Frontiers in Medical Case Reports, ISSN: 2582-8142

Are There Unit Variations Subscapularis Muscles? A Cadaveric and Histological Study

Annaelle RENAULT*

***Correspondence:** Annaelle RENAULT
Address: Department of Orthopedic surgery, Pontchaillou University Hospital, 2, rue Henri Le Guilloux, 35033 Rennes, France
E-mail ✉ : annaelle.renault3@gmail.com
Received: 20 August 2024; **Accepted:** 09 September 2024

ABSTRACT

Introduction: The anatomy of the subscapularis muscle has been rarely described. The aim of this study is to provide an accurate description of its anatomy, based on macroscopic and histological analysis.

Methods: This descriptive study included 13 shoulders. Macroscopic criteria included the number of muscle bundles and fibrous septa, the number of bone dimples and ridges, and the number of nerve branches, specifying their origin and their point of entry into the muscle. On the same shoulders, we took 3 to 6 histological sections. Microscopic criteria included muscle fiber orientation and fibrous fascia.

Results: 93% of shoulders had 3 or 4 muscle bundles. 3 to 6 nerve branches innervated the muscle. The anterior surface of the body of the scapula was formed in its medial part in 67% of cases by 3 bony ridges. Histological analysis revealed 2 to 6 fibrous septa, 2 and 1 orientations of muscle fibers in 67% and 33% of cases respectively.

Discussion: The anatomy of the subscapularis muscle is highly variable. The various results form a set of arguments, that make us think that within the subscapularis muscle itself, there is a variable number of muscle bundles and nerve branches, forming neuromuscular functional units.

Keywords: *Subscapularis, Anatomy, Histology, Nerves, Muscular Fascicle*

Introduction

The subscapularis muscle is the largest of the four muscles of the rotator cuff (Keating *et al*., 1993). It inserts on the anterior surface of the scapula (subscapular fossa) (Rouviere, 1976). Its muscle fibres extend upwards and outwards, and are inserted laterally on the minor tubercle of the humerus (Kamina, 2011).

The humeral insertion of the subscapularis muscle has two parts: an upper tendinous portion and a lower muscular portion (Hinton *et al*., 1994).

In 2020, the study by Zielinska, *et al*. (2021) revealed anatomical variations, both in the insertion zone and in the number of tendons. In their anatomical studies of 64 subjects, they found 1 to 8 lateral tendon bands.

This muscle is also known for the high variability of its muscular structure and innervation (Cho *et al*., 2019; Yung *et al*., 1996; Kasper *et al*., 2008; Tubbs *et al*., 2007). Cleeman, *et al*. (2003) described several 'packages' within the muscle structure in their cadaveric study.

The innervation of the subscapularis muscle has been the subject of many studies, with sometimes conflicting results due to a large number of anatomical variations.

Kamina describes two subscapular nerves arising from the posterior bundle of the brachial plexus (C5 and C6 roots) (Kamina, 2011). The superior subscapular nerve innervates the upper half of the subscapularis muscle, and the inferior subscapular nerve the lower half of the muscle.

Cho, *et al*. (2019) demonstrated variations in the number of nerve branches (upper subscapular nerve alone, upper and lower subscapular nerve, upper subscapular nerve and axillary nerve). The only constant is the existence of the superior subscapular nerve.

Functionally, the main role of the subscapularis muscle is medial rotation (Otis *et al*., 1994), and shoulder adduction (Aguirre *et al*., 2024). However, the upper part of the subscapularis muscle is also involved in shoulder abduction (Otis *et al*., 1994; Omi *et al*., 2010; O'Connell *et al*., 2006; Liu *et al*., 1997; Sharkey *et al*., 1994). Finally, the lower part of the muscle plays a role in the anterior elevation of the shoulder (Collin *et al*., 2013; Bassett *et al*., 1990).

According to recent data in the literature, the subscapularis muscle can be divided into two different functional parts (an upper and a lower part) if we refer to the classification of massive cuff tears proposed by Collin, *et al*. (2014) and the electromyographic study by Kadaba, *et al*. (1992).

