **a** The gluteus maximus acts in coordination during flight movement. **b** The gluteus medius acts in coordination during stair climbing

Practical conclusion

An understanding of the aesthetically functional unit of the subcutaneous gluteal fascia and gluteal muscle anatomy is a prerequisite for surgical or non-surgical approaches to successful treatment in the gluteofemoral region. This region often undergoes aesthetic body contouring by means of liposuction, buttock augmentation, as well as surgical cellulite treatment. Conservative, non-surgical methods should also be offered in a holistic approach, since these can only succeed if the musculofascial dynamics are additionally and appropriately activated.

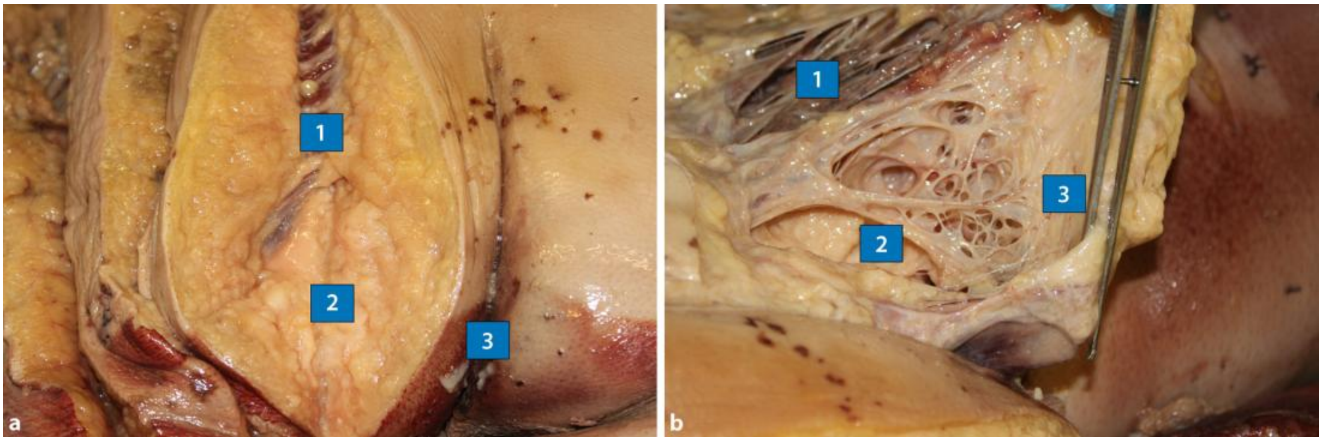

Fig. 11 ▲ Medial-distal from the attachment of the gluteus maximus and its fascia, a soft, elastic, light-colored fat pad is shown; this is the "ischioanal fat pad," which lines the pelvic floor externally. After radical aspiration of this fat pad (**b**), one can see connective tissue strings that radiate from the bottom edge of gluteus maximus towards the sphincter muscles. Voluntary contraction of the gluteal muscles thus support the sphincter function of the pelvic floor. **a** *1* Gluteus maximus; *2* ischioanal fat pad; *3* anus. **b** *1* Distal gluteal fascia; *2* retinacula radiating in the sphincter region; *3* subcutaneous fat in the anal area

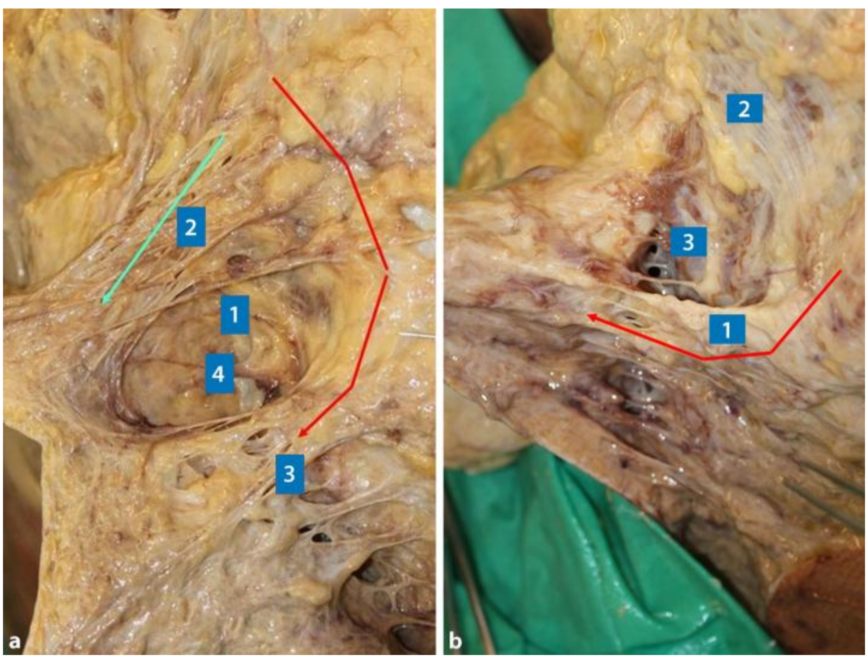

Fig. 12 ▲ During a lateral dissection, the "gluteal foramen" emerges as the border region between the gluteal and thigh fat pads. The roof is formed by the collagen bundle radiating inward from the broad fascia, which forms the ischiatic holster (1st hammock). These fibers finally end at the ischial tuberosity. This ischiatic holster covers the distal part of gluteus maximus and keeps the gluteal fat pad from sliding off. Its structure originates from horizontal, branching collagen fibers of the broad fascia/gluteus medius and, after following an arc-like course, ends at the ischial tuberosity. In a distal direction, fibers also branch from the broad fascia into the fascia of the thigh flexor and end in the "2nd hammock" (**b**), also at the ischial tuberosity. Both of these parallel branching connective tissue strucures form the basis of a hinged joint-type foramen that opens while standing, and which, on the surface, separates the gluteal fat pad from the fat pad of the thigh on the flexing side. Outwardly, this structure manifests as the gluteal groove. When seated, this foramen closes. **a** *1* gluteal foramen, connective tissue strands coming from the broad fascia, laterally forming the anchor point of the buttocks, *2* finally continuing as ischiatic holster until the ischial tuberosity, *3* connective tissue strands coming from the broad fascia that run into the thigh on the flexing side, *4* retinaculum in the gluteal foramen, starting from the muscle. **b** After opening the proximal connective tissue structures, the distal hammock takes the form of an arc-like connective tissue strand in the thigh fascia. *1* Distal connective tissue arc; *2* broad fascia; *3* gluteal foramen

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Compliance with ethical guidelines

Conflict of interest. M. Sandhofer, P. Schauer, U. Pilsl and F. Anderhuber declare that they have no competing interests.

This article does not contain any studies with human participants or animals performed by any of the authors.

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