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# Morphometry of Human Musculus Gluteus Maximus in Foetal Period

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**A** – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article; **G** – other

## Abstract

**Background.** Magnus gluteal muscle (*musculus gluteus maximus*) belongs to the group of lower limb girdle muscles. It is one of the biggest muscles in human organism and is located mostly superficially in gluteal region. Literature provides discussion concerning its role in movement such as walking, running and climbing as well as plastic surgery in reconstructive operations of trochanter. Magnus gluteal muscle plays an important role in orthopaedic surgery.
**Objectives.** The goal of the study was to analyse the human magnus gluteal muscle in the foetal period.
**Material and Methods.** The analysis was carried out on 154 muscles originating from human foetuses (including 30 females – 39%) belonging to the collection of Normal Anatomy Dept. of Wroclaw Medical University. The body length was assessed with the use of vertex-tuberal (*v-tub*) length and it was included in the range 107–205 mm, which corresponds with the period 17–30 weeks of foetal life. The survey incorporated the following methods: anthropological, preparational and image acquisition which was acquired with the use of high-resolution digital camera. In order to take computer measurements, the following systems were exploited: Image J and Scion for Windows. Statistical analysis was carried out with the use of STATISTICA package v. 9 (*t*-Student test).
**Results.** The magnus gluteal muscle was analysed in respect to sexual dimorphism and symmetry. On the basis of elicited parameters, the model of muscle increase in foetal period was defined. The following measurements were taken: *v-tub*, vertex-plantare (*v-pl*), body mass, muscle particular sides lengths and distance between corresponding measurement points. In every muscle, the lengths of four sections forming the circumference as well as the area were measured.
**Conclusions.** No difference was observed in foetal magnus gluteal muscle sexual dimorphism or symmetry ($p > 0.05$). The correlation diagram was used to calculate the muscle weekly increase in foetal period. The results suggest that lesions and pathologies in the region of magnus gluteal muscle are acquired in post foetal period (**Adv Clin Exp Med 2014, 23, 1, 9–16**).

**Key words:** human musculus gluteus maximus, prenatal period, morphometry.

Magnus gluteal muscle (*musculus gluteus maximus)* belongs to the group of lower limb girdle muscles. It is one of the biggest muscles in human organism and is located mostly superficially in gluteal region [1]. This muscle's characteristic size, anatomy and function makes distinguishes it from the analogous muscles of monkeys and other primates [2]. The literature presents discussions concerning its role in movement such as walking, running and climbing [3] as well as plastic surgery in reconstructive operations of trochanter [4, 5] or genitourinary interseptum [6–8]. Literature includes reports of the muscle anatomical distinctness like its duplication [1] or congenital deficiency [9]. So far, no metrological analysis of magnus gluteal muscle has been carried on analogically big material with the use of the most contemporary computer and statistical methods [Image, Scion]. Only Kołaczkowski and Toboła were presented a morphological description of the foetal period gluteal muscle [10]. However, measurement methods incorporated by the authors were

far less accurate and reliable than those applied in these surveys.

## Material and Methods

Examination material consisted of 154 magnus gluteal muscles originating from 77 human foetuses (30 females – 39%) belonging to Normal Anatomy Dept., Wroclaw Medical University. Body length assessed on the basis of vertex-tuberale (*v-tub*) length was included in the range 107–205 mm, which corresponds with the period 17–30 weeks of foetal life. The survey incorporated anthropological and preparational methods as well as image acquisition achieved with high resolution digital camera. These methods have already been utilized by other authors using the above material from the collection mentioned above [11, 12].

Magnus gluteal muscles were taken from three sides (Fig. 1) with the use of long focal length lens. On the basis of these photos, the following measurements were made: vertex tuberale (*v-tub*), vertex plantare (*v-pl*), body mass, each muscle four sides lengths (the total composed the circumference), angles included between the muscle sides and the distances between the measurement corresponding points.

On total, 1386 measurements were made with the use of free and available online computer systems Image J and Scion Image for Windows [13, 14]. The two advantages of these systems were the possibility of multiple repetition of demanded measurement, accuracy and the option of using the muscle photo for conducting measurements (figure). Other papers exploring the problem of foetal muscles metrology also incorporated the two systems [11, 12 – sartorius and scapula]. The quantitative assessment was made as well. Statistical analysis was carried on with the use of STATISTICA v.9 package (*t*-Student test).

