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The Proximal Origin of the Gluteus Maximus: A Cadaveric Study

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Abstracts

Objectives: Many anatomy textbooks describe the origin of the gluteus maximus indistinctly as the gluteal surface of the ilium, lumbar fascia, sacrum, and sacrotuberous ligament and depict it laterally along the sacral margin. Our observation is that the origin of the gluteus maximus occurs much more medial and just off midline than what is typically depicted in standard anatomy textbooks. The purpose of the present study was to define the anatomy of the proximal origin of the gluteus maximus through anatomical dissections of donated human fresh tissue and compare the findings with multiple anatomy drawings, textbook figures, and MRI depictions of the gluteus maximus.

Methods: Six donated human torso cadaveric specimens, for a total of 12 gluteus maximus specimens, were dissected in the prone position. The proximal origin of the gluteus maximus and its relationship to the surrounding structures were documented and measured with the use of digital calipers. Photographs were obtained of the dissections, which were compared with 30 illustrative depictions of the origins of the gluteus maximus. These were compared with MRI scans of 12 patients.

Results: The gluteus maximus originates on the gluteal surface of the ilium, lumbar fascia, sacrum, sacrotuberous ligament, and laterally along the sacral margin. A number of measurements were obtained. In the cadavers and MRI samples a larger percentage of the gluteus maximus was medial to the posterior superior iliac spine (PSIS). In the cadaver specimens, the gluteus maximus was on average $29 \pm 6\%$ medial to the PSIS. In the MRI scans, the gluteus maximus was on average $21 \pm 6\%$ medial to the PSIS. In the illustrative depictions, the gluteus maximus was on average $15 \pm 20\%$ medial to the PSIS. A larger percentage of the space between the midline and the PSIS was occupied by gluteus maximus in the MRI depictions and cadaver specimens. In the cadaver specimens, $82 \pm 11\%$ of the area between the midline and the PSIS was occupied by the gluteus maximus. In the MRI scans, $80 \pm 12\%$ of the area between the midline and the PSIS was occupied by the

gluteus maximus. In the illustrative depictions, $28 \pm 37\%$ of the area between the midline and the PSIS was occupied by the gluteus maximus. The gluteus maximus origins in both the fresh-tissue dissections and the MRI scans were much more midline than what was depicted in the textbooks and anatomy drawings.

Conclusions: Many anatomy textbooks incorrectly depict the origin of the gluteus maximus. Care must be taken to preserve the medial fibres of the gluteus maximus origin when a posterior approach to the sacroiliac joint is undertaken. Because of the mid-maximus vascular pedicle, incision through a standard approach based on text figures will amputate the medially based fibres. This leads to devitalized muscle in the surgical field with increased risk for wound complications.

Keywords: Gluteus maximus; Sacrotuberous ligament; Posterior pelvic ring

Introduction

Surgical approaches for open reduction and internal fixation of the posterior pelvic ring through a posterior approach require an understanding of the origin of the gluteus maximus [1]. Many anatomy textbooks describe the origin of the gluteus maximus indistinctly as the gluteal surface of the ilium, lumbar fascia, sacrum, and sacrotuberous ligament. Illustrations typically depict it laterally along the junction of the sacrum and ilium posteriorly. In our experience, these textbook descriptions of the origin of the gluteus maximus reflect an inaccurate anatomic understanding of the origin of the gluteus maximus [2,3].

The purpose of the present study is to describe the anatomy of the origin of the gluteus maximus through anatomical dissections of donated human fresh tissue and compare these findings to multiple sources of anatomy including anatomy drawings, textbook illustrations, and MRI depictions of the gluteus maximus [4].

Materials and Methods

Standardized measurements of the anatomy and origins were assessed on 3 different sources: human cadaver dissections (Figure 1), MRI images of normal pelvis (Figure 2), and images from published anatomy references (Figure 3) [5-9].