However, the presence of multiple fibrous bands between the different muscle heads (Burkhart *et al*., 1993), more than two nerves innervating the same muscle and multiple functions have led us to question the hypothesis of a 'two-part subscapularis muscle' (Otis *et al*., 1994; Aguirre *et al*., 2024; Omi *et al*., 2010; Klapper *et al*., 1992; Klapper *et al*., 1992).

We want to describe the anatomy of the subscapularis muscle in detail, with the main hypothesis being that there are several neuromuscular functional units with inter- and intra-individual variability.

DOI: http://dx.doi.org/10.47746/FMCR.2024.5501

The main aim of this cadaveric study is to describe the anatomy of the subscapularis muscle in detail, based on macroscopic and histological analysis of the muscle structure and innervation.

The secondary objectives are:

- To demonstrate the presence of several neuromuscular anatomical units, i.e. more than two muscle heads;
- To identify a correlation between anatomical variations in the muscle body and its innervation.

Methods

This study comprises two parts. The first is anatomical, carried out on cadavers, followed by the production of histological sections and their analysis based on dissection specimens.

The local ethics committee approved the study

1) Anatomical study

The cadaveric part of our research was approved by our institution's donation department and anatomy laboratory. All dissections were performed in the anatomy laboratory of the Faculty of Medicine at Rennes 1 University.

Thirteen cadaveric shoulders were included. During dissection, the scapula, subscapularis muscle and its innervation were extracted and studied as a single block (Fig. 1).

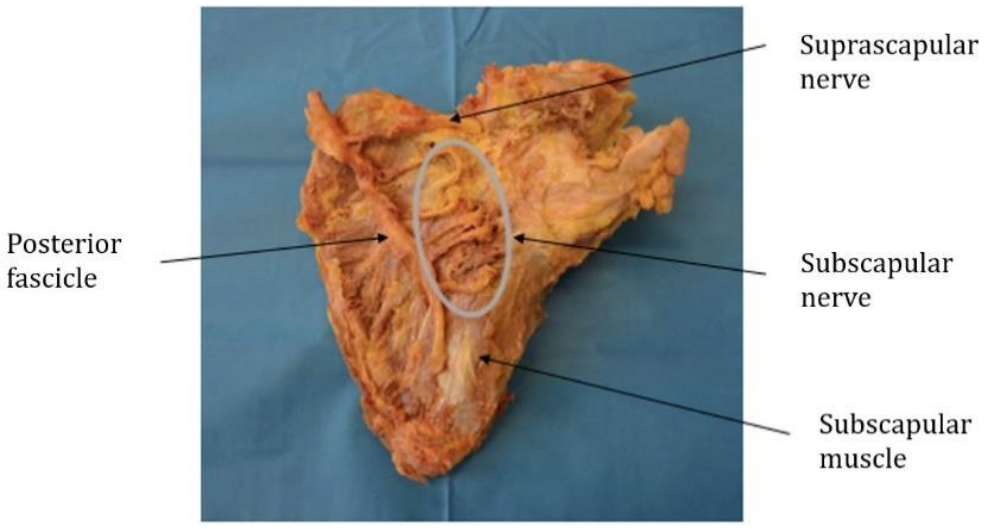

Figure 1: Front view of dissection specimen, 81-year-old man.

We carry out the following objective measurements on each part:

- The number of muscle fascicles (or groups)
- The number of fibrous septa
- The location of these septa
- The number of nerve branches
- The area where the nerve enters the muscle
- Number of anterior fossae
- Number of bony ridges

The origin of each subscapular nerve is also specified.

2) Histological Study

The samples were techniqued at the Inserm histopathology laboratory - H2P2 platform at the University of Rennes 1 - from the 13 dissected shoulders.

Samples were taken from the anatomical parts dissected previously.

