A CADAVERIC AND MAGNETIC RESONANCE IMAGING STUDY OF THE ANATOMICAL VARIATIONS OF LEVATOR SCAPULAE

A THESIS SUBMITTED IN FULFILMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN MEDICAL SCIENCES WITH SPECIALISATION IN ANATOMY

OF

THE UNIVERSITY OF NAMIBIA

BY

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201203124

APRIL 2025

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ABSTRACT

Levator scapulae muscle (LSM) is a deep muscle found in the posterior triangle of the neck. It is reported to be a lead cause of neck and shoulder pain and discomfort in patients. The muscle anatomically presents with an average of four muscle slips, originating from the transverse processes of the first four cervical vertebrae (C1-C4) and inserts onto the superomedial border of the scapula. The main function of the levator scapulae muscle is to elevate the scapula.

This study aimed to determine the morphometric variation in levator scapulae muscle and its related neurovasculature via cadaveric and MRI studies. There were 20 available cadavers, and their posterior and anterior neck triangles were dissected to expose the levator scapulae and its neurovasculature. The MRI study used randomly selected axial scans (n = 167) to identify accessory attachments of the levator scapulae muscle.

The study observed the levator scapulae muscle with two to six muscle slips, with four muscle slips dominating. The average proximal distance was 53.46 ± 13.22 mm, distal distance was 60.63 ± 10.78 mm, anterior distance was 87.10 ± 9.27 mm and posterior distance was 158.08 ± 15.94 mm. The cadaveric study observed the accessory muscle slip attachments to the middle scalene, the first two ribs. The MRI study observed accessory attachments to the serratus posterior superior, serratus anterior, trapezius, rhomboid minor, and splenius cervicis. The levator scapulae muscle was supplied by the dorsal scapular, transverse cervical ascending cervical arteries, and innervated by up to six nerve branches, stemming from C2, C3/C4, and C5 nerve roots.

Clinically, the current study is important to medical students, anatomists, radiologists, and physicians, as it confirmed the available data and provided additional knowledge about the levator scapulae muscle and its related neurovasculature, hence voiding misinterpretation of possible muscle anatomy, inaccurate diagnoses and prevent injuries to neurovasculature during surgical procedures. Further research on the levator scapulae muscle is crucial to provide adequate information regarding the levator scapulae muscle variations.

Keywords: cadaveric, levator scapulae muscle, MRI, muscle slips, and neurovasculature.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACA:	Ascending cervical artery
ANOVA:	Analysis of Variance
AS:	Anterior scalene
C:	Cervical vertebrae
C1-C7:	Cervical vertebral 1-7
CDST:	Cervicodorsoscapular trunk
CDT:	Cervicodorsal trunk
CST:	Cervicoscapular trunk
CT scan:	Computed Tomography scan
DEC:	Decentralised ethic committee
DSA:	Dorsal scapular artery
DSN:	Dorsal scapular nerve
DST:	Dorsoscapular trunk
ICC:	Intra-class correlation coefficients
Inf:	Inferior
Lat:	Lateral
LSM:	Levator scapulae muscle
Med:	Medial
MET signalling:	Mesenchymal epithelial transition signalling
MRI:	Magnetic resonance imaging
MS:	Middle scalene

Occip:	Occiput
OH:	Omohyoid
RIR:	Real interest rate
RM:	Rhomboid major
Rm:	Rhomboid minor
RCH:	Roman Catholic Hospital
SA:	Serratus anterior
SC:	Splenius cervicis
SCA:	Subclavian artery
SCap:	Splenius capitis
Scap:	Scapula
SCM:	Sternocleidomastoid
SoM:	School of Medicine
SP:	Scalene posterior
SPS:	Serratus posterior superior
Sup:	Superior
T:	Thoracic vertebrae
Turkey's HSD post-hoc:	Turkey's Honestly Significant Difference post-hoc
TCA:	Transverse cervical artery
TCT:	Thyrocervical trunk
Trap:	Trapezius
UNAM:	University of Namibia

ACKNOWLEDGMENT

I would like to express my sincere acknowledgement to the following individuals and institutions for their contribution to this research. Firstly, I praise God for his guidance and protection. Secondly, my gratitude goes to my supervisor Prof Quenton Wessels for the best and consistent effort, guidance, and encouragement, my co-supervisor Ms. Janine Carla Correia for her guidance, Prof. Jan Smit for introducing me to this study and training, Mr Jan van der Merwe and Mr Joseph Lakanemo for always available for laboratory assistance, the entire Anatomy department staff for providing me with a wonderful anatomical background and great hospitality during my study period. I am grateful to Dr Alex van der Horst and his team for the warm welcome and for allowing this study to make use of his medical MRI records. My final appreciation goes to my family and friends, especially Ms Atanasia Mbonge, for the support.

DEDICATION

Firstly, I would like to dedicate this research to my late Mother, Regina Gaus, because growing up and facing this complex world without her has given me the courage to work harder and believe in myself. Secondly, I would like to dedicate this research study to the anatomists and researchers in general who are working restlessly to make anatomy and the world a better place. Thirdly, I would like to dedicate this work to medical schools and students globally, as well as to the neck specialists and surgeons who work daily with neck-related diagnoses. To the individuals who suffered from or experienced shoulder pain, neck pain, and syndromes associated with the levator scapulae muscle. Lastly, to our gracious donors who made this research possible.

DECLARATION

I, Ester Ndagwedha Iita, hereby declare that this study is my own work and is a true reflection of my research and that this work or any part thereof has not been submitted for a degree at any other institution.

I, Ester Ndagwedha Iita, granted the University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which the University of Namibia may deem fit.

Ester Ndagwedha Iita		April 2025
Name of Student	Signature	Date

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Introduction

Chapter One provides an overview of the study. This chapter focused on the orientation of the proposed study, statement of the problem, research objectives, significance of the study, limitations, and delimitations of the study.

1.2 Background of the study

A skeletal muscle called the levator scapulae muscle (LSM) can be discovered in the neck's posterior triangle (Kikuta et al., 2019; Smit & Todd, 2019). According to Beger et al. (2018), Dalley and Agur (2023), and Netter (2014), the levator scapulae muscle proximally attached to the dorsal tuberosity of the transverse processes of the first four cervical vertebrae (C1-C4). However, Dalley and Agur (2023), Netter (2014), and Van De Graaff (2002) stated that the levator scapulae muscle is distally attached to the medial border of the scapula, or the superomedial border of the scapula (Beger et al., 2018). According to Chotai et al. (2015), the muscle is proximally linked to the C1-C4 and C1-C5 transverse processes of the cervical vertebrae, with an average of four muscle slips (Figure 1.1).

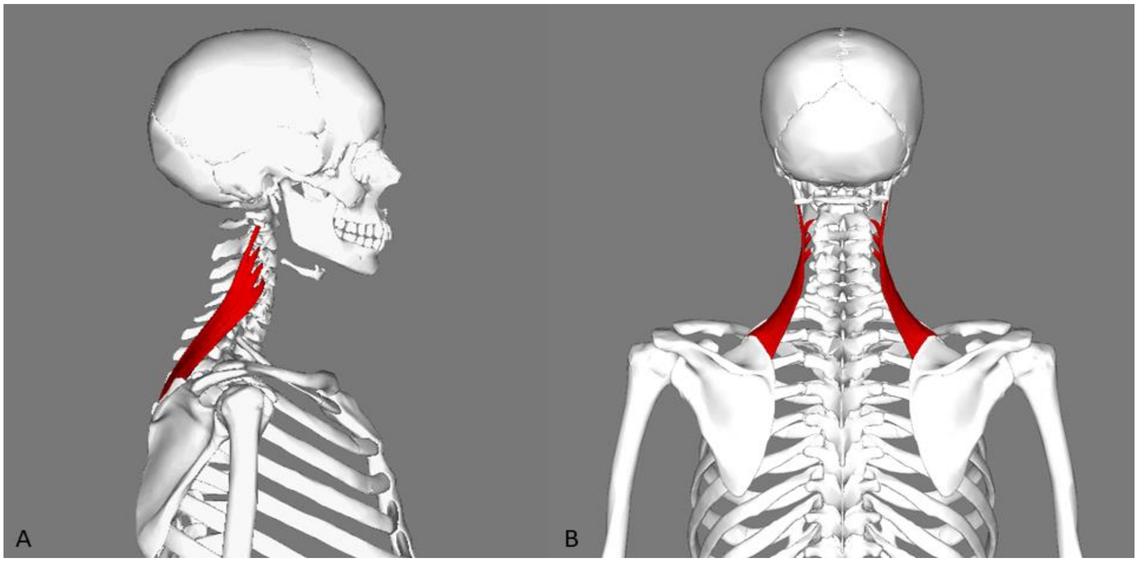

Figure 1.1: A typical levator scapulae muscle. Key: A: A lateral view illustrating the proximal origin of the levator scapulae muscle on the transverse processes of the cervical vertebrae (*File: Levator Scapulae Muscle lateral.png - Wikimedia Commons*, 2012b). B: A posterior view illustrating the distal insertion of the levator scapulae muscle on the superomedial borders of the scapula (*Levator Scapulae Muscle back.png - Wikimedia Commons*, 2012).

According to Valasek et al. (2010), the scapula is the bone of the shoulder girdle that joins the proximal upper extremities to the axial skeleton. The vertebrae, commonly known as the spine or the backbone, have finger-like extensions on either side (lateral) that are referred to as transverse processes (Asher, 2022). Aside from the seventh cervical transverse processes (C7), which lack or have just simple anterior tubercles, the transverse processes of the cervical spine are distinct from other transverse processes in that they are oriented downward and outward and have both anterior and posterior tubercles (Ihnatsenka & Boezaart, 2010).

The levator scapulae muscle is located on the surface compartment of the superficial back muscles (Grujičić, 2022; Vasković, 2022), deep to the sternocleidomastoid muscle proximally and deep to the trapezius muscle distally (Lima et al., 2012). The trapezius muscle forms the posterior boundary of the neck, the sternocleidomastoid muscle forms the anterior border, and the clavicle forms the inferior border of the triangle (Ihnatsenka & Boezaart, 2010). The levator scapulae muscle marks the floor of the posterior triangle, and because the centre segment of the levator scapulae muscle is not covered, palpating the muscle in this place is made easier (Grujičić, 2022).

Due to the levator scapulae muscle's position in the posterior triangle of the neck, it is believed to be associated with discomfort in patients with serious neck and shoulder pain, due to its variations (Naik & Lokanadham, 2019). The muscle is also associated with other clinical diagnoses, for example, the levator scapulae syndrome, the snapping scapula syndrome (Henry & Munakomi, 2022), and cervical dystonia (Lima et al., 2012) amongst others.

The main function of the levator scapulae muscle is to elevate the scapula, with the help of the trapezius, rhomboid minor, and rhomboid major muscles (Dalley & Agur, 2023; Fakoya et al., 2020; Netter, 2014; Smit & Todd, 2019; Van De Graaff, 2002). It also plays a role in stabilising and mobilising the scapula when the humerus is in action, together with the pectoralis minor, trapezius, serratus anterior, and rhomboid major (Bae et al., 2022).

