

Accessory thoracic muscles in human fetuses

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Background: Typically, the anterior thoracic wall musculature is composed of the pectoralis major and pectoralis minor. Embryologically, these 2 muscles originate from a common pectoral muscle mass; therefore, disruption of the normal development and differentiation could give rise to an aberrant or accessory muscle. The main aim of this study is to demonstrate and classify the accessory muscles of the pectoralis region in human fetuses.

Material and methods: Fifty spontaneously aborted human fetuses (25 male and 25 female, 100 sides) aged 18–38 weeks of gestation at death, and fixed in 10% formalin solution were examined. Following parental approval, the fetuses were donated to the Medical University anatomy program. The pectoralis major and minor muscle's morphology, the possible occurrence of accessory muscles of the pectoral region and its morphology, their origins, and insertions, as well as the morphometric details, were assessed.

Results: The pectoralis major and minor were bilaterally found in all fetuses (100 cases). The accessory muscles of pectoral region were found in 16 cases (16%), and 4 types were differentiated. The pectoralis quartus muscle was the most common type of accessory muscle found in this study and occurred in 8 cases. The axillary arch muscle was observed in 3 cases. The chondrocoracoideus muscle was observed in 3 cases. The sternalis muscle occurred in 2 cases, and one of them was bifurcated.

Conclusions: The thoracic region is characterised by a large number of morphological variations, which are observed not only in the adult population, but also among human fetuses. The pectoralis quartus was the most frequent variation in this study. Accessory structures like the sternalis muscle, chondrocoracoideus muscle, pectoralis quartus muscle, or axillary arch muscle may have clinical implications, and knowledge about them is very useful for clinicians, especially plastic surgeons, thoracic surgeons, and orthopaedic surgeons. (Folia Morphol 2024; 83, 3: 700–706)

Keywords: pectoral region, pectoralis major muscle, pectoralis minor muscle, sternalis muscle, chondrocoracoideus muscle, pectoralis quartus muscle, axillary arch muscle, human fetuses

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INTRODUCTION

Typically, the anterior thoracic wall musculature is composed of the pectoralis major (PM) and pectoralis minor (PMi). Embryologically, these 2 muscles originate from a common pectoral muscle mass; therefore, disruption of the normal development and differentiation could give rise to an aberrant or accessory muscle [16]. The accessory thoracic muscles (ATM) can be identified with great morphological variability and the most observed ones are the sternalis muscle, the axillary arch (of Langer's), the pectoralis quartus, the chondrocoracoideus (of Wood), the pectoralis intermedius, and the pectoralis minimus (of Gruber) [3]. The morphological variability is high enough that even recently, unreported variations have been found [23].

Several studies have investigated the prevalence and morphology of the abovementioned variations, but few of them have been studied for over 200 years [2]. For example, sternalis muscle pooled prevalence was estimated at 5.96% (adult cadavers) and was classified in 8 different morphological types [2]. Interestingly, the coexistence of accessory thoracic muscles have also been reported, complicating even more the thoracic wall typical anatomy [6].

Except of the great anatomical interest, these variants present with great clinical significance. Accessory muscles of the thoracic wall and axilla should be kept in mind by surgeons performing axillary lymphadenectomy to avoid iatrogenic lesions, while accessory structures are closely related to potential compression sites [13].

Although the thoracic region is morphologically variable, in the available literature there is not a general study carried out among human foetuses. Because these morphological variations may be associated with embryological development, the main aim of this study is to investigate ATM in human foetuses.

MATERIAL AND METHODS

Fifty spontaneously aborted human foetuses (25 male and 25 female, 100 sides) aged 18–38 weeks of gestation at death, and fixed in 10% formalin solution were examined. Following parental approval, the foetuses were donated to the Medical University anatomy program. Their ages were calculated using head and craniosacral measurements. The thoracic wall, abdomen, shoulder region, and anterior and medial regions of the arm were the first areas of the dissection to have their skin and superficial fascia

removed. To visualise muscles of the pectoral region, the subcutaneous tissue had to be removed [22]. If there are no accessory structures, then proximal attachments and the subcutaneous tissue of the PM had to be removed. The PMi structure as a whole was meticulously cleaned. Following dissection, the morphological and morphometric characteristics of ATM were evaluated as follows:

- the PM, and PMi morphology,
- the possible occurrence of ATM,
- the morphometric measurements of ATM.