The muscles were analysed in respect to sexual dimorphism and symmetry and their somatic features were defined.

## Results

Table 1 presents basic somatic features (v-tub, v-pl, body mass) of the examined material. Foetuses of both sexes were compared in respect of these features and in the analysed material, male and female foetuses did not differ significantly (Fig. 2 – $p > 0.05$). In the analysed material female and

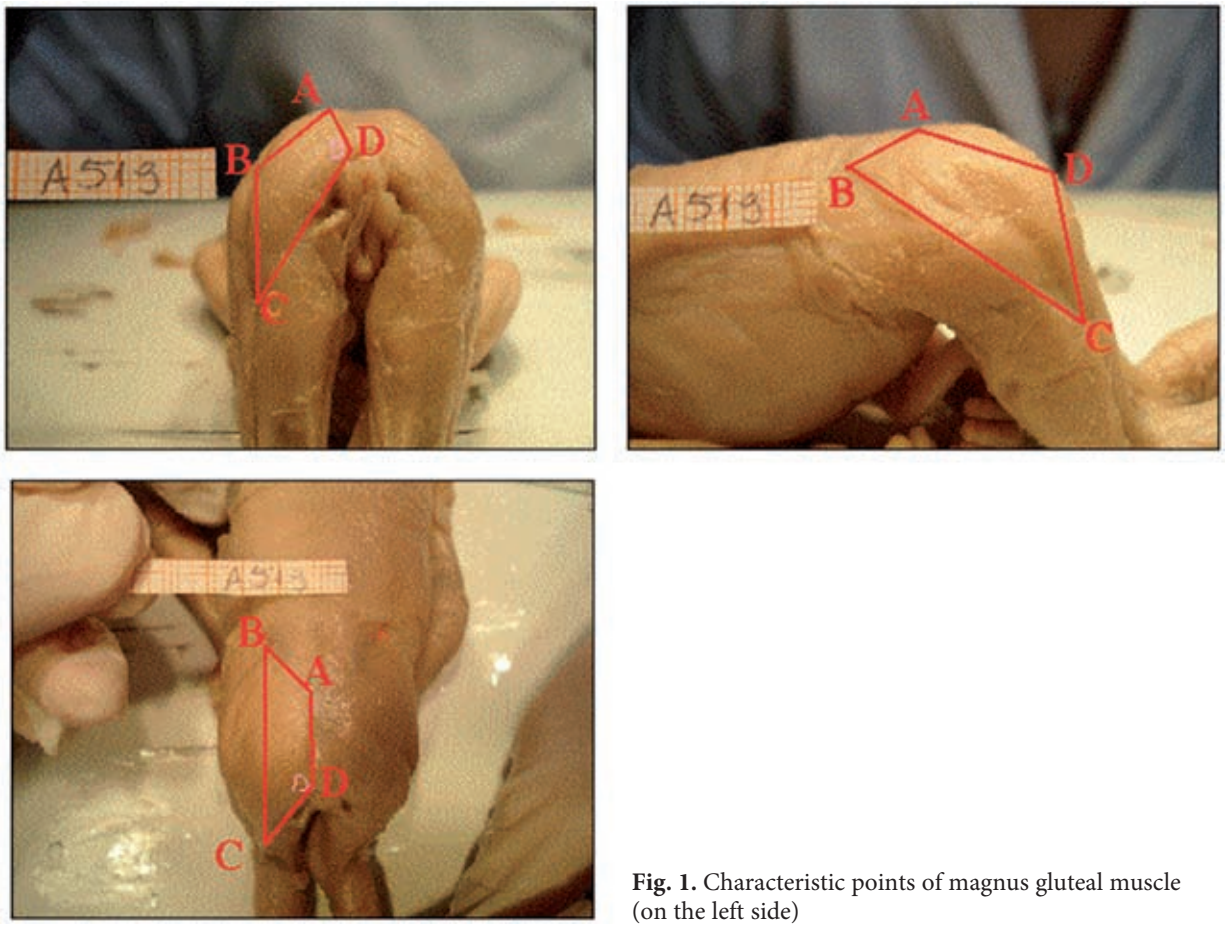


**Fig. 1.** Characteristic points of magnus gluteal muscle (on the left side)

**Table 1.** Characteristics of somatic features of 77 foetuses

| Age group | N | Sex | Vertex tuberale (mm) | | Vertex plantare (mm) | | Body mass (g) | |
|---|---|---|---|---|---|---|---|---|
| | | | M | SD | M | SD | M | SD |
| I | 0 | F | – | – | – | – | – | – |
| (17. and 18. week) | 8 | M | 118.2 | 9.4 | 165.6 | 15.7 | 94 | 22 |
| | 8 | FM | 118.2 | 9.4 | 165.6 | 15.7 | 94 | 22 |
| II | 8 | F | 148.4 | 5.2 | 211.4 | 7.9 | 208 | 57 |
| (19. and 20. week) | 7 | M | 148.4 | 5.7 | 215.0 | 9.3 | 230 | 34 |
| | 15 | FM | 148.4 | 5.2 | 213.1 | 8.4 | 218 | 48 |
| III | 14 | F | 166.2 | 7.0 | 241.6 | 19.9 | 273 | 62 |
| (21. and 22. week) | 20 | M | 168.5 | 5.5 | 237.4 | 26.5 | 290 | 36 |
| | 34 | FM | 167.6 | 6.2 | 239.2 | 23.7 | 283 | 48 |
| IV | 8 | F | 188.8 | 8.3 | 277.2 | 10.3 | 431 | 70 |