The levator scapulae muscle is also responsible for the inferior rotation of the scapula with the aid of the descending fibres of the trapezius, pectoralis major and minor, latissimus dorsi, and rhomboids, leading to a depression of the glenoid cavity (Dalley & Agur, 2023; Henry & Munakomi, 2022; Netter, 2014). It laterally flexes and rotates the vertebral column as well as extends the neck (Behrsin & Maguire, 1986; Dalley & Agur, 2023). Moreover, the levator scapulae muscle is a major muscle responsible for stabilising the axial-appendicular skeletons (Chotai et al., 2015; Dalley & Agur, 2023; Henry & Munakomi, 2022).

There are variations associated with the levator scapulae muscle (Smit & Todd, 2019). Normally, the levator scapulae muscle originates from the cervical vertebrae, but there are accessory slips reported in the cadaveric studies, which extend to the occipital bone, temporal bone, serratus posterior superior, serratus anterior, rhomboid and trapezius muscles (Lima et al., 2012). The muscle was also reported to have accessory muscle slips extending to the spinous process of the thoracic vertebrae, first two ribs, and the clavicle (Au et al., 2017; Fakoya et al., 2020; Smit & Todd, 2019).

Other than the levator scapulae muscle attachments, studies by Chotai et al. (2015), and Smit and Todd (2019) reported the muscle to have various numbers of muscle slips. The muscle was initially described as having three slips, followed by another description of the muscle with an average of four muscle slips proximally attached to C1-C4 (Chotai et al.,2015; Smit & Todd, 2019). Other studies cited in Smit and Todd (2019) described the levator scapulae muscle to have up to five muscle slips with C1-C5 proximal attachments.

However, recent studies have observed the levator scapulae muscle with six muscle slips (Naik & Lokanadham, 2019; Smit & Todd, 2019).

The levator scapulae muscle is innervated by the dorsal scapular nerve, as well as by nerve branches from the cervical plexus (Beger et al., 2018; Dalley & Agur, 2023; Fakoya et al., 2020; Van De Graaff, 2002). The dorsal scapular nerve originates from nerve root C5, whereas the cervical nerve branches originate from C3-C4 nerve roots (Netter, 2014; Som & Laitman, 2017).

In addition, Dalley and Agur (2023), and Netter (2014) described the dorsal scapular nerve as receiving contribution from C4. Taira et al. (2003) described the cervical nerve branches to originate from C2-C5. The levator scapulae muscle receives blood supply from the dorsal scapular artery (Dalley & Agur 2023; Netter, 2014; Reiner & Kasser, 1996), which is a branch of the transverse cervical artery originating from the thyrocervical trunk, or the subclavian artery (Fakoya et al., 2020; Henry & Munakomi, 2022; Netter, 2014).

1.3 Statement of the problem

Inadequate attention is paid to the levator scapulae muscle, hence its variations might subsequently be overlooked (Smit & Todd, 2019). The levator scapulae muscle has a potential contribution to pathological conditions of the neck and back regions (Lima et al., 2012; Smit & Todd, 2019). For instance, the variations associated with the levator scapulae muscle may play a role in levator scapulae syndrome and cervical dystonia

(Chotai et al., 2015). It is also the major cause of cervical myofascial pain, snapping scapula syndrome, fibromyalgia, and Sprengel's deformity (Henry & Munakomi, 2022).

Moreover, the cervical myofascial syndrome is influenced by the levator scapulae muscle location, accompanied by the extreme use of the muscle groups, local traumatism, and the existence of anatomical variations (Lima et al., 2012). Therefore, this study focused on the levator scapulae muscle, its variations and its neurovasculature, using both cadaveric and magnetic resonance imaging (MRI) studies. Thus, adding and strengthening the available information about the levator scapulae muscle and its variations.

1.4 Aim and objectives of the study

The overall aim of this study was to determine the morphometric variations in levator scapulae muscles and the muscle's related neurovasculature. The specific objectives are:

1. To examine the existence of the levator scapulae muscles attachment variations, both proximal and distal attachments.
2. To characterise the typology and locality of variations of the levator scapulae muscles
3. To explore the frequency of the muscle slips and attachment variations
4. To explore the frequency of neurovasculature and associated variations
5. To critically appraise the clinical significance of these variations

1.5 Significance of the study

According to reports, the levator scapulae muscles may be the primary cause of several neck and shoulder disorders, or it may be clinically significant as it is. To appropriately differentiate between anatomical variations and potential neck diseases, doctors must also be aware of the levator scapulae muscle accessory attachments. The results of cadaveric and MRI studies can be utilised to educate surgeons and other medical practitioners on the possible effects of the levator scapulae muscle variations on the varieties of musculoskeletal and neurological disorders that patients may experience.

On the other hand, the MRI is crucial for clinical diagnosis, but interpretation is difficult due to the inability to distinguish between structures. The ability to distinguish between two or more conditions that have similar symptoms and signs is made possible by the accurate identification of individual cervical spine muscles (Au et al., 2016). As a result, the current study is crucial for radiologists to avoid misinterpreting normal variants such as clotted veins or cervical lymphadenopathy as stated in (Au et al., 2017).

In addition, in head and neck surgery, the levator scapulae muscle flaps are frequently utilised to treat diseases including oral and oropharyngeal tumours (Beger et al., 2018). Equally important, the levator scapulae muscle plays a critical role in muscle transfer procedures in orthopaedic, head, neck, and shoulder surgery because variations in the levator scapulae muscle can impact how the muscle moves and functions in its new place (Au et al., 2017).

Moreover, this study is clinically significant during the triple-tendon transfer (T3 transfer) procedure, which is a tendon transfer involving the levator scapulae muscle, rhomboid major, and rhomboid minor muscles, innervated by the dorsal scapular nerve (Pinto et al., 2019). Hence, adequate anatomical studies of the dorsal scapular nerve are required to improve knowledge and reduce injuries to the dorsal scapular nerve during surgeries (Pinto et al., 2019).

Since there are few research studies on levator scapulae muscle variations (Smit & Todd, 2019). This study concentrated on the anatomical variations of levator scapulae muscles in the adult cadaver population at the Anatomy Department of the University of Namibia, at the School of Medicine It also focussed on the MRI records from the Roman Catholic Hospital. Therefore, this study is significant to fill the current gap on the potential variations related to the levator scapulae muscle and confirm the information that is currently available about the levator scapulae muscle and its neurovasculature.

1.6 Limitations of the study

UNAM depends on its southern partners to collect cadavers and have the embalming procedures performed, hence, the principal restriction of this study was the effect of COVID-19 on the regional cadaver programs in southern Africa. Due to the impact of the embalming fluid (formalin-fixed) on the morphometrics of the muscles, some of the cadaver tissues were rigid and of poor quality, and this decelerated the dissection process and increased the chances of damaging the neurovasculature. There were no fresh or unfixed cadaver materials available for this study.

The research was conducted on the same cadaver as medical students, therefore it was entirely dependent on how well their academic program progressed to get to the area of interest and this resulted in some of the neurovasculature of interest being destroyed by the medical students. Moreover, only adult cadavers were used in the study, which was supplemented by several MRI records that were accessible from 2017 to 2022 at Roman Catholic Hospital.

1.7 Delimitations of the study

The cadaveric study made use of the UNAM (School of Medicine) cadavers that were on hand during the research period. Medical students' destruction of the neurovasculature and the laterally flexed necks were not considered. The cadavers' quality was evaluated to determine whether they would make good study subjects, but the shrinkage of the musculoskeletal tissues was ignored. The MRI study used a random selection of the scan records that were available from 2017 to 2022, however, the scans that were cloudy and unclear were excluded.

1.8 Chapter summary

The focus of this chapter was on the overview and significance of the morphometric study of the levator scapulae muscle. The chapter included the background of the levator scapulae muscle. The research problem of the study was included, which was mainly the lack of literature related to the morphological variations of the levator scapulae muscle. In addition, the significance of the levator scapulae muscle variation was to fill the gap of inadequate literature, as well as to provide additional information for the researchers, and clinicians to be aware of possible variations associated with the levator scapulae muscles.

The next chapter will be the literature review of the levator scapulae muscle embryology, the levator scapulae muscle variations, the blood supply, the nerve supply, and the clinical correlations related to the levator scapulae muscle.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A literature review is a methodical search for details regarding the research problem, Dawidowicz (2010, as cited in Alhassan, 2017). The information used for this section includes articles from abstracts, journals, textbooks, and reports. The goal of the literature review is to create a framework for comparing new results in the discussion section of a thesis to earlier discoveries (Randolph, 2009). This chapter provides a review of previous literature studies on morphology, neurovasculature, the variations as well as the clinical correlations associated with levator scapulae muscles.

2.2 Embryology and foetal development of the levator scapulae muscle

There is insufficient information on the development of the levator scapulae muscle (Au et al., 2017). The levator scapulae muscle, along with the serratus anterior and rhomboid muscles are referred to as hypaxial muscles, due to their common embryonic origin (Lima et al., 2012). According to the spinal investigation, the levator scapulae muscle, serratus anterior, and rhomboid muscles are more sophisticated than the upper limb muscles (Au et al., 2017). Unlike the lateral plate mesoderm, these muscles appear to have developed from the thoracic myotome (Au et al., 2017) as presented in Figure 2.1.

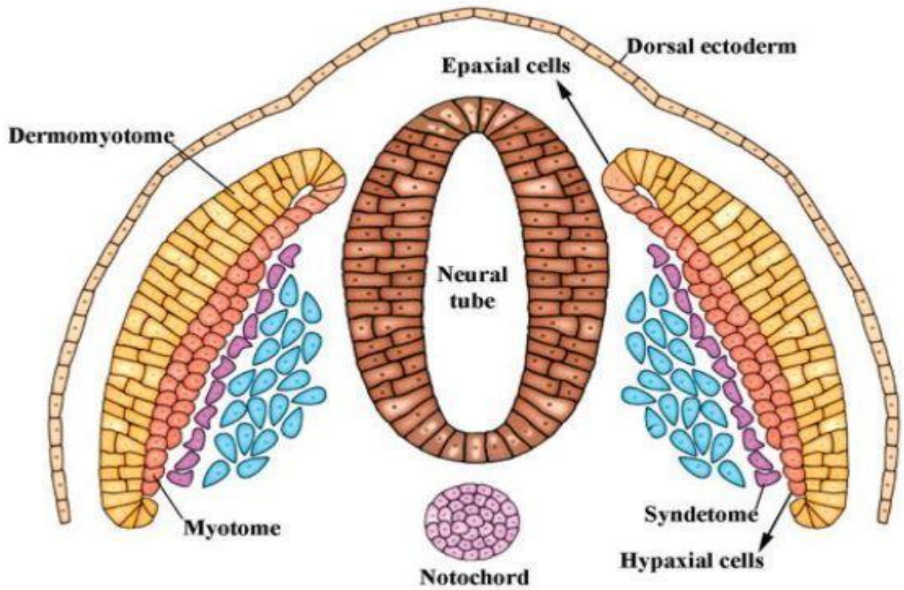

Figure 2.1: A coronal drawing of a traditional separation of the somite into the myotome (Adapted from Som & Laitman, 2017).

According to Henry and Munakomi (2022), the rhomboid muscles and the levator scapulae muscle come from the paraxial mesoderm, while the axial skeleton and the levator scapulae muscles come from the axial somites. Cell migration from the somites promotes the levator scapulae muscle and axial skeleton's development under the influence of Mesenchymal epithelial transition (MET) signalling (Lima et al., 2012).