When dissecting the PM and PMi:

- special attention should be paid when removing the fascia because some accessory muscle could be present in the area.

A digital caliper (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan) with an accuracy of up to 0.01 mm was used for all measurements. The same researcher conducted each measurement twice, recording the mean value of the 2 measurements or calculating the interobserver error. The foetuses belonged to the Department of Anatomical Dissection and Donation at the Medical University of Lodz, Poland, and the study protocol was approved by the Bioethics Committee (resolution RNN/137/20/KE).

RESULTS

The PM and PMi were found bilaterally in 50 foetuses (25 male, 25 female), which means 100 sides (50 R, 50 L). During anatomical dissection, 16 ATM were found (16%). Four different types of ATM were differentiated based on their course. Morphometric measurements of all accessory muscles are listed in Table 1.

Pectoralis quartus muscle — this type of ATM was identified in 8% of studied cases (50% of observed ATM; 4 F, 4 M, 3 R, 5 L). In all cases the point of origin was the fifth or sixth rib. Five cases were distally attached to the bicipital groove located on the humerus, and 3 cases were fused with fascia of the upper limb — Fig. 1.

Axillary arch muscle — this type of ATM was identified in 3% of studied cases (18.75% of observed ATM; 1 F, 2 M, 2 R, 1 L). All cases originating from latissimus dorsi muscle were distally fused with the PM — Fig. 2.

Chondrocoracoideus muscle — this type of ATM was identified in 3% of studied cases (18.75% of observed ATM; 1 F, 2 M, 1 R, 2 L). All cases originated from the sixth or seventh rib and rectus sheath

Table 1. Morphometric measurements of ATM.

	Sex	Side	P.A. width [mm]	P.A. thickness [mm]	M.B. length [mm]	M.J. width [mm]	M.J. thickness [mm]	T. length [mm]	D.A. width [mm]	D.A. thickness [mm]
Pectoralis quartus muscle — 8 cases										
1.	M	L	1.32	0.17	16.84				0.91	0.08
2.	M	L	1.66	0.14	18.59				0.53	0.19
3.	F	L	1.52	0.49	13.77				0.30	0.08
4.	F	R	1.80	0.28	10.39				1.30	0.39
5.	F	R	2.60	0.45	18.16				2.13	0.56
6.	F	L	6.11	0.73	11.13				3.29	0.62
7.	M	R	3.09	0.40	17.82				3.49	0.54
8.	M	L	2.88	0.59	17.36				0.85	0.28
Axillary arch muscle — 3 cases										
1.	M	L	0.63	0.33	8.64				3.44	0.61
2.	M	R	1.02	0.37	7.59				3.71	0.38
3.	F	R	1.61	0.14	12.59				2.94	0.45
Chondrocoracoideus — 3 cases										
1.	F	R	5.36	0.27	19.38	3.17	0.98	5.62	3.31	0.37
2.	M	L	0.67	0.33	23.48	0.46	0.27	6.45	0.45	0.23
3.	M	L	0.68	0.02	16.13	1.13	0.13	6.59	1.47	0.19
Sternalis muscle — 2 cases										
1.	M	R	3.52	0.25	11.21				3.86	0.46
2.	F	L	1.86	0.30	17.03				2.77	0.52

D.A. — distal attachment; M.B. — muscle belly; M.J. — myotendinous junction; P.A. — proximal attachment; T. — tendon.

as a muscle belly. Two cases were distally fused as a tendinous structure with the short head of the biceps brachii and attached to the coracoid process. One case was distally attached as a tendinous structure directly to the coracoid process — Fig. 3.

