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Authors: Krzysztof Koptas, Krystian Maślanka, Nicol Zielinska, Ewa Klejman, Łukasz Olewnik

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The deltoid muscle: a proposed classification system on human fetuses

Krzysztof Koptas[1], Krystian Maślanka[1], Nicol Zielinska[2], Ewa Klejman[3], Łukasz Olewnik[2]

[1]Department of Anatomical Dissection and Donation, Medical University of Lodz, Łódź, Poland

[2]Department of Clinical Anatomy, Masovian Academy in Plock, Płock, Poland

[3]Department of Biostatistics and Translational Medicine, Medical University of Lodz, Łódź, Poland

Address for correspondence: Łukasz Olewnik, MD, PhD, Department of Clinical Anatomy, Masovian Academy in Plock, Plac Dąbrowskiego 2, 09–402 Płock, Poland; e-mail: lukaszolewnik@gmail.com

ABSTRACT

Background: The deltoid muscle originates from the spine of the scapula, the lateral border of the acromion and the lateral third of the clavicle. It inserts on the deltoid tuberosity. It is divided into three parts: spinal, acromial and clavicular. Our research shows that each part of the deltoid muscle can have up to three bellies during prenatal life.

Materials and methods: The material included 80 upper limbs of spontaneously-aborted human fetuses (32 male, 48 female; Central European population), 18–38 weeks of gestation at the time of death.

Results: Each part had one (Type I), two (Type II) or three (Type III) bellies. In all parts, the most common form was Type I: it was present in 81.25% of cases in the clavicular part, 73.75% in the acromial part and 57.5% in the spinal part. In contrast, Type III was the rarest form in all parts: it was present in 3.75% of cases in the clavicular part, 12.5% in the acromial part and 7.5% in the spinal part.

Conclusions: The deltoid muscle is characterized by morphological variability, even in fetuses.

Keywords: deltoid muscle, shoulder girdle, human fetuses, prenatal development

INTRODUCTION

The deltoid muscle is associated with shoulder girdle musculature [7]. It originates from the spine of the scapula, the lateral border of the acromion and the lateral third of the clavicle. It inserts on the deltoid tuberosity, located on the lateral humeral shaft [27]. The muscle generally speaking consists of three parts: the spinal deltoid or posterior part, the acromial deltoid or middle part, and the clavicular deltoid or anterior part [7, 21].

The deltoid muscle is responsible for various movements depending on which parts are involved. When all three parts of the deltoid muscle contract, it assists the humerus in abduction past 15 degrees. Although the deltoid muscle does not initiate abduction. The clavicular part is responsible for shoulder flexion and medial rotation. The spinal part allows lateral rotation and shoulder extension [7, 11]. The deltoid muscle is crucial in sports involving an overhead throwing motion, such as volleyball [22] and softball [19].

Studies of the variations of the deltoid muscle in adults indicate that each of its parts may be absent or undeveloped [9, 18, 25]. Mori [23] observed that each part can be separated from the rest of the deltoid muscle and, in some cases, it has been found that the deltoid muscle can be fused with the pectoralis major muscle [10, 26]. However, no studies have examined the variability of the deltoid muscle in human fetuses.

Although previous studies have explored the development of the deltoid muscle during intrauterine life [2, 3], the present study is the first to focus on the variation of the deltoid muscle. The status of the deltoid muscle has medical significance, especially when an anterior surgical approach is necessary, such as in the case of open Bankart repair [6], shoulder arthroplasty [4] or remplissage [20].

The aim of the present study is therefore to examine the anatomical variation in the deltoid muscle present in the fetus during gestation. To achieve this, a series of morphometric measurements were performed on a large sample of 80 upper limbs.

MATERIALS AND METHODS

Anatomical dissection protocol

All upper limbs were carefully investigated for visible signs of defects. All kinds of mechanical damage, visibly underdeveloped or unevenly developed upper limbs were treated as defects. Limbs with such signs were excluded from further examination. Whole dissection procedures were carefully performed using microsurgical scissors with curved blades and microsurgical forceps to minimize the probability of damaging muscle. Cuts were made parallel to the muscle surface. Every dissection started with the removal of the skin and subcutaneous tissue from the shoulder and upper arm regions. After cutting the skin, the deltoid facia was removed. The surface of the exposed deltoid muscle was cleaned.