Based on how they relate to the horizontal vertebral septum, the muscles of the trunk can be split into two main groups: the ventral hypaxial muscles and the dorsal epaxial muscles (Lima et al., 2012). Somatic cells are also thought to have given rise to the serratus posterior superior,as a result, the same somatic origin of these muscles is likely to explain the prevalence of accessory muscle attachments between the levator scapulae muscle and the serratus anterior, and serratus posterior superior (Au et al., 2017).

In addition, Som and Laitman (2017) stated that the levator scapulae muscle is a true posterolateral neck muscle that migrates to the scapula dorsally, whereby it begins with the serratus anterior muscle and progresses to the posterolateral thoracic region, and these muscles develop from an extra pre-muscle mass located towards the ventral extremities of the lower cervical myotomes.

Som and Laitman (2017) also added that the levator scapulae muscle and serratus anterior muscles start to separate from the mesenchyme at about 47 embryonic days. Soon after, this pre-muscle mass forms a column without any attachments to the vertebrae or the ribs that it stretches over. The lower parts of the levator scapulae and serratus anterior muscles are well-defined by 50 embryonic days in this column of cells, which runs from the cervical region to the thorax. The levator scapulae muscle has started to approximate its mature shape and is attached to the scapula by 54 embryonic days (Som & Laitman, 2017).

Equally important, a left-side proximal attachment of the two-headed levator scapulae muscle variation was observed during the dissection of a 21-week female foetus. The longer head originated from the transverse process C1–C2 vertebrae while the shorter head originated from the transverse process C5–C6 vertebrae. Both heads united before it inserted into the superomedial borders of the scapula (Beger et al., 2018) as presented in Figure 2.2.

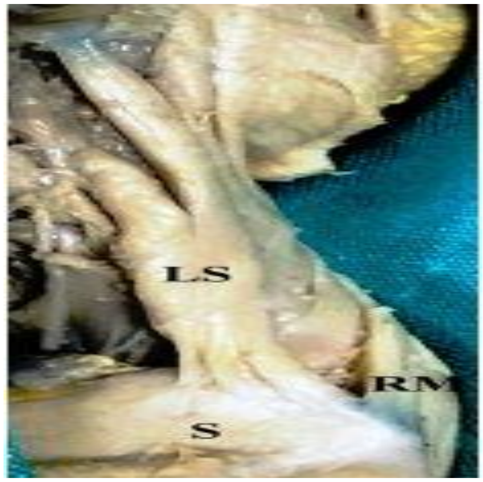

Figure 2.2: Variant levator scapulae muscle. Keys: RM: rhomboid muscles, S: scapula (Adapted from Beger et al., 2018)

2.3 The location of the levator scapulae muscle

The levator scapulae muscle is a deep muscle found in the posterior triangle of the neck (Henry & Munakomi, 2022). Three structural borders make up the posterior triangle of the neck, the posterior is made up of the anterior margins of the trapezius muscle, the anterior is made up of the posterior border of the sternocleidomastoid, while the inferior is made up of the two-thirds of the clavicle (Ihnatsenka & Boezaart, 2010). The posterior neck triangle is however subdivided into two triangles (the occipital and subclavian triangles) by the inferior slip of the omohyoid muscle (Kohan & Wirth, 2014). Therefore, the levator scapulae muscle, splenius capitis, middle scalene, and posterior scalene muscles are found specifically on the floor of the occipital triangle, which is the superior triangle of the posterior neck triangle (Kikuta et al., 2019).

According to the atlas of the body sections, CT and MRI images demonstrated in the Human sectional anatomy by Dixon et al. (2017), and Ellis et al. (2007), at C3, the levator scapulae muscle was located deeper to the sternocleidomastoid and anterior to the splenius capitis. At C4, the levator scapulae muscle was located anterolateral to the splenius cervicis, anterior to the splenius capitis, deeper to the sternocleidomastoid and posterolateral to the longissimus capitis and cervicis. At C5, the levator scapulae muscle was located anterior to the splenius capitis, superficial to the splenius cervicis and superficially covered by the fat of the posterior triangle (Dixon et al., 2017; Ellis et al., 2007).

Dixon et al. (2017), and Ellis et al. (2007) also stated that at C6-7, the levator scapulae muscle was located to the middle scalene, anterolateral to splenius capitis, lateral to splenius cervicis, and deeper to the trapezius muscles. At C7, the levator scapulae muscle was located anterior to the trapezius muscle, lateral to the rhomboid minor and medial or deeper to the supraspinatus. At C7-T1, the levator scapulae muscle was lateral to the splenius cervicis, posterior to the scalene muscles and deeper to the trapezius muscle (Dixon et al., 2017; Ellis et al., 2007).

2.4 Anatomical variations of levator scapulae muscle

2.4.1 The attachments of levator scapulae muscle

The levator scapulae muscle is greatly associated with accessory attachments (Au et al., 2017) Even though some of the small muscle fibres or tendinous accessories of the levator scapulae muscles are clinically not important (Loukas et al., 2006).

The first incident was observed by Loukas et al. (2006) in a 71-year-old Caucasian female. The levator scapulae muscle was observed arising from the posterior tubercles of the transverse processes of the C3 and C4. The muscle bifurcated into two heads: The lateral head was inserted into the superomedial border of the scapula, while the medial head extended inferomedially and widened into a thick aponeurotic band. The superior part of the aponeurosis fused with the ligamentum nuchae at the level of C6, the inferior part inserted into the tendon of the rhomboid major, and the serratus posterior superior as presented in Figure 2.3

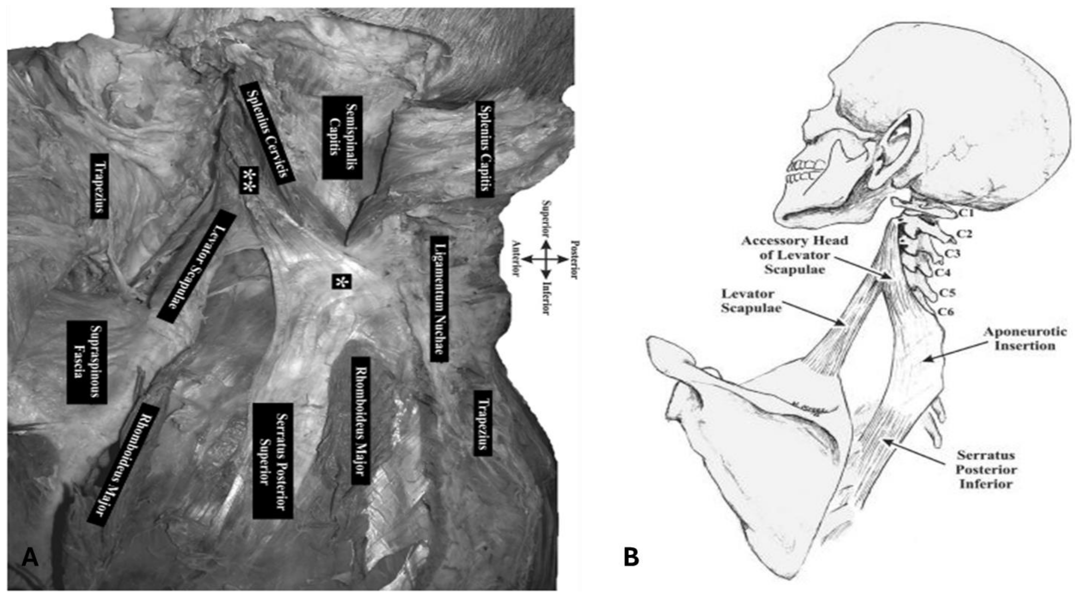

Figure 2.3: Levator scapulae muscle accessory attachment to ligamentum nuchae, rhomboid major, and serratus posterior superior. Key: A- A single star indicates the flat, broad, triangular aponeurosis of the accessory levator scapulae. A double star indicates the muscular head of the accessory levator scapulae. B- A diagrammatic representation of the accessory head of the levator scapulae and its broad aponeurotic insertion (Adapted from Loukas et al., 2006).

The second incident was observed by Fakoya et al. (2020) in an 88-year-old male cadaver died from myocardial infarction. On the left side of the cadaver, the levator scapulae muscle had two slips. The first slip originated from the transverse processes of the cervical vertebrae C1-C4, while the second slip originated from the mastoid process. These two slips unite and distally insert into the superomedial border of the scapula as presented in Figure 2.4.

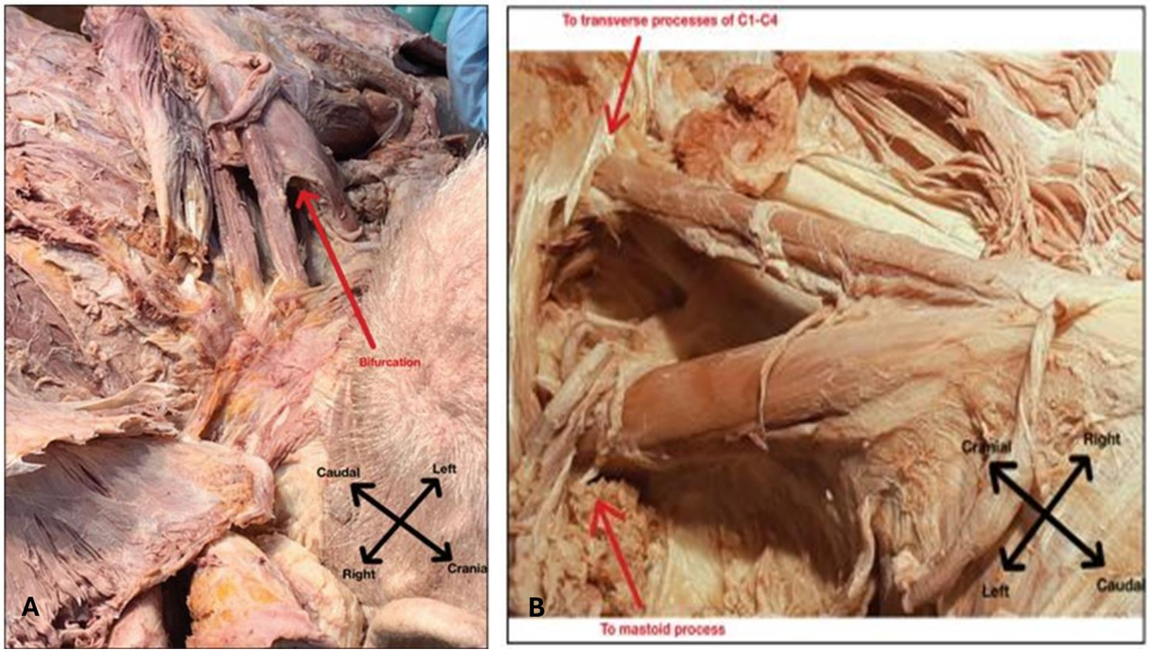

Figure 2.4: Levator scapulae muscle accessory slip from mastoid process. Key: A- An 88-year-old man with a bifurcated left levator scapulae muscle (indicated with an arrow). B- Insertion points of the levator scapulae muscle (indicated with arrows) (Adapted from Fakoya et al., 2020).

Lashley and Granite (2021), observed a unilateral levator scapulae muscle instance within a 73-year-old Caucasian male human cadaver. On the left side of the cadaver, the levator scapulae muscle was observed with a total of five muscle slips. The first two superior slips both originated from C1. There were no slips observed originating from C2. The third, fourth, and fifth slips originated from C3, C4, and C5.