Sternalis muscle — this type of ATM was identified in 2% of studied cases (12.5% of observed ATM; 1 F, 1 M, 1 R, 1 L). The first case originated from the body of sternum at level of the second intercostal space as a single muscular band and inserted to the fifth rib — Fig. 4a. The second case originated from distal part of sternocleidomastoid muscle and sternum, as bifurcated muscle belly distally merged into one belly attaching to the sixth and seventh ribs — Fig. 4b.

DISCUSSION

The pectoralis region is characterised by high morphological variability, and the main cause of it is the abnormal development of pectoral muscle mass [3]. The PM and PMi originate from the same pre-muscle mass in the first embryonic stage (5-week embryo), which is derived from the proximal part of the hu-

merus and the second rib. There are 2 layers in this pre-muscle mass: a superficial layer for the development of the PM and a deep layer for the development of the PMi and subclavius. The pre-muscle structure of the pectoral mass grows inferiorly during the early stages of embryogenesis. In an 11 mm embryo, PM and PMi are represented by a common mass attached to the humerus, clavicle, and CP. In a 14 mm embryo, the caudal portion of this structure extends to the tip of the fifth rib. At that point, the distal connection is still merged, but the proximal portion splits into the PM (insertion to humerus) and Pm (insertion to the CP) [5, 10]. These 2 muscles are separated in a 16 mm embryo. Interestingly, one piece of information found in the literature that is currently available states that the PM is separated into 3 bellies during embryological development [10].

The disrupted process of embryological development seems to be the best explanation for the occurrence of different morphological variants. What is interesting, the frequency of muscular variations in the thoracic region is significantly higher than in any other region [7].

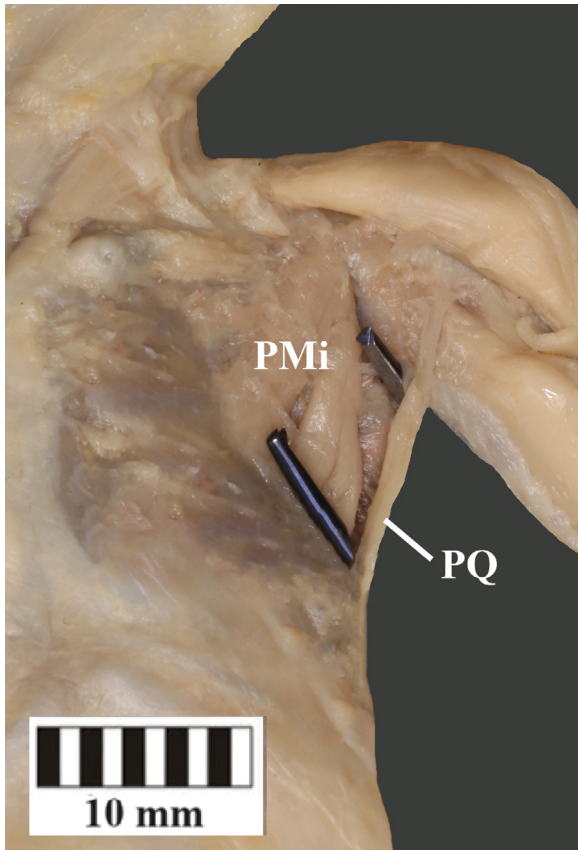


Figure 1. Pectoralis quartus muscle. PMi — pectoralis minor muscle; PQ — pectoralis quartus muscle.