Samples and measurements

Eighty upper limbs of 40 spontaneously-aborted and unborn human fetuses (32 males obtained from 16 male fetuses, 48 females obtained from 24 female fetuses; Central European population), 18–38 weeks of gestation at the time of death were studied.

The age of the fetuses was determined based on crown-rump length [14].

All measurements were made with an electronic digital caliper (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan). The Bioethics Committee of the Medical University of Lodz approved the study protocol (RNN/1337/20/KE).

After dissection, crown-rump length was measured, as was the number of bellies of the deltoid muscle and its fusion with the pectoralis major muscle. In addition, various morphometric measurements (Fig. 1) of the deltoid were taken such as:

- width of each belly origin,
- length of each belly,
- thickness of each belly in the half-length.

Creating a classification

The samples were classified based on the number of bellies in each part of the deltoid muscle (the spinal deltoid, the acromial deltoid and the clavicular deltoid). Bellies which were components of one part of the deltoid muscle fused at the insertion.

Statistical analysis

The normality of the distribution of all tested morphometric parameters was confirmed using the Shapiro–Wilk test. Following this, the parameters were compared with regard to muscle type, side and sex using the Student's t-test. Continuous variables were reported as means with standard deviation (SD). Statistical analysis was performed with Statistica 13.1 software (TIBCO, Palo Alto, CA, USA).

Nominal variables were compared using the Chi-squared test, with or without Yates' continuity correction or using Fisher's exact test. The study group characteristic was compared with literature values using one sample proportion z-test. Results with p-values lower than 0.05 were regarded as statistically significant. In the absence of additional information, the results are presented as mean and standard deviation.

RESULTS

The deltoid muscle was present in all 80 dissected limbs. All of the deltoid muscles consisted of clavicular, acromial and scapular parts. Each part can have from one to three bellies. The bellies were visibly separated one from each other.

Types in the clavicular part

Type I (65 limbs: 81.25%) — one belly with its origin on the anterior margin of the lateral third of the clavicle (Fig. 2A). The inferior part of the belly merges with the muscle fibers of the remaining parts of the deltoid muscle.

Type II (12 limbs: 15%) — two belies with origins on the anterior margin of the lateral third of the clavicle. Belly attached medially is medial belly of the clavicular part of the deltoid muscle. Belly attached laterally is lateral belly of the clavicular part of the deltoid muscle (Fig. 2B). The inferior parts of the bellies merge with each other. Following this, the common muscle fibers of the clavicular part merge with the muscle fibers of the remaining parts of the deltoid muscle.

Type III (three limbs: 3.75%) — three belies with origins on the anterior margin of the lateral third of the clavicle. Belly attached medially is the medial belly of the clavicular part of the deltoid muscle. Belly attached laterally is the lateral belly of the clavicular part of the deltoid muscle. Belly with origin between medial and lateral belly of the clavicular part of the deltoid muscle is intermedial belly of the clavicular part of the deltoid muscle (Fig. 2C). Inferior parts of bellies merges with each other. Following this, the common muscle fibers of the clavicular part merges with muscle fibers of the remaining parts of the deltoid muscle.

Types in the acromial part

Type I (59 limbs: 73.75%) — one belly with its origin on the lateral border of the acromion (Fig. 3A). The inferior part of the belly merges with the muscle fibers of the remaining parts of the deltoid muscle.

Type II (11 limbs: 13.75%) — two bellies with origins on the lateral border of the acromion. Belly attached anteriorly is anterior belly of the acromial part of the deltoid muscle. Belly attached posteriorly is posterior belly of the acromial part of the deltoid muscle (Fig. 3B). The distal parts of the bellies merge with each other. Following this, the common muscle fibers of the acromial part merge with the muscle fibers of the remaining parts of the deltoid muscle.

Type III (10 limbs: 12.5%) — three bellies with origins on the lateral border of the acromion. Belly attached anteriorly is the anterior belly of the acromial part of the deltoid muscle. Belly attached posteriorly is the posterior belly of the acromial part of the deltoid muscle. Belly with origin between anterior an posterior belly of the acromial part of the deltoid muscle is the lateral belly of the acromial part of the deltoid muscle (Fig. 3C). The inferior parts of the bellies merge with each other. Following this, the common muscle fibers of the acromial part merge with the muscle fibers of the remaining parts of the deltoid muscle.