Each sample was first encapsulated in paraffin, then cut with a microtome and placed under a slide. Each slide was then stained with HES. HES staining reveals muscle tissue in pink, adipose tissue in white, connective tissue in yellow and nerve fibres in grey. The surface of the specimens in sagittal section was stained with Indian ink to facilitate orientation of the resulting histological images.

Histological samples from parts 4 to 13 were used to study two microscopic criteria:

- The number of fibrous septa
- The number of muscle groups

Results

Thirteen formalin-preserved shoulders were included and dissected from nine different cadaveric subjects aged 77-91 years (mean age 83.6 years). All were of Caucasian origin. There were four males and five females.

DOI: http://dx.doi.org/10.47746/FMCR.2024.5501

For four subjects, two shoulders were sampled (shoulders number 4 and 6, number 8 and 9, number 10 and 11, number 12 and 13), and only one for the other five subjects (shoulders number 1 to 3, number 5 and number 7). A total of six male shoulders and seven female shoulders were studied.

1) Macroscopic Results

93% of shoulders (12/13) had three or four muscle fascicles. The intermuscular septa are most often located in the central part of the muscle. In 61% of cases (8/13), they were located between the 2nd and 3rd muscle fascicles and in 15% of cases (2/13) between the 1st and 2nd fascicles.

Subjects with shoulder numbers 4/6, 8/9 and 12/13 had the same number of muscle fascicles (4 fascicles for shoulders 8 and 9, 3 fascicles for shoulders 4 and 6, 12 and 13). Only the subject with shoulders 10/11 had a different number (3 fascicles for shoulder 10, 4 fascicles for shoulder 11).

The number of septa was identical for shoulders 8 and 9 (1 septa) and 12 and 13 (2 septa), whereas it was different between shoulders 4 and 6 (none in shoulder 4, 1 in shoulder 6), and 10 and 11 (none in shoulder 10, 1 in shoulder 11) (Table 1).

Table 1: Macroscopic findings. Muscles and intermuscular fibrous septa.

Shoulder number	Number of muscle fascicles	Number of septa	Location of septa (between which muscle fascicles)
1	6	*	*
2	4	2	2/3, 3/4
3	3	1	2/3
4	3	0	pas de septa
5	4	1	2/3
6	3	1	2/3
7	4	1	3/4
8	4	1	3/4
9	4	1	2/3
10	3	0	pas de septa
11	4	1	2/3
12	3	2	1/2, 2/3
13	3	2	1/2, 2/3

* : not feasible

In almost half of the dissections (46%) (6/13), there were 3 nerve branches. Their number varied from 2 to 6 nerves, with a mean of 3.4 nerves and a standard deviation of 1.12.

DOI: http://dx.doi.org/10.47746/FMCR.2024.5501

In the majority of dissected shoulders (69%) (9/13), all the nerves came from the posterior bundle of the brachial plexus, and in 30% of cases (4 shoulders), the nerves came from both the posterior bundle and the axillary nerve, systematically for the most distal nerve.

In 69% of dissected specimens (9/13), the first nerve entered the first muscle fascicle and in the remaining 31% (4/13), the first nerve entered the 2nd muscle fascicle. In only 31% of the shoulders (4/13) did we find that a single nerve entered a single muscle fascicle, and in the reverse case, each muscle fascicle had a branch which innervated it. In the other cases, we did not have this pattern of correspondence.

Concerning the study of intra-individual variability, shoulders 10/11 and 12/13 had respectively the same number of nerves (4 and 3 nerves) unlike shoulders 4/6 and 8/9 (Table 2).

Table 2: Macroscopic results. Nerve-muscle fascicle pair.

Shoulder number	Number of nerve	Origin of the subscapular nerves	Division of the subscapular nerve before penetration into the muscle
1	3	posterior fascicle	no division
2	5	posterior fascicle	no division
3	3	posterior fascicle	no division
4	3	posterior fascicle and axillar nerve	no division
5	3	posterior fascicle	
6	2	posterior fascicle	divides into 3 before entering the muscle
7	2	posterior fascicle and axillar nerve	divides into 7 before entering the muscle
8	6	posterior fascicle and axillar nerve	no division
9	4	posterior fascicle	no division
10	4	posterior fascicle	divides into 3 before entering the muscle
11	4	posterior fascicle and axillar nerve	no division
12	3	posterior fascicle	no division
13	3	posterior fascicle	no division

After detaching the entire muscular structure of the scapula, we noted the presence of bony reliefs on the anterior surface of the scapula. For each scapula, the bony prominences took the form of bony ridges running longitudinally, separating concave dimples towards the front.