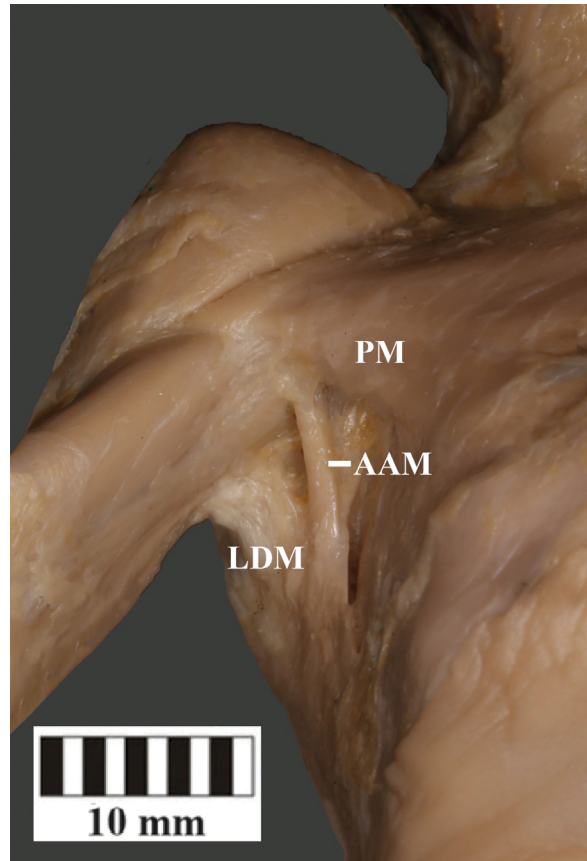


Figure 2. Axillary arch muscle. AAM — Axillary arch muscle; LDM — latissimus dorsi muscle; PM — pectoralis major muscle.

Standard muscles, like PM and PMi, may be variable because of various locations or places of insertions and levels of proximal attachment [2]. The results of some studies [21, 23] showed that the PM and PMi may be divided into types based on the number and course of bellies, and these differences are observed already in the embryonic stage [20].

It is interesting to note that the PM or PMi may not exist at all. However, there are situations where the PM or PMi is double [3]. A large group of morphological variations within the chest comprise additional muscles. The pectoralis quartus, the pectoralis intermedius, the pectoralis minimus, the chondrofascialis, the sternohumeralis, the sternochondrocoracoideus, the axillary arch muscle, the pectoralis tertius, the chondroepitrochlearis, and the chonrocoracoideus muscles are included in this group. There is an immense amount of confusion because these muscular variances are referred to by a variety of names [3].

In the present study the PM and PMi were found bilaterally in all foetuses, and the ATM were observed in 16% of studied cases. The most common type

of ATM was the pectoralis quartus muscle, which occurred in 50% of foetuses with ATM. Usually the pectoralis quartus originates from the fifth or sixth rib, and the lateral border of the PM, or the rectus sheath. It may insert into the bicipital groove of the humerus or the fascia of the upper arm [3]. In the present study, in all cases, the point of origin was the fifth or sixth rib. Five cases were distally attached to the bicipital groove located on the humerus, and 3 cases were fused with the fascia of the upper limb. The prevalence of this muscle in available literature varies. For example Natsis et al. [3] found the pectoralis quartus in 2.8% of studied cases; in turn, Bonastre et al. [6] found rates as high as 11% to 16%. The results of our study showed that prevalence of the pectoralis quartus is closer to the results obtained by Bonastre et al. [6], who also described the coexistence of a pectoralis quartus muscle with an unusual axillary arch muscle, and the pectoralis quartus originating from the rectus sheath, fused with the inferior medial border of the axillary arch band at the point of lateral part of the PM [6]. What is interesting, not only Bonastre et al.