Types of the spinal part

Type I (46 limbs: 57.5%) — one belly with its origin on the spine of the scapula (Fig. 4A). The inferior part of the belly merges with the muscle fibers of the remaining parts of the deltoid muscle.

Type II (28 limbs: 35%) — two bellies with origins on the spine of the scapula. Belly attached medially is the medial belly of the spinal part of the deltoid muscle. Belly attached laterally is the lateral belly of the spinal part of the deltoid muscle (Fig. 4B). The inferior parts of the bellies merge with each other. Following this, the common muscle fibers of the spinal part merge with the muscle fibers of the remaining parts of the deltoid muscle.

Type III (six limbs: 7.5%) — three bellies with the origins on the spine of the scapula. Belly attached medially is the medial belly of the spinal part of the deltoid muscle. Belly attached laterally is the lateral belly of the spinal part of the deltoid muscle. Belly with an origin between medial and lateral belly of the spinal part of the deltoid muscle is intermedial belly of the spinal part of the deltoid muscle (Fig. 4C). The inferior parts of the bellies merge with each other. Following this, the common muscle fibers of the spinal part merge with the muscle fibers of the remaining parts of the deltoid muscle.

Of the 27 possible combinations regarding the arrangement of muscle bellies in the deltoid, 17 were observed in the present study. Statistical analysis was possible only for the following combinations: clavicular type I + acromial type I + spinal type I (n = 36, referred to further as 111) and clavicular type I + acromial type I + spinal type II (n = 15, referred to further as 112). The remaining combinations were too rare for analysis.

Combination 111 was observed in the upper limbs of 24 female and 12 male fetuses. No significant differences in head width, thickness or length were found between sides (i.e. left vs right) in this group.

Combination 112 was noted in the upper limbs of seven female and eight male fetuses. No significant differences were found in morphometric parameters between sides.

Another observed variant of deltoid muscle origin was the fusion between the clavicular part of the deltoid muscle and the pectoralis major muscle (n = 21 limbs) (Fig. 5). The relationship of occurrence of the pectoralis major and deltoid muscles fusion with variation of the deltoid muscle is shown in Table 3. A significant relationship was observed between the occurrence of combination 121 (clavicular type I, acromial type II, spinal type I) and the fusion of the clavicular part of the deltoid muscle (75% vs 26.25%, p = 0.0038). In addition, significantly more fusions were noted in the present study than by Haładaj et al. [10] (26.25% vs 5%, p < 0.0001).

DISCUSSION

To better understand the morphology of the deltoid muscle, it is necessary to review its potential variations. All parts of the deltoid muscle have been reported to be absent or undeveloped in at least one case [9, 18, 25]. Mori [18] observed that parts of the deltoid muscle can be separated from each other. In rare cases, the deltoid muscle can have six to 20 separate sections [13]. The deltoid muscle fibers can blend with the teres major, latissimus dorsi, trapezius and infraspinatus muscles [1, 18].

The fibers of the deltoid muscle that are located most posteriorly can be separated from the rest of the muscle with a fascial sheath [5]. Separation has been classified as perfect separation, imperfect separation and no separation [23]. In the present study, perfect separation was observed in all specimens. We assume that this is due to the ongoing development of the deltoid muscle.

In some cases, the clavicular part of the deltoid muscle may be fused with the pectoralis major muscle [10, 18, 26]. Haładaj et al. [10] report such fusion in 5% of specimens; however, it was far more prevalent in the present study (26.25%). This variation suggests that in some cases, fusion between the deltoid and the pectoralis major muscles may be lost during later development.

The deltoid, infraspinatus, supraspinatus, teres minor and deltoid muscles arise from a common premuscle mass. After reaching 11 mm of the crown-rump length in the embryo, the deltoid muscle partially splits off from the premuscle mass towards its superior attachment from the acromion and the clavicle. When the embryo is 14–16 mm long, the deltoid muscle more closely resembles its fully developed form: a differentiated slip arising from the fascia over the infraspinatus muscle. In 20 mm embryos, the attachments of the deltoid muscle are very similar to the adult form [2, 3].

In the course of our research, we noted the occurrence of one, two or three bellies in each part of the deltoid muscle. We hypothesise that the evolutionary trend involves an increase in the number of bellies. A singular belly exhibits greater strength compared to narrower bellies. The presence of a single belly may have been prevalent among animals with quadrupedal locomotion. As evolution progressed towards a bipedal gait, there was a rise in the number of bellies, potentially influencing the execution of more complex movements with the upper limb.