| (23, 24 and 22. week) | 12 | M | 185.1 | 7.8 | 260.2 | 25.0 | 348 | 92 |
| | 20 | FM | 186.6 | 8.0 | 267.1 | 21.8 | 381 | 92 |

M – mean; SD – standard deviation.

**Table 2.** Basic statistics (mean value ± standard deviation) of magnus gluteal muscle of 77 foetuses and *t*-Student test results for related variables

| Gluteal muscle size | Left side | Right side | *t*-Student test results |
|---|---|---|---|
| AB length (mm) | 10.4 ± 2.7 | 10.4 ± 2.8 | p = 0.991 |
| AD length (mm) | 12.1 ± 2.7 | 12.3 ± 2.8 | p = 0.119 |
| BC length (mm) | 30.6 ± 5.6 | 30.9 ± 5.5 | p = 0.473 |
| CD length (mm) | 41±7,3 | 41±7,3 | P = 0,520 |
| ABC angle (°) | 76 ± 17 | 75 ± 17 | p = 0.306 |
| ADC angle (°) | 137 ± 9 | 141 ± 9 | p = 0.001 |
| BAD angle ((°) | 138 ± 11 | 135 ± 9 | p = 0.015 |
| BCD angle (°) | 45 ± 12 | 45 ± 11 | p = 0.751 |
| Area ($mm^2$) | 401 ± 132 | 411 ± 148 | p = 0.156 |

Significant differences at p < 0.05 level were marked.

male foetuses did not differ significantly in respect of somatic features (Fig. 2 – p > 0.05)

## Symmetry Analysis

Significant differences at p < 0.05 level were marked.

No statistically significant difference was found between left and right side sizes (p > 0.05) (Fig. 3, Table 2). Only ADC angle and BAD angle sizes reveal asymmetry. However, this may have resulted from the foetus' uneven position during the photos being taken.