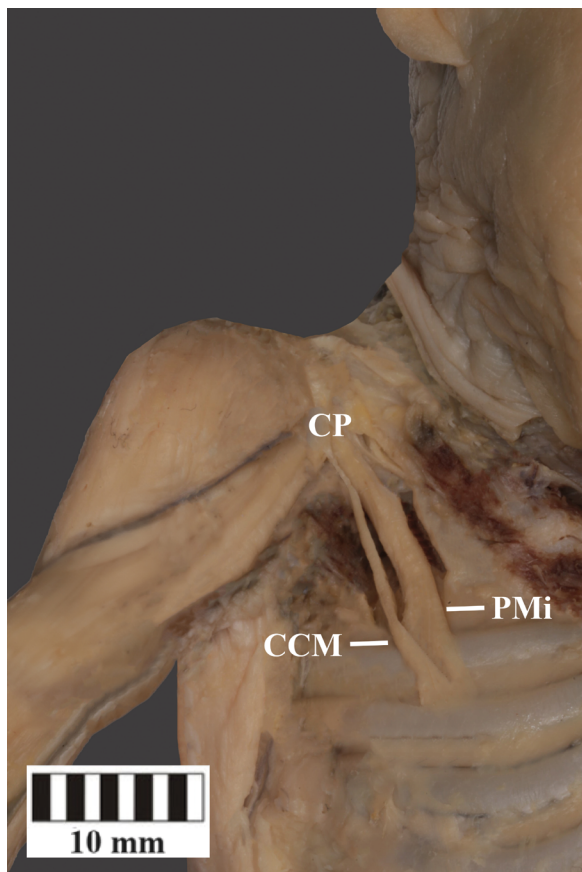


Figure 3. Chondrocoracoideus muscle. CCM — chondrocoracoideus muscle; CP — coracoid process; PMi — pectoralis minor muscle.

[6] described the pectoralis quartus coexisting with another variation, but also Arican et al. [1] described the pectoralis quartus muscle (originating from the 5th and 6th ribs, forming a long flat band inserted into the intertubercular groove of the humerus and tendon of the shorth head of the biceps brachii) coexisting with the pectoralis intermedius muscle [1].

The axillary arch muscle is another interesting type [23] of ATM found in the present study, and its prevalence was 18.75%, which was significantly higher than in previous studies. For example, Rizk and Harbaugh [14] assessed its frequency at 4.3%, Bertone et al. [4] at 11.5%, and Karanlik et al. [9] at 1.2%. The axillary arch muscle, first described by Bugnone in 1783 [4], usually originates from the latissimus dorsi muscle, and its insertion is fused with the PM, and in the present study the proximal and distal attachments were the same in all cases. However, this structure can also be variable. All cases described, as mentioned, by Rizk and Harbaugh [14] arose from the latissimus dorsi muscle, and its inser-

tion was located on the intertubercular groove. In the other study, there were some cases distally attached to the aponeurosis level of the coracobrachialis muscle [4]. In the literature there are also descriptions of axillary arch muscle distally attached to the PM, PMi, and coracoid process [11] or short head of the biceps brachii [17].

The chondrocoracoideus muscle (sometimes called the costocoracoideus or muscle of Wood) [21] is another example of ATM observed in the present case, which was identified in 3% of studied cases. As mentioned above, all cases originated from the sixth or seventh rib and rectus sheath. Two cases were distally fused with the shorth head of the biceps brachii and attached to the coracoid process. One case was distally attached as a tendinous structure directly to the coracoid process cases. It is a very rare variation, so in the literature there are very few described cases. One of them is the chondrocoracoideus muscle originating as 3 distinct slips from the sixth to eighth ribs and external oblique aponeurosis. Its distal attachment was represented as a small fusion with the tendon of the shorth head of the biceps brachii and as a common junction was inserted to the coracoid process [18]. Another case concerned the chondrocoracoideus originating from the sixth to eighth ribs and the external oblique muscle aponeurosis, and distally attached to the coracoid process, as a small fusion with the short head of the biceps brachii [8].

Another interesting variation is sternalis muscle, observed in 2% of studied cases. The first case originated from the body of sternum at level of the second intercostal space as a single muscular band and inserted into the fifth rib. The second case originated from distal part of the sternocleidomastoid muscle and sternum, as bifurcated muscle belly distally merged into one belly attaching to the sixth and seventh ribs. Snosek et al. [15] created a classification system of this muscle and divided it into 3 categories: "simple type", "mixed type", and "other". The simple type was divided into 6 subtypes: single, double, bicipital diverging, bicipital converging, single midline crossing, and double midline crossing. In the mixed type we can find a lot of variations, for example double sternalis with single midline cross, double with single bicipital converging, bicipital diverging with double cross, and others. The last category, named "other", contains all variants not previously described [15]. Looking for some similarity between