The morphology of the deltoid muscle influences shoulder girdle biomechanics. It plays a crucial role in sports with overhead throwing motion, such as volleyball [22] or softball [19]. It is possible that the presence of a higher number of muscle bellies provides better control of the humerus. Therefore, in cases where the deltoid muscle is more divided during prenatal life, better shoulder movement performance may be observed after birth.

Fusion of the deltoid muscle with the pectoralis major muscle can be very problematic during surgeries. In some cases, it can even eliminate the deltopectoral triangle. Natsis et al. [24] described such case in adult.

The deltoid muscle is generally classified as being divided into three parts: the spinal deltoid or posterior part, the acromial deltoid or the middle part and the clavicular deltoid or anterior part [7, 21]. However, other approaches to the deltoid muscle division have been proposed. For example, the three parts of the deltoid muscle can be further subdivided [28]. Fick [8] divides the deltoid muscle into seven functional parts, while Lorne et al. [17] note that the deltoid muscle consists of eight half-cone shaped distal fibrous structures which merge together into the tendon of the deltoid muscle and insert into the humerus. Our research has shown that each part of the deltoid muscle consists of one to three parts during ontogeny. The approach to the deltoid muscle division proposed by Williams and Warwick [28] takes into account that each part of the deltoid muscle can be further subdivided. Research made by Fick [8] suggests that the deltoid muscle is divided into seven parts. Although from the point of view of biomechanics, this is correct, our research shows that the most popular approach is also the most reasonable one in the context of fetal development.

The deltoid muscle is, most commonly, innervated by the axillary nerve [15]. The clavicular part of the deltoid muscle can be innervated by the pectoral nerve [16]. The posterior and middle parts of the deltoid muscle are perfused by the posterior circumflex humeral artery, while the anterior part is supplied by the deltoid artery and the acromial artery, i.e. branches of the thoracoacromial artery [12].

Our study has some limitations. Although the sample size (n = 80) is sufficient to construct a reliable classification, a larger sample would enable more accurate statistical analysis. The sample is also geographically constrained, with all of the cadavers coming from the Lodz province in Poland. Therefore, studies conducted on a larger sample and in a different part of the world would aid in the development of a more accurate classification. It is noteworthy that, despite its limitations, this study is the first classification of the deltoid muscle in human fetuses.

CONCLUSIONS

The deltoid demonstrates considerable variation, even during prenatal life. Our data from 80 upper limbs indicates that while each part of the deltoid muscle can be divided into up to three bellies during prenatal life, each part typically has only one belly. We also propose a classification for the deltoid muscle in human fetuses. This is an important addition to current knowledge which we hope will guide the approach of clinicians and scientists to the deltoid muscle.

Article information and declarations

Data availability statement

Please contact authors for data requests (Łukasz Olewnik PhD — e-mail address: lukaszolewnik@gmail.com)

Ethics statement

The cadavers belonged to the Department of Anatomical Dissection and Donation, Medical University of Lodz.

Authors' contribution

Krzysztof Koptas — project development, data collection and management, data analysis and manuscript writing. Krystian Maślanka — data collection, data analysis and manuscript editing. Nicol Zielinska — data collection, data analysis and manuscript editing. Ewa Klejman — data analysis and manuscript editing. Łukasz Olewnik — data collection, data analysis and manuscript editing. All authors have read and approved the manuscript.

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Conflict of interest

The authors declare that they have no competing interests.

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Table 1. Comparison of morphometric parameters of the combination 111 in relation to the sides.

Variable	Mean left	SD left	Mean right	SD right	p-value
WC I	5.81	2.13	5.16	1.50	0.2975
TC I	0.74	0.35	0.74	0.31	0.9809
LC I	20.05	3.59	19.95	4.65	0.9404
WA I	9.41	2.09	8.83	1.99	0.4065
TA I	1.35	0.51	1.09	0.55	0.1577
LA I	22.63	4.08	22.27	4.00	0.7950

WS I	12.92	7.21	10.77	2.70	0.2340
TS I	0.88	0.27	0.97	0.37	0.3983
LS I	21.26	2.48	19.93	3.74	0.2248

I — type I; A — acromial; C — clavicular; L — length; S — spinal; SD — standard deviation; T — thickness; W — width.