In addition, an unusual muscle slip was observed originating from the left transverse process of C1 together with the upper portion of the splenius cervicis muscle and the first two superior muscle slips. The unusual muscle slip extended inferiorly to insert onto the serratus posterior superior. The tendinous fibres of the unusual muscle slip to the serratus posterior superior and the superior tendinous fibres of the serratus posterior superior fused and extended to the spinous process of the C7 vertebrae. In length, the unusual muscle measured 125.00 mm and 6.50 mm wide as presented in Figure 2.5.

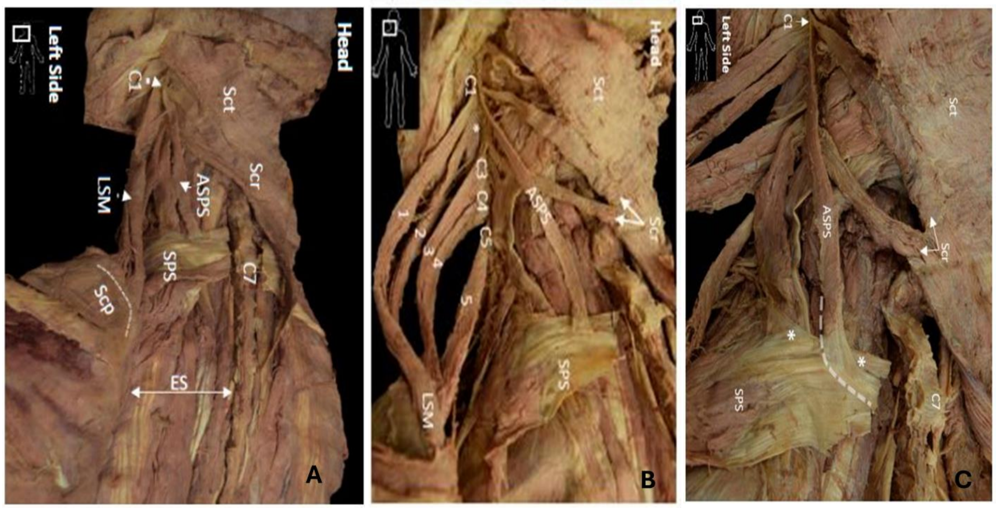

Figure 2.5: Levator scapulae muscle accessory attachment to serratus posterior superior and spinous process of the C7 vertebrae. Key: A- The posterior view neck demonstrating the accessory serratus posterior superior (ASPS) muscle. B- left-sided variations in levator scapulae muscle anatomy. No muscular slip originating from C2 (*). C- Origin and insertion sites for ASPS. The dashed line illustrates insertion of the ASPS onto the proximal portion of the SPS. Asterisks indicate the upper tendinous connection of the SPS traveling deep to the ASPS. Accessory serratus posterior superior (ASPS) muscle, Atlas transverse process (C1), Spinous process of cervical vertebra 7 (C7), Erector Spinae (ES) Muscles, Levator scapulae muscle (LSM), Scapula (Scp), Spinous process of cervical vertebra 7 (C7), Serratus posterior superior

(SPS) Muscle, Splenius capitis (Sct) Muscle, Splenius cervicis (Scr) (Adapted from Lashley & Granite, 2021).

Moreover, Lima et al. (2012) presented a case of an anatomical variation connected to the left levator scapulae muscle, the study showed additional proximal attachments which bifurcated into two insertions. According to the aforementioned study, a case was found in a 58-year-old Caucasian female cadaver, with atypical superior attachment of the left levator scapulae muscle to the spinous processes of C1-C4 vertebrae (Lima et al., 2012). Lima et al. (2012) added that the levator scapulae muscle bifurcated into two muscle slips at the midpoint, the medial muscle slip extended to the anterior part of the left rhomboid major muscle at the level of the T2 vertebrae, while the lateral slip was inserted onto the superior angle of the scapula (Figure 2.6).

However, before the lateral slip was inserted into the scapula, its accessory muscle branched off towards the aponeurosis of the serratus anterior muscle (Lima et al., 2012). The morphometric analysis of this study revealed that the levator scapulae muscle had a maximal width of 36.00 mm. The point bifurcation was located 66.00 mm apart from the C1, whereby the medial slip had a length of 57.00 mm and a width of 8.00 mm, whereas the lateral slip had a length of 65.00 mm and a width of 21.00 mm (Lima et al., 2012) (Figure 2.6).

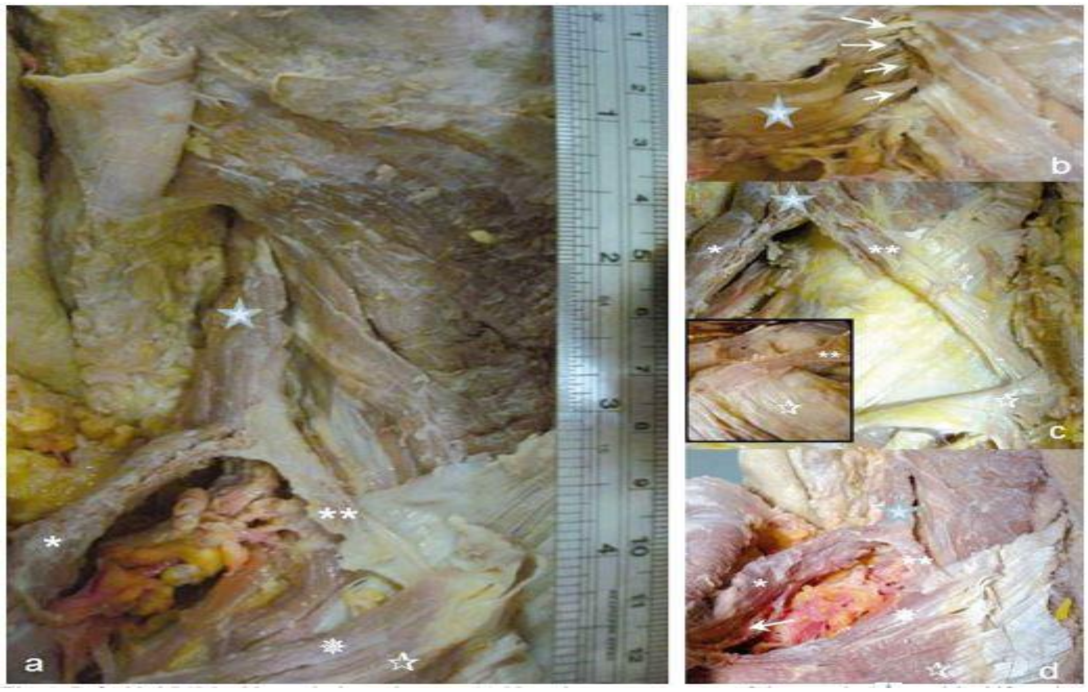

Figure 2.6: left-sided levator scapulae muscle with atypical attachments to the rhomboid major and serratus anterior muscle. Key: a: Note Accessory attachment (☆) and its lateral slip (*) and a medial slip (**) running in the direction of the rhomboideus major (☆) and minor muscles (✹). (b) Detail of the superior attachments (☆) of the upper segment of the LSM (→). (c) The medial band (**) running down to the anterior aspect of the left rhomboideus major muscle (☆) at the level of the second thoracic vertebra. Note detail in the inlet picture, in which the left rhomboideus major muscle was folded to enable visualization of the insertion of the medial slip (**). (d) The lateral slip (*) releasing a muscle expansion (←) to the aponeurosis of the serratus anterior muscle (Adapted from mm Lima et al., 2012).

Chotai et al. (2015) reported an attachment of the levator scapulae muscle to the left mastoid process, posterior to the mastoid attachment of the left sternocleidomastoid muscle. The left levator scapulae muscle of an 88-year-old female human cadaver was observed originating from C1-C4 vertebrae and distally inserted into the superomedial borders of the scapula. However, there was an additional muscle slip extending from the mastoid process and united with the rest of the levator scapulae muscle before inserting to the superomedial borders of the scapula. The additional slip had a length of 120.00 mm, and a width of 5.00 mm (Chotai et al., 2015) as presented in Figure 2.7.

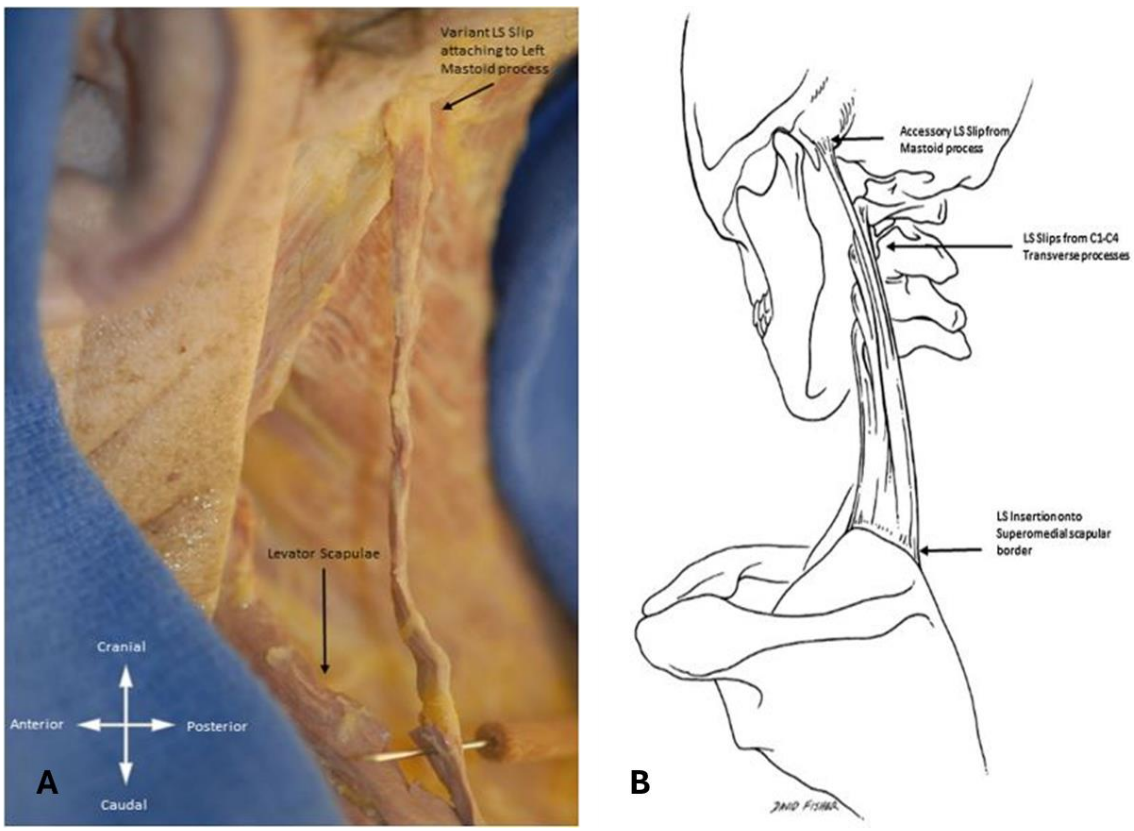

Figure 2.7: Levator scapulae muscle attachment to the mastoid process. Key: A: Cadaveric specimen with an additional muscle slip levator scapulae muscle slip attaching onto the mastoid process: Schematic drawing of the case showing normal proximal attachment of the levator scapulae muscle onto the transverse processes of the upper four cervical vertebrae and the additional muscle slip of the levator scapulae muscle attaching onto the left mastoid process (Adapted from Chotai et al., 2015)

In addition to the incidents reported, numerous levator scapulae muscle variations have been widely pronounced, including the caudal accessory attachments to the rhomboid, subscapularis, first and second ribs, serratus anterior, clavicle, spinous processes of the thoracic vertebrae, serratus posterior superior, and the thoracolumbar fascia (Au et al., 2017). Equally important, Smit and Todd (2019) also stated that various studies described the levator scapulae muscle as having additional attachments to the occipital bone, mastoid process, first and second ribs, trapezius muscle, scalene muscles, serratus muscles, the ligamentum nuchae and onto the rhomboid major tendon. Moreover, the levator scapulae muscle may also have tendinous expansions to the temporal and occipital bones (Lima et al., 2012).