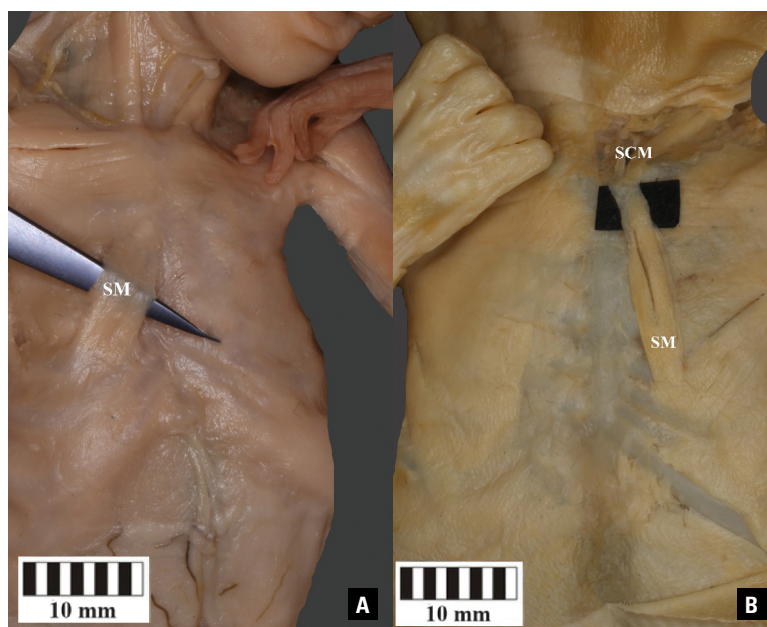


Figure 4. Sternalis muscle. **A.** Single belly; **B.** Bifurcated belly. SCM — sternocleidomastoid muscle; SM — sternalis muscle.

the mentioned classification and the present study, the first case originated from the body of sternum at level of the second intercostal space as a single muscular band, and inserted into the fifth rib, may be classified as a right single sternalis muscle. In turn, the second case may be named left bicipital converging type; however, its bifurcated proximal attachment arose from the distal part of the sternocleidomastoid muscle and distally merged into one belly. Mori et al. [12] also carried out a study on the sternalis, and they found this muscle in about 10.0% of the bodies, appearing more frequently in the right than in the left. The classification system divided the sternalis muscle into 6 types based on its morphology [12].

Summing up the results of the present study, the statement that muscles of thoracic region are characterised by large amount of morphological variations was confirmed. Knowledge about possible accessory muscles, bellies, or different origins and insertions is important for surgeons, especially for plastic surgeons, orthopaedics, or thoracic surgeons. For example, the sternalis muscle may be observed during mastectomy. Some accessory structures may be located in close relation to axillary vessels and the brachial plexus. This may result in neurovascular compression, for example leading to pectoralis minor syndrome [19]. On the other hand, accessory structures may be used as a graft material during some reconstructions.

CONCLUSIONS

The thoracic region is characterised by a large amount of morphological variations, which are observed not only in the adult population, but also among human foetuses. The pectoralis quartus was the most frequent variation in this study. Accessory structures like sternalis muscle, chondrocoracoideus muscle, pectoralis quartus muscle, or axillary arch muscle may have clinical implications, and knowledge about them is very useful for clinicians, especially plastic surgeons, thoracic surgeons, and orthopaedics.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

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

Ethics statement

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

Author contributions

Nicol Zielinska — project development, data collection and management, data analysis, and manuscript writing. Marta Pośnik — data analysis and manuscript editing. Krzysztof Koptas — data analysis and manuscript editing. George Triantafyllou — data

analysis and manuscript editing. Janusz Moryś — data analysis and manuscript editing. Łukasz Olewnik — data collection, data analysis, and manuscript editing.

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Conflict of interest

The authors declare that they have no competing interests.

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