Table 2. Comparison of morphometric parameters of the combination 112 with regard to side.

Variable	Mean left	SD left	Mean right	SD right	p-value
WC I	5.67	1.20	5.67	0.70	0.9987
TC I	0.69	0.29	0.50	0.20	0.2185
LC I	19.55	5.06	22.59	1.60	0.2179
WA I	8.96	2.28	9.39	1.78	0.7208
TA I	1.16	0.51	0.84	0.46	0.2589
LA I	21.30	4.13	19.65	10.60	0.6656
WS I	4.36	1.65	5.02	2.02	0.5133
TS I	0.78	0.58	0.66	0.25	0.6718
LS I	18.13	3.07	18.53	3.80	0.8315
WS II	6.48	1.79	7.12	1.13	0.4840
TS II	0.75	0.27	0.74	0.33	0.9560
LS II	22.32	3.19	22.94	4.70	0.7632

I — Type I; II — Type II; A — acromial; C — clavicular; L — length; S — spinal; T — thickness; W — width.

Table 3. The relationship between deltoid muscle combination type and the presence of fusion between the clavicular part of the deltoid muscle with the pectoralis major muscle. The frequency of each type was compared to the population rate (26.25%). The obtained frequencies were compared to the expected rate as reported by Haładaj et al. [10] (5%).

Types	Clavicular — fusion with pectoralis major	p-value
111	30% (11/36)	0.1262
112	33% (5/15)	0.4515
121	75% (3/4)	0.0038

122	20% (1/5)	0.6024
212	25% (1/4)	0.5684
Total	26% (21/80)	< 0.0001

Types are coded as described above: CAS — clavicular, acromial, spinal; numbers 1 to 3 indicate Types I–III as described above.

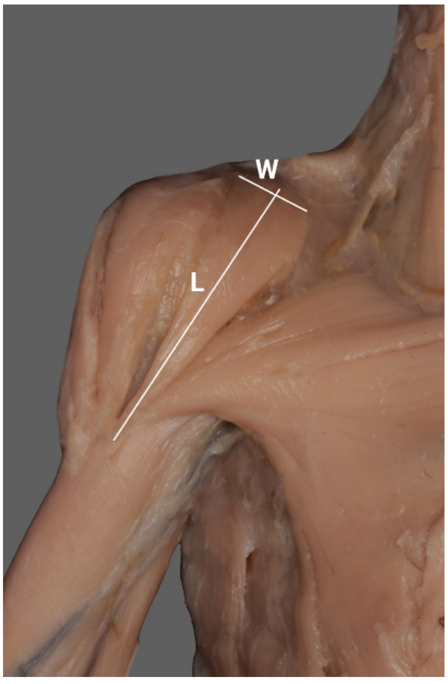

Figure 1. The figure presents type I of the clavicular part of the deltoid muscle. L — length of the belly; W — width of the belly origin.