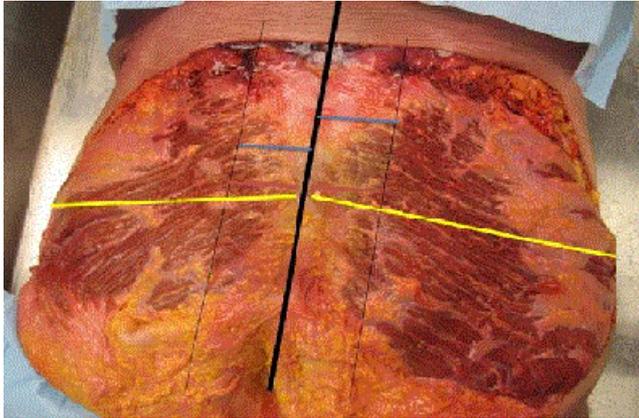


Figure 1: Digital image of Cadaveric specimen reflecting medial origin and widest lateral portion of gluteus maximus on both sides. The blue line indicates the space between midline and the PSIS (posterior superior iliac spine). The red line indicates the proportion of the gluteus maximus that is medial to the PSIS. The yellow line indicates the widest portion of the gluteus maximus.

Six donated human torso cadaveric specimens with intact soft-tissue envelope about the posterior pelvic ring for a total of 12 gluteus maximus specimens were dissected in the prone position. The skin and subcutaneous tissues were reflected to expose the gluteal musculature (Figure 2) [10].



Figure 2: MRI coronal pelvic T1 image reflecting medial origin and widest lateral portion of gluteus maximus on both sides.

The blue line indicates the space between midline and the PSIS (posterior superior iliac spine). The red line indicates the proportion of the gluteus maximus that is medial to the PSIS. The yellow line indicates the widest portion of the gluteus maximus [11,12].

Relationships were described and measured between the origin of the gluteus maximus muscle and the surrounding osseous and soft tissue anatomy. The site of origin of the gluteus maximus was documented. High-quality digital images were taken of each specimen (both gluteus maximus muscles) for each specimen.

MRI measurements were obtained from pelvic coronal T1 images that reflected the medial origin and widest lateral portions of the gluteus maximus on both sides [13].

High-quality images from 30 depictions of the gluteus maximus origins were obtained from published anatomy references. The images included both unilateral and bilateral illustrations of the relevant anatomy (Figure 3).

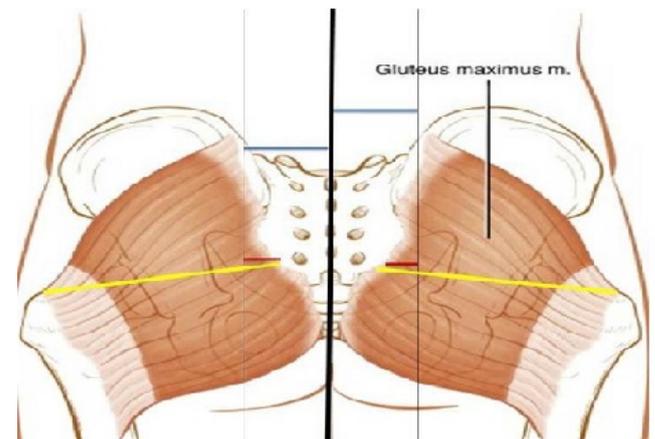


Figure 3: Textbook illustration reflecting medial origin and widest lateral portion of gluteus maximus on both sides. The blue line indicates the space between midline and the PSIS 254 (posterior superior iliac spine). The red line indicates the proportion of the gluteus maximus that is medial to the PSIS. The yellow line indicates the widest portion of the gluteus maximus.

Similar methodology was used to record measurements taken from all images. All measurements were made with digital calipers by a trained investigator. Each image was measured on three different dates. The measures were then averaged. The mean value of the three measurements for the image of each specimen is reported [14-17].