The cervical MRI study by Au et al. (2016) observed bilateral accessory attachments of the levator scapulae muscle to the serratus anterior and the serratus posterior superior muscles. The accessory attachments to the serratus anterior were observed bilaterally arising from the anterior aspect of the levator scapulae muscle, coursing inferiorly and anteriorly, and then attaching to the serratus anterior muscles. The accessory attachments to the serratus posterior superior were observed bilaterally arising from the medial aspect of the levator scapulae muscle, coursing inferiorly and medially, becoming a thin aponeurosis, and then attaching to the serratus posterior superior muscles as presented in Figure 2.8.

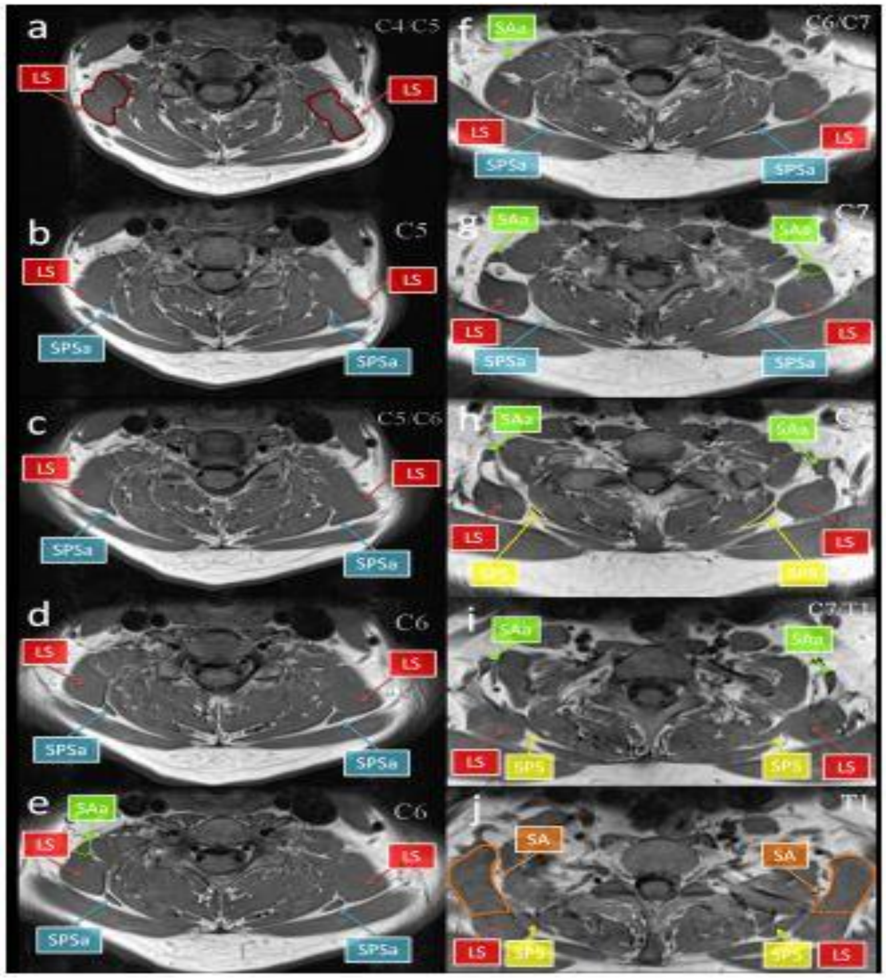

Figure 2.8: T1-weighted MRIs from superior (a) to inferior (j) obtained from a single subject (subject 16) with bilateral accessory attachments (SPSa) to serratus posterior superior (SPS) and bilateral accessory attachments (SAa) to serratus anterior (SA) (Adapted from Au et al., 2016).

Even though the variations of proximal and distal attachment are common, recent studies have reported abnormal levator scapulae muscle attachment instances. One of the instances was the levator scapulae muscle proximally attached to C1-C7 vertebrae, to the temporal bone, mastoid process, and trapezius (Beger et al., 2018).

2.4.2 The possible number of levator scapulae muscle slips

Initially, the levator scapulae muscle was well recognized to have three muscle slips, then in 1867, the muscle was described by Wood to have four muscle slips, and later in 1964, a study in Japan reported the levator scapulae muscle to have three to five muscle slips (Smit & Todd, 2019). In 2015, the levator scapulae muscle was reported to have an average of four muscle slips (Chotai et al., 2015).

Another instance by Smit and Todd (2019) reported a right levator scapulae muscle having six muscle slips, whereby the first two large slips originated from the transverse process of C1 and C2, while the other four muscle slips were attached to the posterior tubercles of transverse processes of C3-C6 (Figure 2.9).

Figure 2.9: The levator scapulae muscle with six muscle slips. Arrows indicate the muscle slips (Adapted from Smit & Todd, 2019).

Naik and Lokanadham (2019) investigated 32 levator scapulae muscles. The results demonstrated five levator scapulae muscles with three muscle slips, proximally attached on C1-C3, 19 levator scapulae muscles with four muscle slips, proximally attached on C1-C4, seven levator scapulae muscles with five muscle slips, proximally attached on C1-C5, and one levator scapulae muscle with six muscle slips, proximally attached to C1-C6 (Naik and Lokanadham, 2019). However, all the levator scapulae observed were distally attached to the medial border of the scapula (Naik & Lokanadham, 2019).

Smit and Todd, (2019) reported that 60.87% of the levator scapulae muscles had four muscle slips, 21.74% had five muscle slips, 15.22% had three muscle slips, and 2.17% had six muscle slips. The distances of each muscle slip category demonstrated that the levator scapulae muscle with six muscle slips had a longer average proximal and posterior distance, four muscle-slipped had longer average distal distance. The three muscle-slipped category had the shortest average proximal and distal distance, however, it demonstrated a higher average posterior distance in comparison with the four-slipped and five-slipped muscle slip categories, as summarised in Table 2.1.

Table 2.1: The levator scapulae muscle distance summary (from Smit & Todd, 2019)

Distances (mm)							
Muscle slips categories	**Frequency (%)**		**Proximal**		**Distal**		**Posterior**
3 slips	15.22		37.60 ± 5.60		40.40 ± 3.40		112.60 ± 16.40
4 slips	60.87		49.00 ± 6.30		46.50 ± 5.40		103.30 ± 8.90
5 slips	21.74		56.90 ± 6.10		45.30 ± 5.90		104.40 ± 11.10
6 slips	2.17		79.20		41.30		131.40

A similar study done by Naik and Lokanadham (2019) reported that out of 32 levator scapulae muscles investigated, 19 (59.37%) of the levator scapulae muscles had four muscle slips. Seven (21.87%) of the levator scapulae muscles had five muscle slips. Five (15.62%) of the levator scapulae muscles had three muscle slips, and one (3.25%) had six muscle slips as presented in Table 2.2.

Table 2.2: The levator scapulae muscle distance summary (From Naik & Lokanadham, 2019)

Distances (mm)							
Muscle slips categories	**Frequency (%)**		**Proximal**		**Distal**		**Posterior**
3 slips	15.62		35.60 ± 5.60		42.40 ± 3.40		112.60 ± 16.40
4 slips	59.37		47.00 ± 6.30		48.50 ± 5.40		103.30 ± 8.90
5 slips	21.87		55.90 ± 6.10		47.30 ± 5.90		104.40 ± 11.10
6 slips	3.25		79.20		41.30		131.40

Naik and Lokanadham's study was however compared to an anatomical study carried out in Japan with 50 cadaver population in terms of muscle slip frequency. Which reported 66.60% of levator scapulae muscles had four muscle slips, 26.60% had three muscle slips and 3.30% had five muscle slips (Naik & Lokanadham, 2019). Hence, the study carried out in Japan contradicted the study findings of Naik and Lokanadham (2019), as far as the levator scapulae muscles with five and three muscle slips are concerned. On the other hand, both Naik and Lokanadham (2019), and Smit and Todd (2019) studies have reported a single levator scapulae muscle with six muscle slips and they both reported the levator scapulae muscles with four muscle slips as the most prevailing.

Nevertheless, the levator scapulae muscle variations can be observed unilaterally or bilaterally (Naik & Lokanadham, 2019). Asymmetrical variations were observed in four (4) out of 16 cadavers, whereby the left levator scapulae muscles had different numbers of muscle slips compared to the right levator scapulae muscles (Naik & Lokanadham, 2019). A good instance observed in a cadaver by Naik and Lokanadham (2019) was of the levator scapulae muscle with three muscle slips on the left and five muscles on the right respectively.

A recent study by Lashley and Granite (2021) reported a case of the right and left levator scapulae muscles with different numbers of muscle slips, found on a 73-year-old Caucasian male cadaver. The right levator scapulae muscle was reported to have four muscle slips which proximally originated from C1-C4, while the left levator scapulae muscle had five muscle slips (Lashley & Granite, 2021). In this instance, Lashley and Granite (2021) stated that the first two muscle slips shared the proximal (vertebral) origin (C1), while the third to fifth muscle slips were proximally attached to C3-C5. Interestingly, the second cervical vertebrae (C2) had no levator scapulae muscle slip attached to it (Lashley & Granite, 2021) (Figure 2.10).

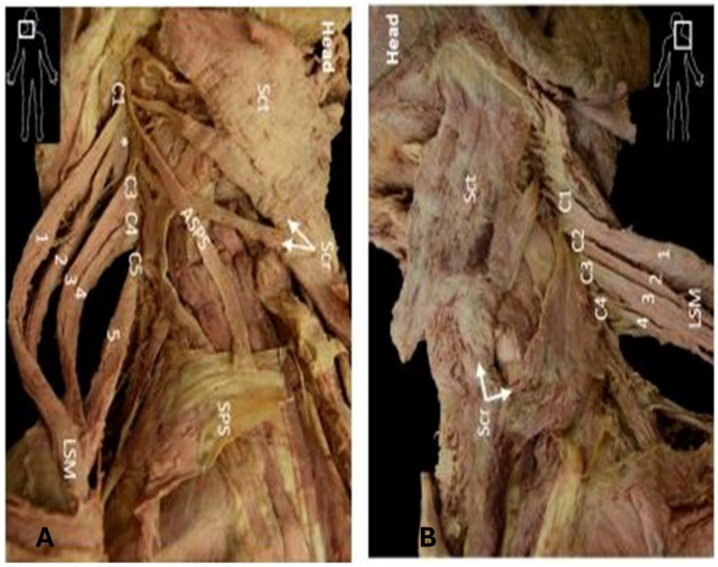

Figure 2.10: The levator scapulae muscle with five and four muscle slips. Key: A: Levator scapulae muscle with five muscle slips (1-5). B: Levator scapulae muscle with four muscle slips (1-4). LSM: levator scapulae muscle, SPS: serratus posterior superior, Scr: splenius cervicis (Adapted from Lashley & Granite, 2021).