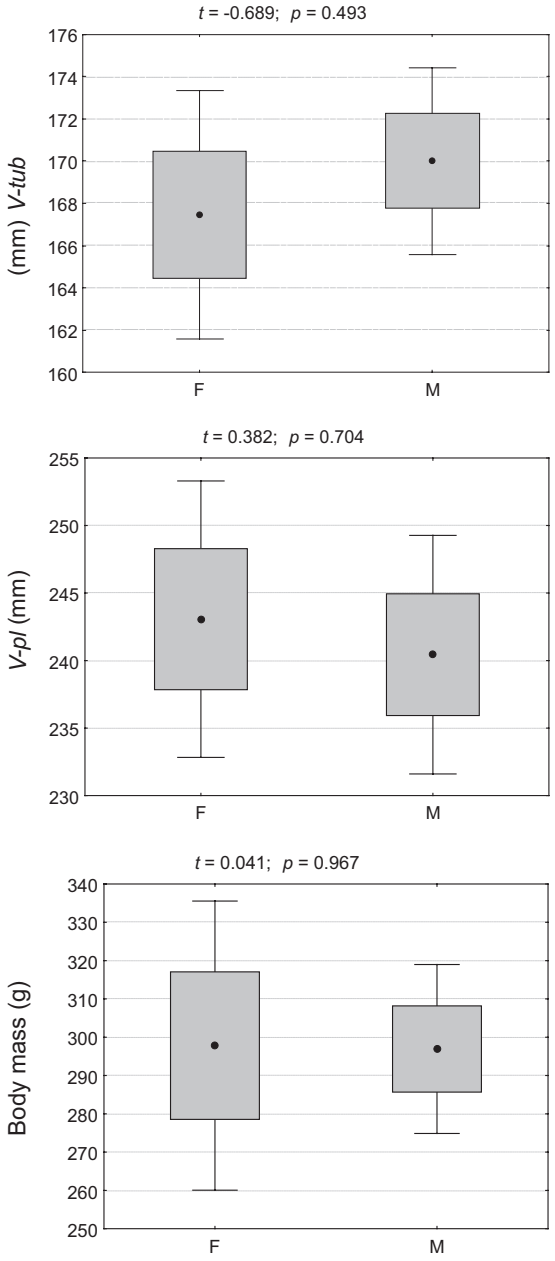


**Fig. 2.** Comparison of somatic features in female and male foetuses, and *t*-Student test results for unrelated variables.

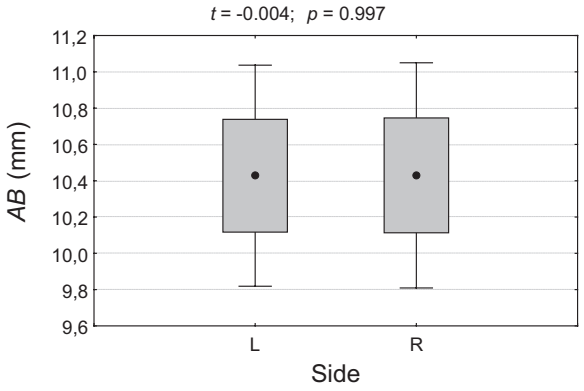


**Fig. 3.** AB lengths comparison on the left and right sides and *t*-Student test results for related variables

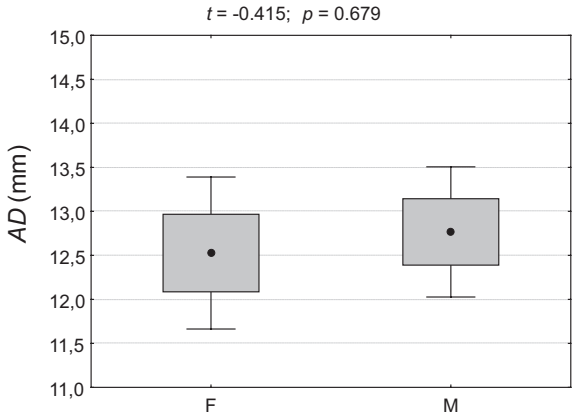


**Fig. 4.** AD lengths comparison in female (F) and male (M) foetuses and *t*-Student test result for unrelated variables

## Sexual Dimorphism Analysis

As the analysed material in age group I (17–18 weeks) did not contain female foetuses, sexual dimorphism analysis was carried on in groups II, III and IV (Fig. 4).

Due to no statistically significant symmetry (Table 3), magnus gluteal muscle size was taken on the left and right sides conjointly and for this group, mean values as well as standard deviations were defined (Table 4).

No statistically significant sexual dimorphism was observed. Length and area sizes of both sexes do not differ significantly ($p > 0.05$).

AB and AD distances were taken in YZ plane, BC distance was measured in XZ plane and CD distance was taken in XY plane (Fig. 6). Magnus gluteal muscle area was defined as the total of ABD, BDE and CDE triangles areas.

Magnus gluteal muscle area increases irregularly. From 17th till 20th, area accession amounts to 59 mm$^2$, from 21th to 25th week to 70 mm$^2$ on average (Fig. 7).