We found between 3 and 5 ridges on the surface of the 12 pieces of bone (piece 1 could not be used), with a mean of 3.4 ridges and a standard deviation of 0.67. There were between 4 and 6 dimples, with an average of 4.4 dimples and a standard deviation of 0.67.

The ridges are not present across the entire width of the scapular piece. They are found in the vast majority of cases on the medial part of the scapula. In 67% of cases (8/12), there were 3 ridges and 4 dimples (Table 3).

Table 3: Macroscopic findings. Bone reliefs: bone crests and scapular fossae.

Shoulder number	Number of crest	Number of scapular fossae	Number of muscular fascicles
1	*	*	6
2	4	5	4
3	4	5	3
4	3	4	3
5	3	4	4
6	3	4	3
7	3	4	4
8	3	4	4
9	3	4	4
10	3	4	3
11	5	6	4
12	4	5	3
13	3	4	3

* : not feasible

In 4 of the 12 specimens (33% of cases) we found the same number of dimples and muscle fascicles. For the other parts (8/12) (67% of cases), the number of dimples and muscle fascicles was different. In each case, there were fewer muscle fascicles than dimples.

2) Histological Results

An initial cross-section (Fig. 2) revealed several muscle orientations. We can see muscle fibres cut transversely, but also fibres cut longitudinally. These two muscle 'groups' are clearly separated by connective tissue.

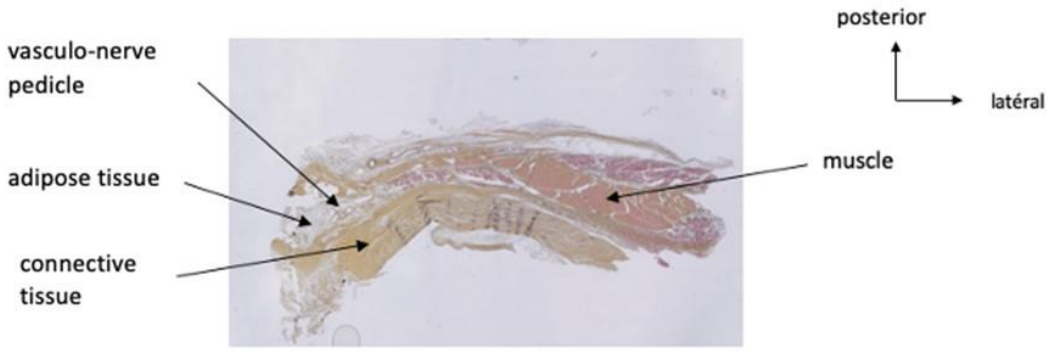

Figure 2: Histological view of a sample in axial view.

DOI: http://dx.doi.org/10.47746/FMCR.2024.5501

Another section (Fig. 3), which is a coronal view, shows two groups of muscle fibres with perpendicular orientations. Between the two, we can clearly see the connective tissue, coloured yellow with the saffron of the HES stain, and the presence of a vascular-nerve pedicle within this connective tissue.

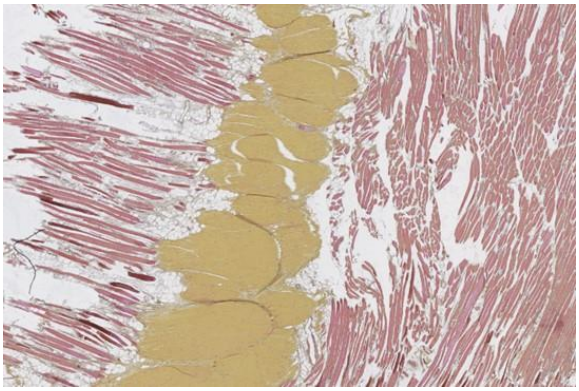

Figure 3: Coronal section zoomed in at the interface of muscle fibre groups of different orientation.