2.5 The relationship of the levator scapulae muscles with the serratus anterior, serratus posterior superior and the rhomboid muscles

The levator scapulae muscle along with the rhomboids, serratus anterior, posterior superior, and inferior muscles are regarded as muscles of scapular mobility (Grujičić, 2022). The study by Au et al. (2017) observed the accessory attachment of the levator scapulae muscle to the serratus anterior, serratus posterior superior muscles, and to the first and second ribs. The prevalence of accessory muscle attachments between the levator scapulae muscle and the serratus anterior, and serratus posterior superior could be due to shared somitic origin of these muscles (Au et al., 2017).

The serratus anterior originates from the superolateral aspects of the first eight rib and it inserts to the medial borders of the scapula (Bae et al., 2022; Van De Graaff, 2002). The serratus anterior muscle is made up of three parts, the upper, middle, and lower serratus anterior (Smith et al., 2003). The normal description of the upper serratus anterior is that it extends from the first and second ribs to the superior angle of the scapula (Bae et al., 2022; Smith et al., 2003). With the aid of the middle and lower parts of the serratus anterior, the upper serratus anterior muscle is thought to cause scapular abduction and upward rotation (Smith et al., 2003).

The two distinct muscles that make up the rhomboids are the major and minor muscles, which are located right below the trapezius (Farrell & Kiel 2023). The rhomboid minor muscles originate at the ligamentum nuchae, as well as the C7 and T1 vertebrae (Farrell & Kiel 2023; Van De Graaff, 2002). It inserts along the medial border of the scapula, whereas the rhomboid major muscles originate from the spinous processes of the T2-T5 vertebra and insert on the medial border of the scapula (Farrell & Kiel 2023; Van De Graaff, 2002). The dorsal scapular artery is the main circulatory source for the rhomboid muscles (Dalley & Agur, 2023; Farrell & Kiel 2023; Van De Graaff, 2002).

The serratus posterior superior originates from the nuchal ligament and spinous processes of vertebrae (C7-T3) and inserts on the superior borders of the second to fifth ribs (Vilensky et al., 2001). The function of the serratus posterior superior is to elevate the ribs (Vilensky et al., 2001).

2.6 Blood supply to the levator scapulae muscle

2.6.1 The main blood supply to the levator scapulae muscle

The theory described the dorsal scapular artery as the main blood supply to the levator scapulae muscle (Beger et al., 2018; Fakoya et al., 2020; Netter, 2014). However, Reiner and Kasser (1996) described the dorsal scapular artery as a frequent blood supply to the rhomboid muscles. The dorsal scapular artery is described to originate from two main arterial branches, the transverse cervical artery, and the subclavian artery, which also supply blood to the trapezius muscle (Netter, 2014; Reiner and Kasser, 1996).

According to Bulbul et al. (2019), the transverse cervical artery is also known as the cervicodorsal trunk. Reiner and Kasser (1996) noted that the dorsal scapular artery ascended from the transverse cervical artery as a deeper branch that passes deep to the levator scapulae muscle, and to the rhomboid muscles, while the superficial branch extended to the trapezius muscle. Netter (2014) also described the dorsal scapular artery to be the deeper branch of the transverse cervical artery, in addition to the superficial branch.

Recent studies by Fakoya et al. (2020) and Henry and Munakomi (2022), stated that the levator scapulae muscle is mainly supplied by the dorsal scapular artery, which mostly originated from two thyrocervical trunk branches, the subclavian artery and the transverse cervical artery. However, the dorsal scapular artery was said to frequently originate from a subclavian artery compared to the transverse cervical artery (Reiner & Kasser, 1996; Verenna et al., 2016).

Another study by Henry and Munakomi (2022) emphasised that the transverse cervical artery bifurcates at a level of the levator scapulae muscle, into deep and superficial branches. The deep transverse cervical artery branch is the dorsal scapular artery (Henry & Munakomi, 2022). In addition, the levator scapulae muscle can be supplied by the ascending cervical artery, which is a branch of the thyrocervical trunk (Grujičić, 2022; Netter, 2014). Huelke (1958) also stated that the dorsal scapular artery mostly originates from the transverse cervical artery or the second or third part of the subclavian artery (Figure 2.11).

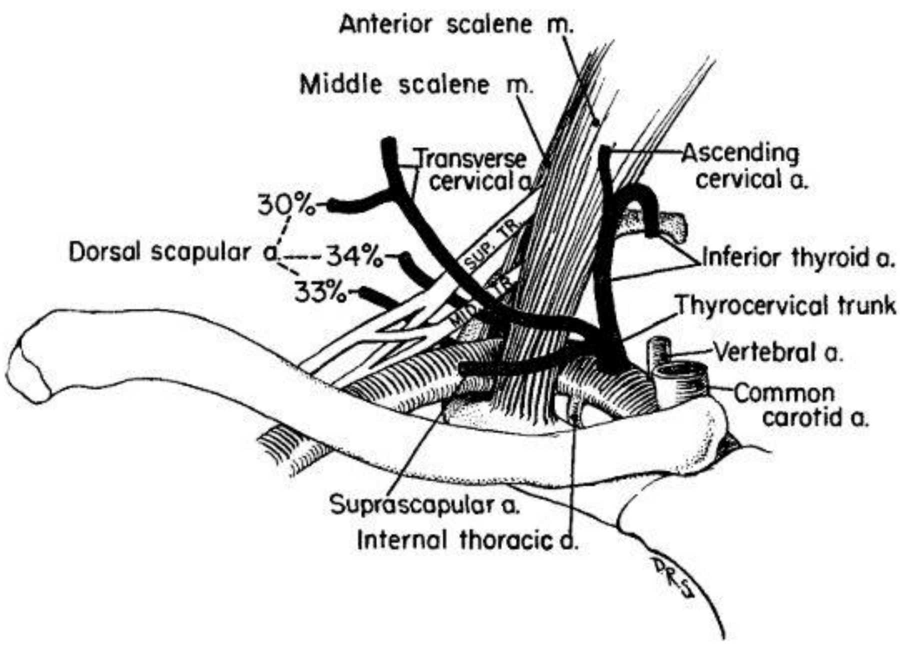

Figure 2.11: The three major sites of origin of the dorsal scapular artery (Adapted from Huelke, 1958).

Similarly, a study done by Reiner and Kasser (1996) stated that 75.00% of the dorsal scapular artery arose from the subclavian artery while 25.00% arose from the transverse cervical artery (Figure 2.12, Table 2.3). On the other hand, a cadaveric study by Verenna et al. (2016) observed that 71.00% of dorsal scapular arteries originate from the subclavian artery and 35.00% from the thyrocervical trunk Table 2.3.

Table 2.3: The source of dorsal scapular artery (From Reiner & Kasser, 1996; Verenna et al., 2016)

Source of dorsal scapular artery		
Authors	**Subclavian artery**	**Transverse cervical artery**
Reiner and Kasser (1996)	75.00%	25.00%
Verenna et al. (2016)	71.00%	35.00%

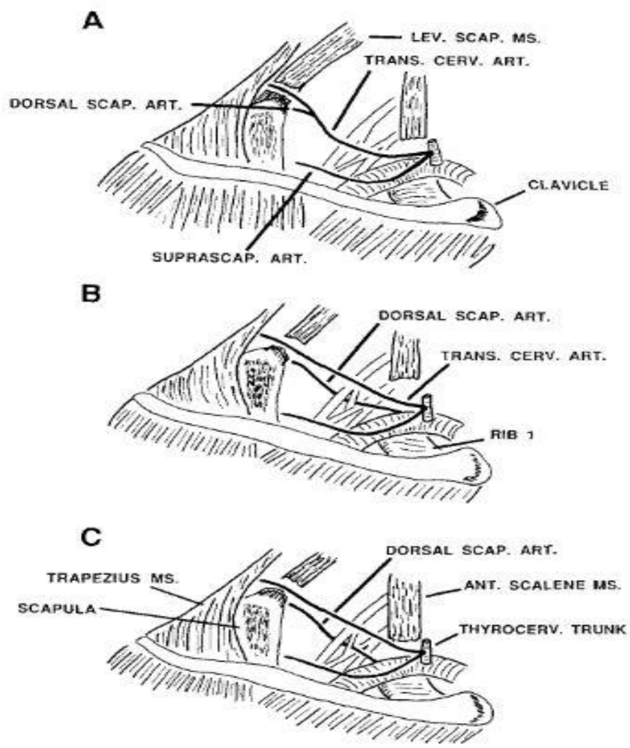

Figure 2.12: Semischematic drawings of the posterior triangle region of the right side of the neck showing the three major variants for the origin of the dorsal scapular artery (Dorsal Scap. Art.). Key: A: The artery to the rhomboids arises as a deep branch of the transverse cervical artery (Trans. Cerv. Art.) to the trapezius muscle. B, C: The dorsal scapular artery to the rhomboids arises directly from the second (posterior to the anterior scalene muscle) or third part (lateral to the anterior scalene muscle) of the subclavian artery. Ant. Scalene Ms: Anterior scalene muscle, Suprascap. Art: Suprascapular artery (Adapted from Reiner & Kasser, 1996).

Moreover, the dorsal scapular artery was described to frequently stem from the transverse cervical artery and subclavian artery, however, the transverse cervical artery was the main source (Manyacka Ma Nyemb et al., 2018). Chaijaroonkhanarak et al. (2014, as cited in Bulbul et al., 2019), described the arterial branch origin to be associated with ethnicity, stating that the dorsal scapular artery mostly originated from transverse cervical artery in

Japanese and Thais. Manyacka Ma Nyemb et al. (2018) also emphasised that variety in arterial origination may be associated with the ethnical background of the study population used.

2.6.2 The dorsal scapular artery and brachial plexus

The relationship of the dorsal scapular artery with the brachial plexus was observed by Huelke (1958), whereby the first part branch specifically originated from the second and third part of the subclavian artery, the second part branch either passed between the superior and middle or between the middle (with 47.00% frequency) and lower trunks of the brachial plexus (with 53.00% frequency), while the third part branch reportedly passed between the superior and middle trunks (with 89.00% frequency) or middle and lower trunks (with 11.00% frequency) of the brachial plexus presented in Figure 2.13..