Mathematical model describing this process ($R^2 = 0.798$) is an exponential model:

$$F = 18.06 \times \exp(0.144 \times \text{week}).$$

**Table 3.** Basic statistics (mean value ± standard deviation) of magnus gluteal muscle sizes in 69 foetuses and *t*-Student test results for unrelated variables

| Magnus gluteus muscle size | Female foetuses | Male foetuses | *t*-Student test results |
|---|---|---|---|
| AB length (mm) | 11.1 ± 2.5 | 10.7 ± 2.2 | p = 0.413 |
| AD length (mm) | 12.5 ± 2.4 | 12.8 ± 2.4 | p = 0.679 |
| BC length (mm) | 32.0 ± 5.2 | 31.3 ± 4.0 | p = 0.512 |
| CD length (mm) | 22.9 ± 4.1 | 23.1 ± 4.0 | p = 0.867 |
| AB+BC length (mm) | 43.2 ± 6.9 | 42.0 ± 4.9 | p = 0.399 |
| A–A distance (mm) | 5.1 ± 1.9 | 5.5 ± 1.7 | p = 0.355 |
| B–B distance (mm) | 17.6 ± 3.4 | 17.5 ± 3.2 | p = 0.847 |
| C–C distance (mm) | 27.9 ± 5.1 | 28.9 ± 3.6 | p = 0.352 |
| D–D distance (mm) | 4.9 ± 1.8 | 5.4 ± 1.9 | p = 0.230 |
| ABC angle (°) | 77 ± 16 | 76 ± 16 | p = 0.934 |
| ADC angle (°) | 141 ± 9 | 139 ± 6 | p = 0.202 |
| BAD angle ((°) | 133 ± 9 | 139 ± 8 | p = 0.004 |
| BCD angle (°) | 46 ± 12 | 44 ± 8 | p = 0.308 |
| Area (mm$^2$) | 444 ± 131 | 382 ± 135 | p = 0.053 |

**Table 4.** Basic statistics (mean value ± standard deviation) of linear and angular sizes of magnus gluteal muscle as well as linear regression index of *b* size and age of 77 foetuses

| Size | Age group (week of foetal life) | | | | *b* (mm/week) |
|---|---|---|---|---|---|
| | 17–18 *N* = 8 | 19–20 *N* = 15 | 21–22 *N* = 34 | 23–25 *N* = 20 | |
| A–A distance (mm) | 4.8 ± 1.3 | 4.4 ± 1.8 | 5.3 ± 1.5 | 6.2 ± 1.9 | 0.23 |
| B–B distance (mm) | 13.0 ± 2.5 | 15.7 ± 3.7 | 17.0 ± 2.5 | 19.8 ± 3.1 | 0.98 |
| C–C distance (mm) | 20.8 ± 2.4 | 25.7 ± 4.2 | 28.3 ± 4.1 | 30.9 ± 3.4 | 1.48 |
| D–D distance (mm) | 5.4 ± 1.1 | 4.3 ± 1.7 | 5.4 ± 1.8 | 5.6 ± 1.8 | 0.12 |
| AB length (mm) | 6.8 ± 2.4 | 9.8 ± 2.2 | 10.6 ± 2.0 | 12.1 ± 2.6 | 0.76 |
| AD length (mm) | 8.4 ± 2.5 | 11.8 ± 1.9 | 12.4 ± 2.4 | 13.8 ± 2.6 | 0.75 |
| BC length (mm) | 22.8 ± 3.8 | 29.4 ± 2.8 | 30.8 ± 4.1 | 34.8 ± 4.8 | 1.67 |
| CD length (mm) | 15.2 ± 3.7 | 21.9 ± 3.3 | 22.2 ± 3.7 | 25.3 ± 4.3 | 1.44 |
| AB + BC length (mm) | 29.6 ± 4.5 | 39.2 ± 4.5 | 41.3 ± 4.6 | 47.0 ± 6.2 | 2.44 |
| ABC angle (°) | 73 ± 14 | 78 ± 18 | 76 ± 15 | 73 ± 17 | – |
| ADC angle (°) | 134 ± 9 | 141 ± 7 | 139 ± 8 | 140 ± 8 | – |
| BAD angle (°) | 139 ± 3 | 137 ± 8 | 135 ± 9 | 136 ± 9 | – |
| BCD angle (°) | 45 ± 13 | 42 ± 11 | 46 ± 9 | 45 ± 11 | – |