On sagittal sections, we found 2 to 6 fibrous septa (mean 4.2 septa, standard deviation 1.3).

In 40% of the shoulders, there were 4 septa, in 20% there were 2 septa, in 20% there were 5 septa and in 20% there were 6 septa.

The coronal sections taken from shoulders 5 to 13 were used to study the orientation of the muscle fibres, which showed little damage, in contrast to the sagittal sections, where sampling resulted in changes to the fibres.

In 67% of cases, we found 2 muscle fibre orientations: longitudinal and transverse. In the remaining 33%, only one fibre orientation (longitudinal) was found.

Discussion

This study allowed us to study the anatomy and innervation of the subscapularis muscle in detail. The macroscopic cadaveric study revealed the presence of several muscle groups, as well as the presence of fibrous fascia separating these muscle groups.

We also studied the various nerve branches from their origin in the brachial plexus to their penetration into the muscle mass of the subscapularis. The number of nerve branches revealed was greater than the two nerves classically described in the literature.

DOI: http://dx.doi.org/10.47746/FMCR.2024.5501

The histological study allowed in-depth study of the muscle, orientation of the muscle fibres, and analysis of the fibrous septa, which are not all equal in terms of thickness and distribution.

Some of the 13 dissection specimens belonged to the same subject. We were therefore able to make both inter-individual and intra-individual comparisons.

All the macroscopic measurements and the analysis of the histological sections were carried out by one and the same operator, eliminating the bias of inter-operator evaluation.

The macroscopic study revealed a high degree of inter- and intra-individual anatomical variability, with between 3 and 6 muscle fascicles and between 0 and 2 fibrous septa in each muscle. We found no correlation between the number of fibrous septa and the number of muscle fascicles.

At this stage, it seems difficult to prove that the muscle fascicles are independent of each other and distinctly separate. Our hypothesis is that there are several 'parts' to the subscapularis muscle, but each part is made up not of one but of several muscle fascicles.

The study of the nerves showed variability, since we found between 2 and 6 nerve branches directly innervating the subscapularis muscle. However, we were unable to establish a rule according to which a nerve branch innervated a muscle fascicle.

All these elements support our hypothesis that the different 'units' of the subscapularis muscle are not identical in terms of muscle volume and number of nerves, and probably do not have the same function.

The originality of our study lies in the parallel study of muscle and nerve anatomy.

The histological study was a complement, but comparison with macroscopic results was impossible because of the different scale, and the fixed landmarks that could not be preserved in microscopy.

Conclusion

Our study highlighted several anatomical features of the muscle. All these anatomical features lead us to believe that there are several distinct groups in the subscapularis muscle. These are not just muscle groups, but neuromuscular functional units, separated from each other by fascia.

Author Contributions: Renault A: conceptualization, investigation, formal analysis, methodology, Writing – original draft, Writing – review and editing.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations of Interests: None.

References

Aguirre K, Mudreac A, Kiel J. Anatomy, Shoulder and Upper Limb, Subscapularis Muscle. 2023 Aug 28. In: StatPearls. *Treasure Island (FL): StatPearls Publishing*; 2024.

Bassett RW, Browne AO, Morrey BF, An KN. Glenohumeral muscle force and moment mechanics in a position of shoulder instability. *J Biomech* 1990; 23: 405-415.

Blasier RB, Guldberg RE, Rothman ED. Anterior shoulder stability: Contributions of rotator cuff forces and the capsular ligaments in a cadaver model. *J Shoulder Elbow Surg* 1992; 1: 140-150.

Burkhart SS, Esch JC, Jolson RS. The rotator crescent and rotator cable: an anatomic description of the shoulder's "suspension bridge". *Arthroscopy* 1993; 9: 611-616.