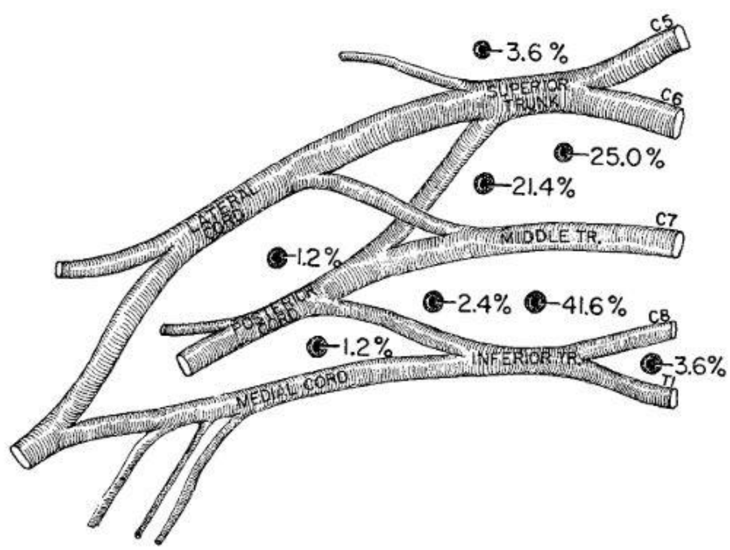

Figure 2.13: The frequency of the various positions of the dorsal scapular artery as it passes through the brachial plexus. Key: Cervical nerve roots (C1-C6); Thoracic nerve root (T1) (From Huelke, 1958).

Verenna et al. (2016) also focused on the dorsal scapular artery pathway and found the dorsal scapular artery to mostly originate from the subclavian artery. The results obtained stated that 40.00% of dorsal scapular artery from the subclavian artery passed between the upper and middle brachial plexus trunks, 23.00% passed between the middle and lower trunks, or inferior (4.00%) or superior to the plexus (1.00%). Whereas the dorsal scapular artery from the thyrocervical trunk demonstrated that 23.00% of the dorsal scapular artery passed regularly superior to the plexus, while 6.00% passed between the middle and lower trunks or 4.00% passed between upper and middle trunks (Verenna et al., 2016) (Figure 2.14, Table 2.4). In addition, Verenna et al. (2016) also observed two dorsal scapular arteries supplying the same levator scapulae muscle, one originated from the subclavian artery and the other from the thyrocervical artery (Figure 2.14).

Table 2.4: A summary of dorsal scapular artery paths between brachial plexus trunks from subclavian artery and thyrocervical trunk (From Verenna et al., 2016)

	Path through the brachial plexus trunks (%)			
Origin	**U/M**	**M/L**	**Sup**	**Inf**
Subclavian artery	40.00	23.00	1.00	4.00
Thyrocervical trunk	4.00	6.00	23.00	-

Key: Inf: inferior to lower trunk; M/L: between middle and lower trunks; Sup: superior to upper trunk; U/M: between upper and middle trunks.

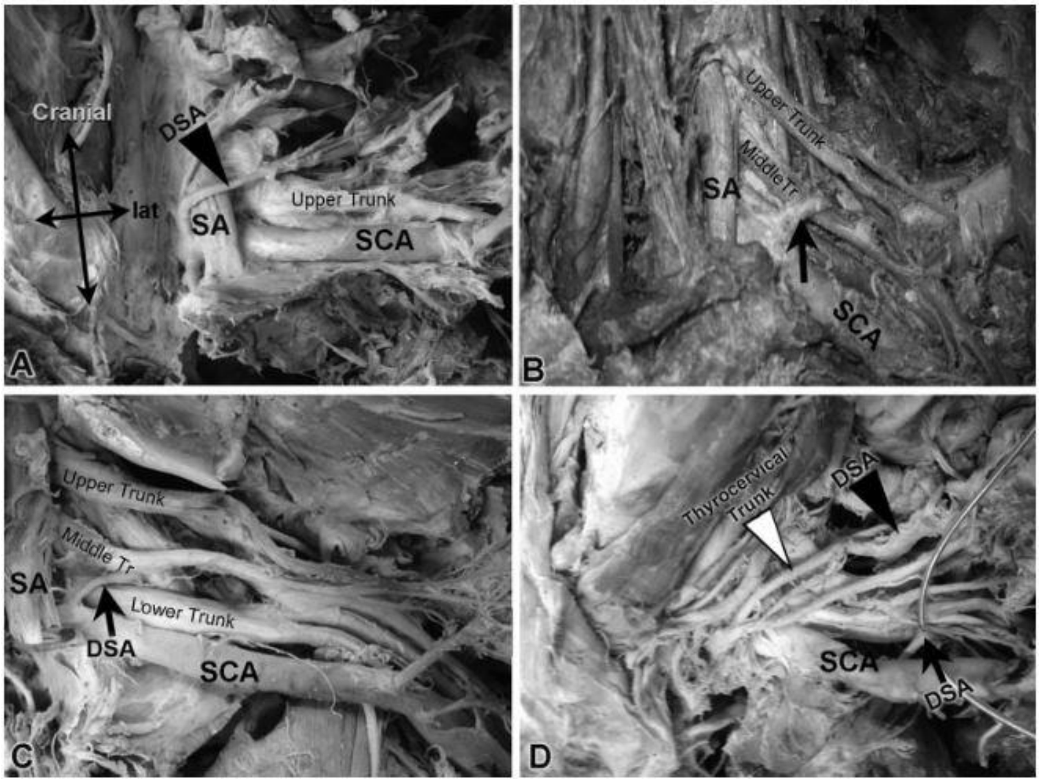

Figure 2.14: Varied paths of the dorsal scapular artery (DSA) between the trunks of the brachial plexus in four different representative cadaveric specimens. Key: A: A cadaver with the DSA (arrowhead) stemming from the thyrocervical trunk rather than from the subclavian artery (SCA). Extending anterior to the scalenus anterior (SA) muscle and superior to the brachial plexus. B: A different cadaver with the DSA (indicated with an arrow) stemming from subclavian artery (SCA) before passing between the upper and middle trunks of the brachial plexus. Trunk (Tr). C: In another cadaver, the DSA (arrow) stems from subclavian artery before passing between the middle and lower trunks of brachial plexus. D: Two DSA branches were observed in some cadavers. One of the DSA branches stems from the thyrocervical trunk (white arrowhead) before taking a path superior to the brachial plexus (black arrowhead). The second DSA branch (arrow) stems from the subclavian artery (SCA) Adapted from Verenna et al., 2016).

2.6.3 The three types of blood supply to the levator scapulae muscle

On the contrary, Manyacka Ma Nyemb et al. (2018) reported that the source of the transverse cervical artery and dorsal scapular artery were classified into three types based on the origin and mode of birth. Type one (type I) was observed in 21 cases, whereby, the transverse cervical artery and dorsal scapular artery branched from a common trunk originating from the subclavian artery, the second type (type II) was observed in 27 cases, where the dorsal scapular artery branched directly from the subclavian artery, whereas transverse cervical artery branched from the thyrocervical trunk, whereas the third type (type III) was observed in 10 cases, both arterial branches of the transverse cervical artery and dorsal scapular artery originated from thyrocervical trunk (Manyacka Ma Nyemb et al., 2018) (Figure 2.15).

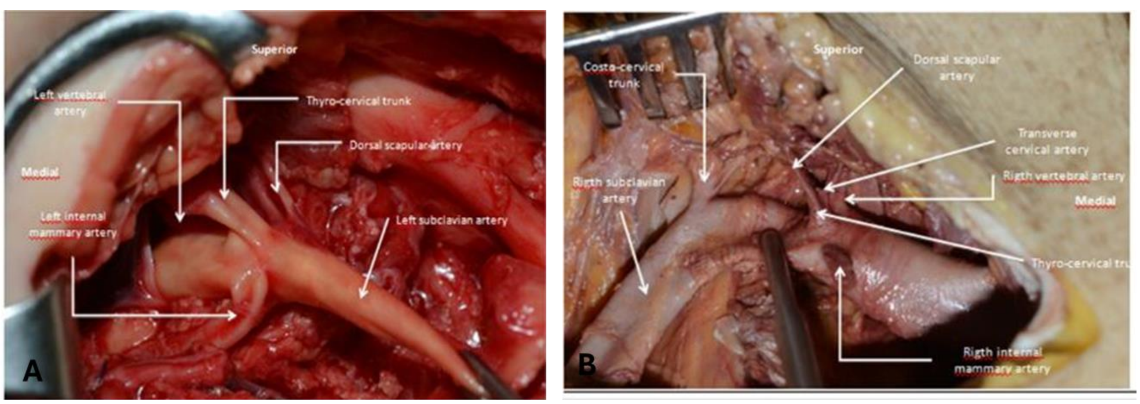

Figure 2.15: Type II and Type III of blood supply to the levator scapulae muscle. Key: A: The dorsal scapular artery originating from the subclavian artery and the transverse artery originating from the thyro-cervical trunk (Type II found in 27 dissections out of 58). B: Both the dorsal scapular artery and the transverse artery originate from thyro-cervical trunk (Type III found in 10 out of 58 dissections) (Adapted from Manyacka Ma Nyemb et al., 2018).

Interestingly, Bulbul et al. (2019) reported the dorsal scapular artery to originate from four sites, 45.60% from the subclavian artery, 38.00% from the transverse cervical artery, 14.20% from the cervicodorsoscapular trunk, 1.80% costocervical trunk and 0.30% dorsoscapular trunk. On the other hand, the transverse cervical artery originated from two sites, from the thyrocervical trunk and directly from the subclavian artery (Bulbul et al., 2019). Figure 2.16 demonstrates the four possible origins of the dorsal scapular artery.

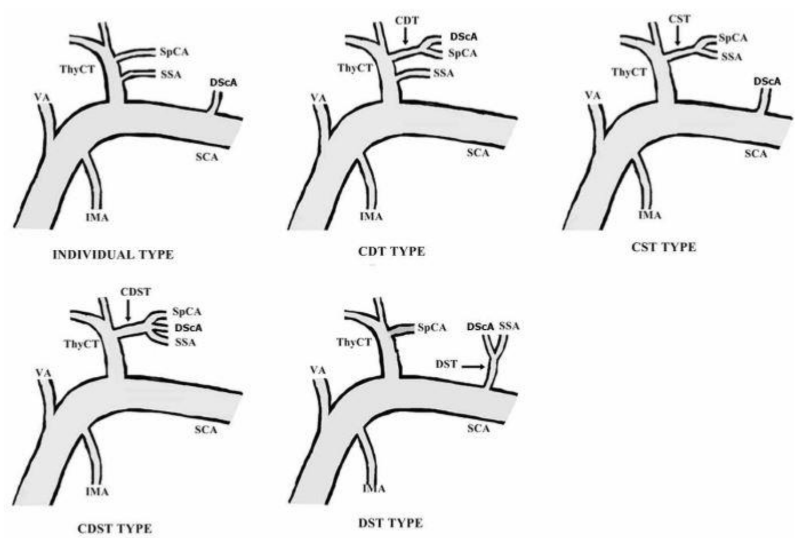

Figure 2.16: Illustration of individual type and trunk formations within the lateral cervical region. Key: CDT: cervicodorsal trunk (transverse cervical artery), CDST: cervicodorsoscapular trunk, CST: cervicoscapular trunk, DScA: dorsal scapular artery, DST: dorsoscapular trunk, IMA: internal mammarian artery, SCA: subclavian artery, SpCA: superficial cervical artery, SSA: suprascapular artery, ThyCT: tyhrocervical trunk, VA: vertebral artery (Adapted from Bulbul et al., 2019).