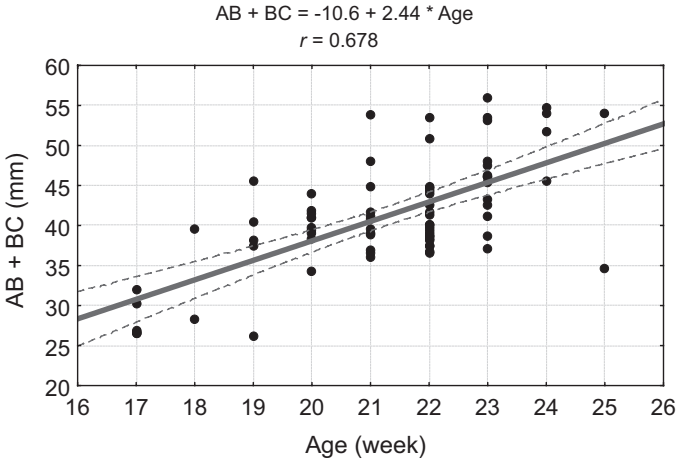


**Fig. 5.** Correlation diagram of AB and BC sections total length and foetal age

# Discussion

Muscular system development with special regard to particular muscles has been repeatedly examined by many authors. In one of the first available publications, Bardeen and Lewis [15] followed the first stages of human embryo formation and observed lower limb structures differentiation till the end of 7th week of foetal period [15]. Other papers present early embryonal stages of foetal development and discuss mainly its histological aspect [16, 17].

The latest techniques enabling image acquisition as well computer programmes for measurements and statistical analyses allow highly accurate morphometric observation of foetal muscles [11, 12]. Available literature provides only one publication presenting magnus gluteal muscle morphometry analysis in human foetuses. The paper by Kołaczkowski and Taboła [10] based on smaller material (25 foetuses) with the use of primitive (available at those times) instruments such as a magnifying glass and a nonius scale scroll bar. The authors presumed that magnus gluteal muscle was diamond-shaped. In this shape the following measurements were made: proximal, medial and distal widths, superior and inferior lengths and attachments lengths. The results were not