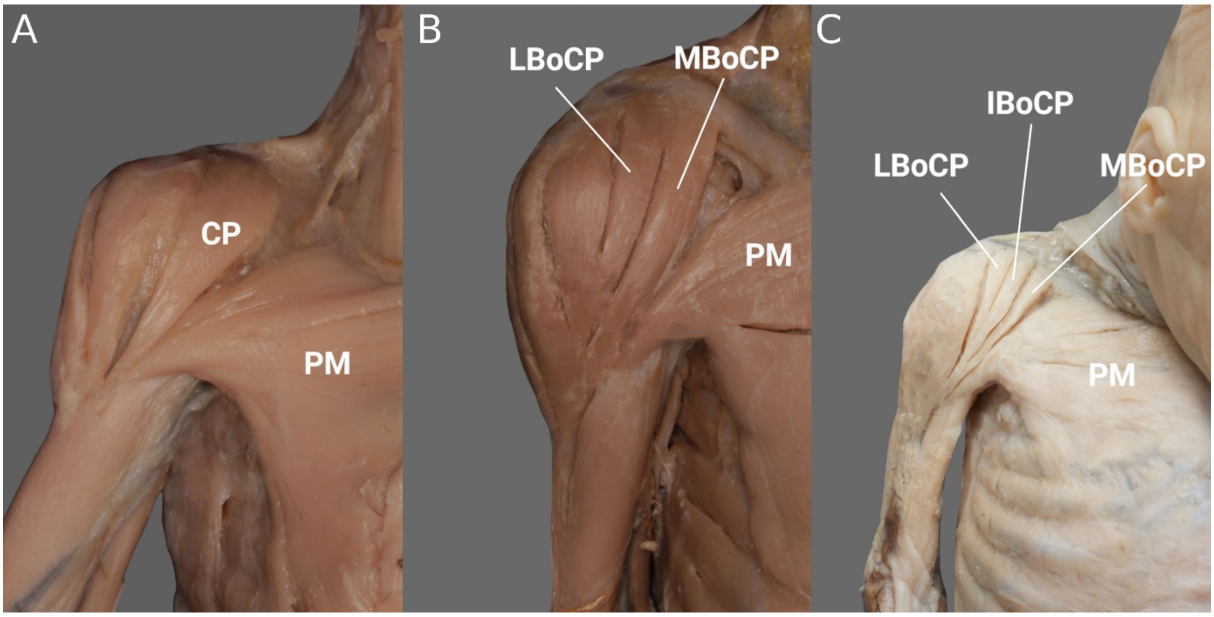

Figure 2. Types of the clavicular part of the deltoid muscle. **A.** Clavicular part Type I; **B.** Clavicular part Type II; **C.** Clavicular part Type III. CP — clavicular part of the deltoid muscle; IBoCP — intermedial belly of clavicular part of the deltoid muscle; LBoCP — lateral belly of clavicular part of the deltoid muscle; MBoCP — medial belly of clavicular part of the deltoid muscle; PM — pectoralis major muscle.

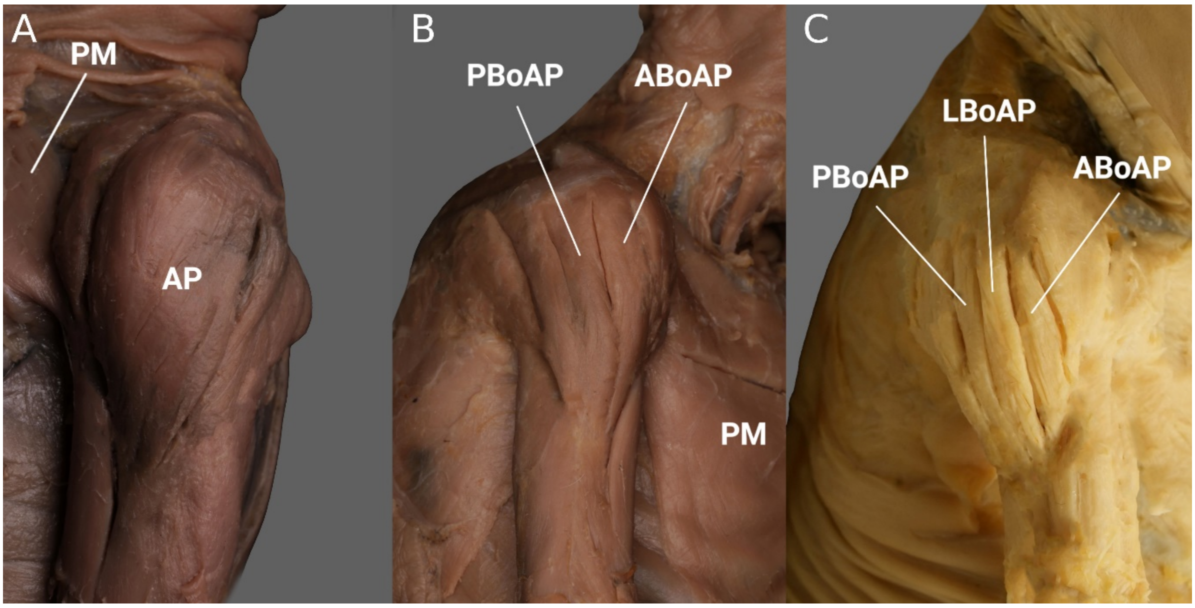

Figure 3. The figure presents types of the acromial part of the deltoid muscle. **A.** Acromial part Type I; **B.** Acromial part Type II; **C.** Acromial part Type III. ABoAP — anterior belly of acromial part of the deltoid muscle; AP — acromial part of the deltoid muscle; LBoAP — lateral belly of acromial part of the deltoid muscle; PBoAP — posterior belly of acromial part of the deltoid muscle; PM — pectoralis major muscle.