Cho TH, Kwon HJ, Choi YJ, O J, Won SY, Yang HM. Intramuscular innervation of the subscapularis muscle and its clinical implication for the BoNT injection: An anatomical study using the modified Sihler's staining. *Clin Anat* 2019; 32: 110-116.

Cleeman E, Brunelli M, Gothelf T, Hayes P, Flatow EL. Releases of subscapularis contracture: an anatomic and clinical study. *J Shoulder Elbow Surg* 2003; 12: 231-236.

Collin P, Lädermann A, Le Bourg M, Walch G. Subscapularis minor--an analogue of the Teres minor? *Orthop Traumatol Surg Res* 2013; 99: S255-S258.

Collin P, Matsumura N, Lädermann A, Denard PJ, Walch G. Relationship between massive chronic rotator cuff tear pattern and loss of active shoulder range of motion. *J Shoulder Elbow Surg* 2014; 23: 1195-1202.

Hinton MA, Parker AW, Drez D Jr, Altcheck D. An anatomic study of the subscapularis tendon and myotendinous junction. *J Shoulder Elbow Surg* 1994; 3: 224-229.

Kadaba MP, Cole A, Wootten ME, McCann P, Reid M, Mulford G, April E, Bigliani L. Intramuscular wire electromyography of the subscapularis. *J Orthop Res* 1992; 10: 394-397.

Kamina P. Anatomie clinique: Neuroanatomie. *Maloine*; 2011.

Kasper JC, Itamura JM, Tibone JE, Levin SL, Stevanovic MV. Human cadaveric study of subscapularis muscle innervation and guidelines to prevent denervation. *J Shoulder Elbow Surg* 2008; 17: 659-662.

Keating JF, Waterworth P, Shaw-Dunn J, Crossan J. The relative strengths of the rotator cuff muscles. A cadaver study. *J Bone Joint Surg Br* 1993; 75: 137-140.

Klapper RC, Jobe FW, Matsuura P. The subscapularis muscle and its glenohumeral ligament-like bands. A histomorphologic study. *Am J Sports Med* 1992; 20: 307-310.

Liu J, Hughes RE, Smutz WP, Niebur G, Nan-An K. Roles of deltoid and rotator cuff muscles in shoulder elevation. *Clin Biomech (Bristol, Avon)* 1997; 12: 32-38.

O'Connell NE, Cowan J, Christopher T. An investigation into EMG activity in the upper and lower portions of the subscapularis muscle during normal shoulder motion. *Physiother Res Int* 2006; 11: 148-151.

Omi R, Sano H, Ohnuma M, Kishimoto KN, Watanuki S, Tashiro M, Itoi E. Function of the shoulder muscles during arm elevation: an assessment using positron emission tomography. *J Anat* 2010; 216: 643-649.

Otis JC, Jiang CC, Wickiewicz TL, Peterson MG, Warren RF, Santner TJ. Changes in the moment arms of the rotator cuff and deltoid muscles with abduction and rotation. *J Bone Joint Surg Am* 1994; 76: 667-676.

Rouviere H. Précis d'anatomie et de dissection, *9è edition*; 1976.

Sharkey NA, Marder RA, Hanson PB. The entire rotator cuff contributes to elevation of the arm. *J Orthop Res* 1994; 12: 699-708.

Tubbs RS, Loukas M, Shahid K, Judge T, Pinyard J, Shoja MM, Slappey JB, McEvoy WC, Oakes WJ. Anatomy and quantitation of the subscapular nerves. *Clin Anat* 2007; 20: 656-659.

Yung SW, Lazarus MD, Harryman DT 2nd. Practical guidelines to safe surgery about the subscapularis. *J Shoulder Elbow Surg* 1996; 5: 467-470.

Zielinska N, Tubbs RS, Podgórski M, Karauda P, Polguj M, Olewnik Ł. The subscapularis tendon: A proposed classification system. *Ann Anat* 2021; 233: 151615.