Measurements

Proportion of gluteus maximus medial to PSIS

On the image a plumb line was drawn down the midline sacrum to represent the center of the specimen. Lines were also drawn through each PSIS and parallel to the plumb line. A straight line measurement in normalized units was taken from

the most medial edge of the gluteus maximus to the vertical line drawn from the PSIS [18]. The widest portion of the gluteus maximus was also measured as a straight line taken perpendicular to midline from the most medial edge of the gluteus maximus to the lateral edge of the gluteus maximus visible on the image. The ratio of length of gluteus maximus medial to PSIS to the maximal width of the muscle was created. Measurements taken in such manner were standardized to ensure uniformity in our data collection [19-21].

Proportion of space from PSIS to midline occupied by gluteus maximus muscle

We also calculated the percentage of the space between midline and the PSIS that is occupied by the gluteus maximus. A straight line measurement in normalized units was taken from the most medial edge of the gluteus maximus to the vertical line drawn from the PSIS (which had been calculated to determine percentage of the gluteus maximus that was medial to the PSIS). This was divided into the length in inches between the plumb line and vertical line of the PSIS, defined as a perpendicular and straight line between the plumb line and PSIS. Comparing data as a percentage allowed us to consistently compare samples, textbook photos, and MRI images of different sizes [1,22-24].

Unpaired t-tests were performed to determine if there was a significant difference between the proportion of the gluteus maximus medial to the PSIS and the proportion of the space from the PSIS to the midline occupied by the gluteus in cadaver specimens, MRI images, and textbook representations.

Results

Table 1 contains 1) the proportion of gluteus maximus medial to PSIS and 2) proportion of space between midline and PSIS occupied by gluteus maximus for each gluteus maximus specimen, MRI image, and anatomy illustration. The t-test analysis data is shown (Tables 1 and 2).

Table 1: Representation of Gluteus Maximus between midline and PSIS of the 30 illustrations.

Specimen	Proportion of Gluteus Maximus Medial to PSIS	Proportion of space between Midline and PSIS occupied by Gluteus Maximus
Cadaver 1	0.33	0.75
Cadaver 2	0.27	0.8
Cadaver 3	0.29	0.93
Cadaver 4	0.25	0.92
Cadaver 5	0.23	0.74
Cadaver 6	0.35	0.88
Cadaver 7	0.23	0.74
Cadaver 8	0.35	0.88
Cadaver 9	0.23	0.74
Cadaver 10	0.35	0.88

Cadaver 11	0.33	0.85
Cadaver 12	0.31	0.76
MRI 1	0.12	0.54
MRI 2	0.16	0.81
MRI 3	0.27	0.89
MRI 4	0.26	0.89
MRI 5	0.18	0.79
MRI 6	0.25	0.9
MRI 7	0.14	0.68
MRI 8	0.12	0.76
MRI 9	0.27	0.82
MRI 10	0.26	0.82
MRI 11	0.22	0.88
MRI 12	0.21	0.77
Illustration 1	0.03	0.06
Illustration 2	0.03	0.05
Illustration 3	0.22	0.44
Illustration 4	0.23	0.34
Illustration 5	0.22	0.35
Illustration 6	0.35	0.28
Illustration 7	0.03	0.1
Illustration 8	0.03	0.11
Illustration 9	0.23	0.43
Illustration 10	0.3	0.37
Illustration 11	0.08	0.25
Illustration 12	0.22	0.65
Illustration 13	0.01	0.07
Illustration 14	0.16	0.43
Illustration 15	0.09	0.25
Illustration 16	0.29	0.16
Illustration 17	0.16	0.4
Illustration 18	0.07	0.25
Illustration 19	0.09	0.23
Illustration 20	0.27	0.43
Illustration 21	0.3	0.37
Illustration 22	0.16	0.24
Illustration 23	0.27	0.43
Illustration 24	0.2	0.34
Illustration 25	0.1	0.23
Illustration 26	0.08	0.19
Illustration 27	0.11	0.34