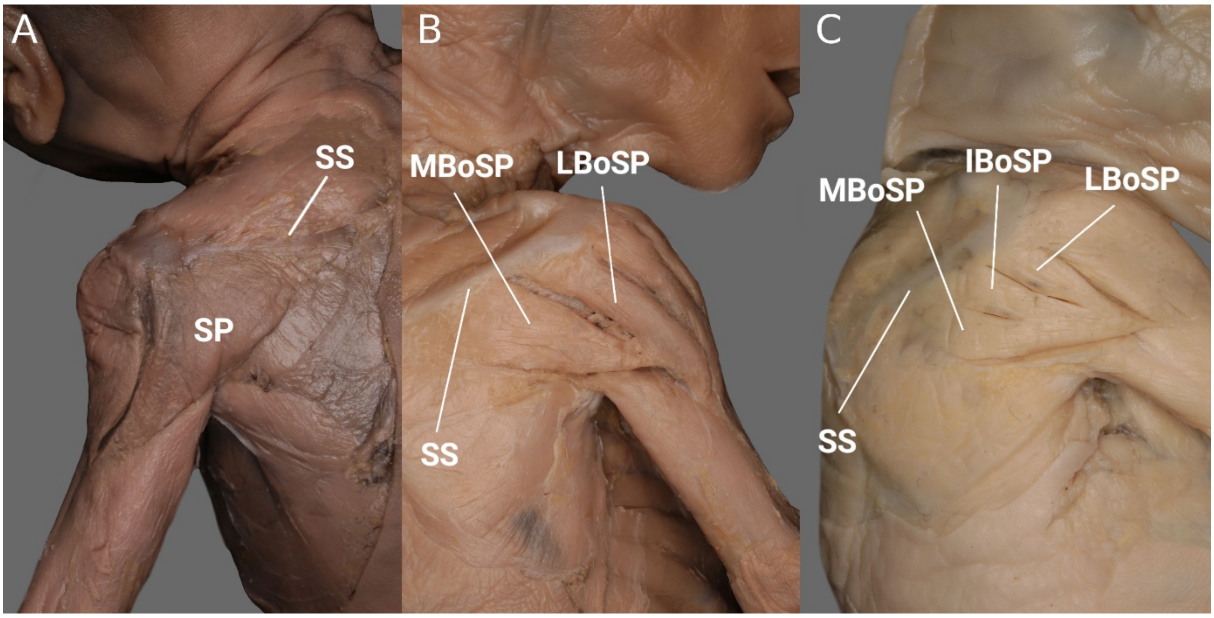

Figure 4. The figure presents types of the spinal part of the deltoid muscle. **A.** Spinal part Type I; **B.** Spinal part Type II; **C.** Spinal part Type III. IBoSP — intermedial belly of spinal part of the deltoid muscle; LBoSP — lateral belly of spinal part of the deltoid muscle; MBoSP — medial belly of spinal part of the deltoid muscle; SP — spinal part of the deltoid muscle; SS — spine of the scapula.

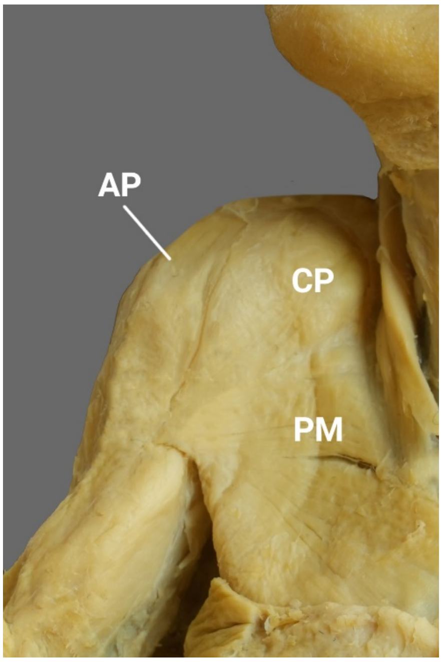

Figure 5. The figure presents fusion between the deltoid muscle and the pectoralis major muscle. AP — acromial part of the deltoid muscle; CP — clavicular part of the deltoid muscle; PM — pectoralis major muscle.