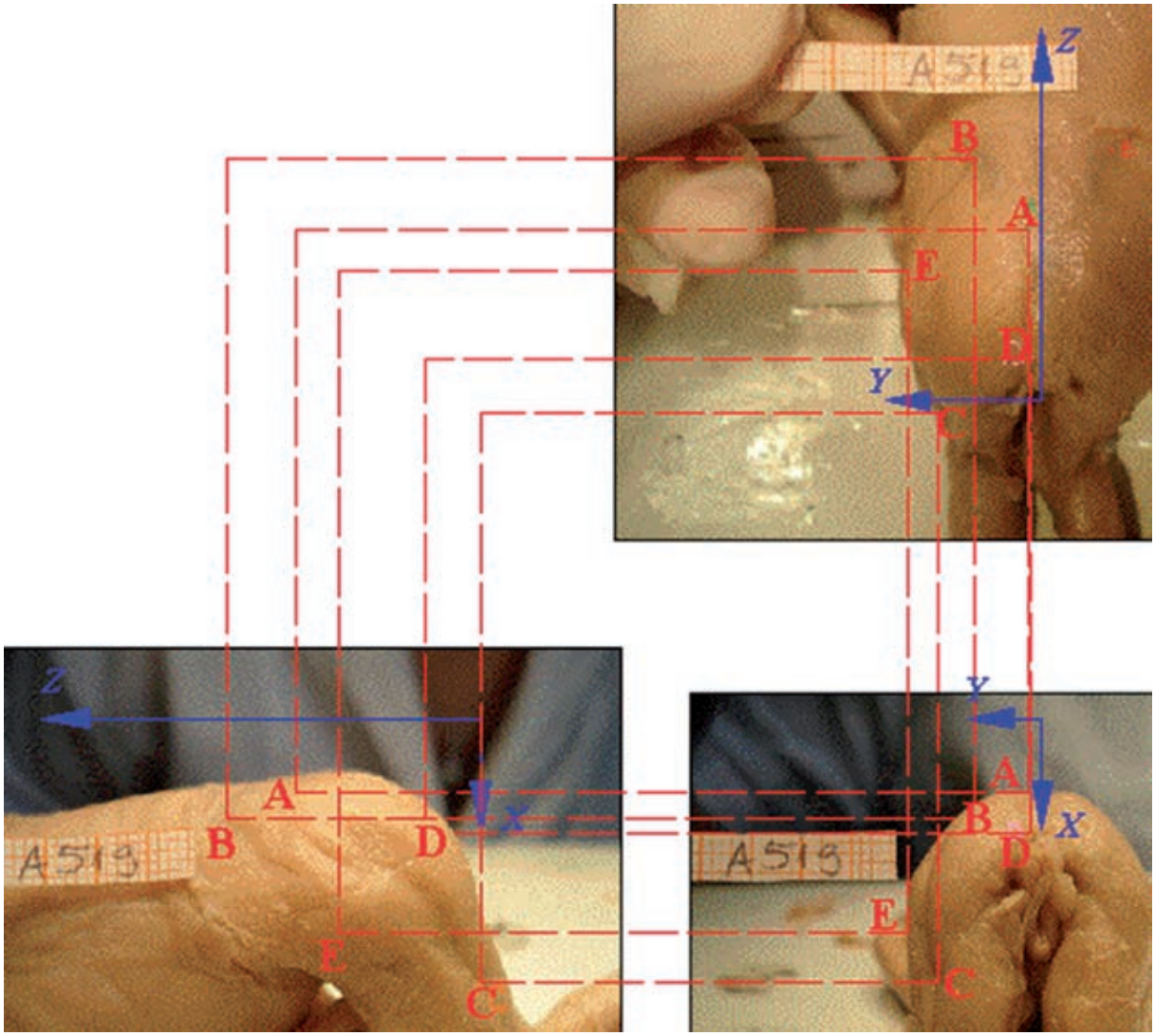


**Fig. 6.** Example photographs of A519 foetus (F, 20th week, *v-tub* = 154 mm) magnus gluteal muscle coordinate system and three-dimensional model of magnus gluteal muscle

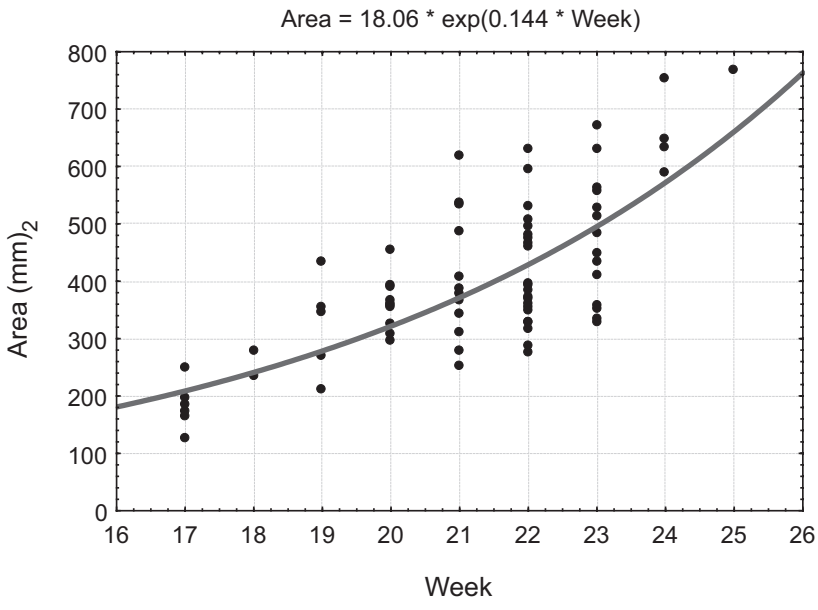


**Fig. 7.** Correlation diagram of magnus gluteal muscle area and foetal age

statistically analysed. However, the abovementioned authors' results correspond with this paper's conclusion. They pointed to the good formation of the muscle and its similarity to the ones found in adult individuals. In the presented study, no asymmetry, sexual dimorphism, somatic variability or developmental anomalies were found in the examined muscle. However, magnus gluteal muscle dissimilarities, such as its duplication, have already been observed [1]. It suggests that the majority of magnus gluteal muscle abnormalities and deformations get acquired during individual life. Magnus gluteal muscle morphology stability is important in the aspect of its use in plastic and reconstructive surgery procedures. The available literature provides a number of papers discussing muscular or dermatomuscular flaps application as autologous grafts in genitourinary interseptum reconstruction [8], breast reconstruction after neoplastic disease [18, 19] or gluteal area defects due to bedsores [7]. Magnus gluteal muscle plays an important role in orthopaedic surgery. In his paper, Whiteside presents operative procedure description of stitching down the belly of the gluteal muscle into magnus trochanter. The operation was performed in 11 patients after complete hip arthroplasty in whom Trendelburg's positive symptom had been observed. The procedure aimed at hip abduction restoration and walking stability restoration. In 9 patients, the goal was achieved [3, 4] which confirms magnus gluteal muscle importance in human organism.

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