Illustration 28	0.16	0.24
Illustration 29	0.09	0.25
Illustration 30	0.07	0.25

Table 2: t-Test analysis of data

	Difference Between Means	P-value ($\alpha=0.05$)
Proportion of gluteus medial to PSIS in cadaver specimens vs. illustrations	0.138 \pm 0.03	P<0.0001
Proportion of gluteus medial to PSIS in MRI specimens vs. illustrations	0.05 \pm 0.03	P=0.1073
Proportion of space between midline and PSIS in cadaver specimens vs. illustrations	0.538 \pm 0.042	P<0.0001
Proportion of space between midline and PSIS in MRI specimens vs. illustrations	0.512 \pm 0.044	P<0.0001

The proportion of the gluteus medial to the PSIS was significantly greater in cadaveric specimens than it was in textbooks, with a difference of $13.8 \pm 3.0\%$ ($p<0.0001$). There was no statistically significant difference found in the proportion of the gluteus medial to the PSIS in MRI images compared to textbooks [25,26].

The proportion of the space between the PSIS and the midline was significantly greater in both cadaveric specimens than it was in textbook representations, with a difference of $53.8 \pm 4.1\%$ ($p<0.0001$) [27]. In addition, the proportion of space between the PSIS and the midline was significantly greater in MRI images than it was in textbook representations, with a difference of $51.2 \pm 4.4\%$ ($p<0.0001$).

Discussion

To our knowledge, no previously published literature has described the medial extent of the origin of the gluteus maximus. The majority of anatomic references show the medial origin of the gluteus maximus as extending just medial to the sacroiliac joint. Cadaveric and MRI data find the origin of the gluteus maximus extends to the sacral spinous processes. This difference is important when a posterior approach to the sacroiliac joint is required. To avoid muscle damage the surgeon must preserve the continuity of the muscle fibers of the origin with the main body of the gluteus maximus. The gluteus maximus has a mid-maximus vascular pedicle [28,29] and dissection directly on to the posterior SI joint will devascularize the medially fibers extending to midline; this will result in devitalized muscle that will increase risks of wound complications.

The posterior approach to the SI joint was originally described by Letournel, though often referenced to the description of the approach provided by those he taught [29,30]. In this approach a posterior incision is made lateral to the PSIS to avoid pressure on the incision line from the PSIS. The dissection raises a full thickness fasciocutaneous flap off the gluteus maximus muscle

to sacral sinuous processes. The gluteus maximus muscle is raised as a full thickness flap from the PSIS medially leaving intact multifidus fascia until the medial fibers are released from the sacral spinous processes. Access to the SI joint, posterior sacrum, greater sciatic notch and posterior ilium is developed by raising gluteus maximus as a vascularized muscle flap [30,31].

Even for a gluteus muscle flap dissection, it is noted that lack of knowledge of the precise muscular origin and a short vascular pedicle makes this approach bloody [29]. If a postoperative wound problem occurs and the fibers have been devitalized, no viable muscle remains between skin and SI joint. Many anatomy textbooks incorrectly depict the origin of the gluteus maximus. The risk is that surgeons unaware of the anatomy could divide the maximus muscle in an approach resulting in devitalized and denervated muscle [30].

A limitation of the present study is the number of dissected cadavers and MRIs evaluated. The consistency of the data found in cadaver and MRI measurements speaks to the value of consistent measurement even in this small number of specimens. However, we believe that the data presented here are adequate to represent the importance of recognizing the accurate anatomical finding of a more midline origin of the gluteus maximus [29,31].

We believe the posterior approach to the sacroiliac joint should be carefully undertaken to preserve the medial fibers of the gluteus maximus origin. The proportion of the gluteus maximus that was medial to the PSIS was significantly greater on the cadaver (human) specimens than what is typically depicted in textbooks and anatomic illustrations. Similarly, the gluteus maximus occupied over 50% more of the space between the midline and the PSIS on the cadaver specimens when compared to the anatomic illustrations. As expected, MRI and cadaver findings were almost identical.

This underscores the need for modification of anatomy drawings in textbooks that may underestimate the amount of gluteus maximus medial to the PSIS. Surgeons undertaking the posterior approach to the sacroiliac joint should, recognizing that the medial fibers of the gluteus maximus frequently extend to midline.

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