Moreover, the study finding by Ikka et al. (2016) stated that, from 50 cases, 38.00% of the dorsal scapular artery was found in type I, 38.00% was a type II and 24.00% was a type III. In their radiology study, from 93 cases, 61.30% of both dorsal scapular artery and transverse cervical artery originated from the subclavian artery, with 23.70% of the dorsal scapular artery branched directly from the subclavian artery and transverse cervical artery (type II) and 15.00% of the dorsal scapular artery and transverse cervical artery originated from thyrocervical trunk (type III) (Ikka et al., 2016).

2.7 Nerve supply to the levator scapulae muscle

The levator scapulae muscle is strategically situated in terms of topography and has a long length, rich vascularization, and nerve supplies that are largely consistent (Lima et al., 2012). Based on the cadaveric study done, about (0%-29.00%) of instances reported that the levator scapulae muscle has various innervations (Pinto et al., 2019). The levator scapulae muscle is innervated by the dorsal scapular nerve arising from the nerve roots of C4 and C5 (Dalley & Agur, 2023; Van De Graaff, 2002). The dorsal scapular nerve originates from the upper part of the brachial plexus, from the anterior rami of C5, and usually the first branch of C5 (Fakoya et al., 2020; Nguyen et al., 2016; Som & Laitman, 2017) (Figure 2.17).

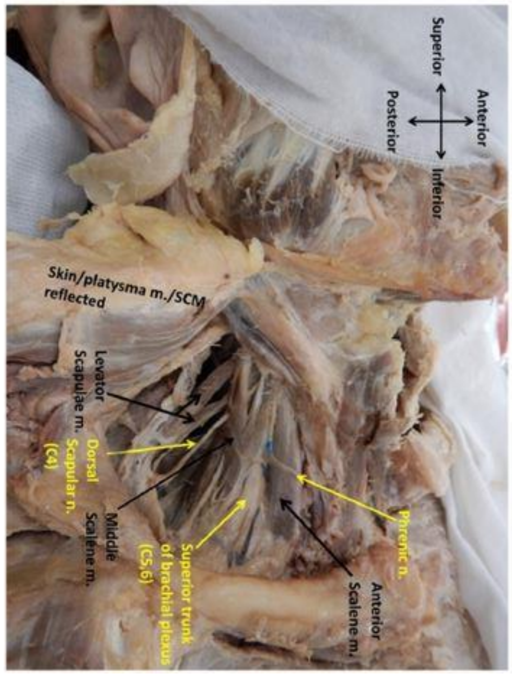

Figure 2.17: An anterolateral view of the right neck region of a 90-year-old female cadaver in the supine position. The dorsal scapular nerve (DSN) branches from C4 and pierces the middle scalene muscle. The DSN travels posteroinferiorly after piercing the middle scalene muscle to supply the levator scapulae, rhomboid minor, and rhomboid major muscles (Adapted from Nguyen et al., 2016).

In addition, Nguyen et al. (2016) stated that there are different spinal root sources and muscle innervations for the dorsal scapular nerve, according to several anatomical investigations in the main literature. Based on one study, the dorsal scapular nerve may receive varied contributions from C4 to T1, in addition to contributions from C5 (Nguyen et al., 2016). Furthermore, contributions to the dorsal scapular nerve reported by several authors were noted by Nguyen et al. (2016), whereby it received contributions from C5, C6 and long thoracic nerve as summarised in Table 2.5.

Table 2.5: Contribution to the dorsal scapular nerve summary (From Nguyen et al., 2016)

Authors	Contributions to the dorsal scapular nerve	Frequency (%)
Ballesteros' and Ramirez's	C5	48.00
	Long thoracic nerve	30.00
Lee et al. (1992)	C5	25.00
Tubbs et al. (2005)	C5	95.00
	C6	5.00
Shilal et al. (2015)	C5	-
	C6	-
	Long thoracic nerve	-

Equally important, the results from Nguyen's study stated that 70.00% of the dorsal scapular nerves arose from the spinal nerve roots of C5, whereas 22.00% arose from C4 and 8.00% of the dorsal scapular nerves arose from C6 (Nguyen et al., 2016). The dorsal scapular nerves were also reported to have three routes related to the middle scalene muscle, 74.00% of the dorsal scapular nerves pierced the muscle, whereas 13.00% of the dorsal scapular nerves were found to travel anteriorly to the middle scalene muscle, and 13.00% of the dorsal scapular nerves travelled posterior to the muscle (Nguyen et al., 2016) (Figure 2.18). Equally important, Dalley and Agur (2023) also stated that the dorsal scapular nerve normally pieces through the middle scalene muscle and extends to the levator scapulae and the rhomboid muscles.

	N and percentage
Origin	
C4	5 (22%)
C5	16 (70%)
C6	2 (8%)
Route	
Anterior to middle scalene m.	3 (13%)
Piercing middle scalene m.	17 (74%)
Posterior to middle scalene m.	3 (13%)
Muscles innervated	
Levator scapulae m. only	11 (48%)
Levator scapulae m. & rhomboid mm.	12 (52%)

Figure 2.18: A table of variation in the spinal roots and innervations of the dorsal scapular nerve (Adapted from Nguyen et al., 2016)

Nevertheless, the levator scapulae muscle can also be innervated by the C3 and C4 cervical nerve branches of the cervical plexus (Dalley & Agur, 2023; Henry & Munakomi, 2022). However, Taira et al. (2003) described the levator scapulae muscle to be innervated by C2- C5 cervical nerve branches, whereby 5.50% of nerve supply is reported to originate from C2, 100.00% from C3 and C4, and 19.00% originated from C5. According to Martins et al. (2021), the nerve branches to the levator scapulae muscles and some of the back and cervical muscles arise from the cervical plexus, and about three or four nerve branches of the cervical plexus innervate the levator scapulae muscle.

2.8 Clinical Correlation of levator scapulae muscle

2.8.1 Cervical myofascial pain

The levator scapulae muscle is associated with the cervical vertebrae and commonly at a point related to fibromyalgia diagnosis, which together with trauma, muscle overuse, and imbalance posture may result in myofascial pain, also known as a musculoskeletal disorder, pain in muscles and their surrounding fascia (Henry & Munakomi, 2022). According to Damgaard et al. (2013), musculoskeletal disorders are one of the main disorders that have an impact on society's day-to-day activities, as they might limit muscle motions for an extended length of time.

Therefore, it is currently thought that levator scapulae muscles are the main source of discomfort in people who have chronic tension-type neck and shoulder pain (Menachem et al., 1993; Damgaard et al., 2013). As a result, it was hypothesised that the muscle's structural differences enhanced the likelihood of experiencing pain (Menachem et al., 1993). The alterations connected to the levator scapulae muscles, according to Chotai et al. (2015), may also affect neck and shoulder pain. Because of this, most physicians in the medical specialities of radiology, neurology, surgery, and musculoskeletal medicine will come across anatomical variations throughout their jobs (Au et al., 2017).

According to a Dutch study, 44.00% of patients with chronic neck pain visited their general consultant with the condition for twelve months, and 51.00% of these were referred to physiotherapy treatment (Damgaard et al., 2013). Navarro-Ledesma et al. (2019) stated that patients with shoulder pain being attended to in primary care do not completely improve after six months after their first incident. Thus, there is a need to explore alternative non-invasive approaches in these patients (Navarro-Ledesma et al., 2019).

2.8.2 Levator Scapulae Syndrome

According to Chotai et al. (2015), the levator scapulae muscle variations were believed to be the leading cause of the pain at the medial angle of the scapula known as the levator scapulae syndrome. However, these theories were not proven due to the posthumous nature of the cadaveric results during the study (Chotai et al., 2015). The levator scapulae syndrome is usually the soreness of the muscle on the superomedial angle of the scapula, and this syndrome is inflated by the stretching of the levator scapulae muscle (Henry & Munakomi, 2022).

2.8.3 Snapping Scapula Syndrome

Henry and Munakomi (2022) stated that the snapping scapula syndrome is also referred to as “washboard syndrome” which is a condition that occurs after overuse, muscle imbalance, or chronic injury that affects the scapulothoracic articulation. Military personnel are frequently reported to develop this condition due to chronic stress and injuries after overloading activities, involving their upper extremities (Henry & Munakomi, 2022).

2.8.4 Cervical dystonia

Laterally cervical dystonia may be brought on by the levator scapulae muscle's unusual contraction (Lima et al., 2012). According to *Dystonia - Symptoms and Causes* (2022) movement disease called dystonia causes muscles to contract uncontrollably, twisting the affected body parts uncontrollably and resulting in abnormal posture and repetitive movement. Therefore, an electromyography examination is carried out to identify the muscles implicated since patients with cervical dystonia typically displays signs of retrocollis, anterocollis, and laterocollis (*Dystonia - Symptoms and Causes*, 2022).

In addition, the levator scapulae muscle is a key muscle that contributes to laterocollis instances and is also present in people who have cervical dystonia (Anderson et al., 2008). Furthermore, levator scapulae muscle accessory attachments may cause myofascial discomfort and may affect how cervical dystonia is managed (Au et al., 2017). Equally important, torticollis is thought to be affected by levator scapulae muscle variations, and a greater understanding of these variations can aid in the management of disorders that are resistant to conventional therapy (Chotai et al., 2015).

2.8.5 Nerve injury

The levator scapulae, rhomboid major and rhomboid minor muscles, which are innervated by the dorsal scapular nerve, are involved in the T3 transfer technique, making the dorsal scapular nerve crucial from a clinical standpoint. In addition, the dorsal scapular nerve injury can affect the functions of the rhomboids and the levator scapulae muscles, causing the scapular to dislocate from the midline (Dalley & Agur, 2023). To increase understanding and reduce dorsal scapular nerve damage during surgeries, adequate anatomical studies of the dorsal scapular nerve are required (Pinto et al., 2019). Moreover, the nerves (C4) to the levator scapulae muscle can be transferred to the lateral pectoral nerve in cases of brachial plexus injuries, to restore the functionality of the affected upper extremities (Martins et al., 2021).

2.9 Chapter summary

In this chapter the focus was on defining the main terms used in this study, the highlights of previous literature on the embryology of the levator scapulae muscle, the anatomical variations, the nerve and blood supply, as well as the clinical correlations of the levator scapulae muscle. However, the lack of data associated with the levator scapulae muscle morphological variations and its neurovasculature highly encouraged the importance of carrying out this study. The next chapter will focus on research methods, which include the procedures used in this study, the data analysis, and ethical clearance.

CHAPTER 3: RESEARCH METHODS

3.1 Introduction

This study was carried out in two phases: The cadaveric study and the magnetic resonance imaging (MRI) study. The cadaveric study involved the dissection of the neck part of the human body. The anterolateral dissection exposed the nerve and blood supply to the levator scapulae muscle while the posterior dissection exposed the posterior view of the levator scapulae muscle and also visualised the proximal and distal attachments. The magnetic resonance imaging (MRI) study included patient scan records and no direct contact with patients was done. MRI scan is a common procedure around the world that uses a strong radio wave magnetic field to generate detailed images of the organs and tissues within the body (Lam, 2018).

This chapter is subdivided into Research design, population study, sampling technique used, research instrument used to collect data, the procedures used for data collection, and the analytical technique the study used to produce the results.

3.2 Research design

3.2.1 Cadaveric study

The quantitative descriptive data under the cadaveric study were obtained from the total number of levator scapulae muscles, the number of muscle slips, the lengths and widths of individual muscle slips, the proximal distances, distal distances, anterior distances, and posterior distances of the levator scapulae muscles.

The cadaveric data were obtained via the anterolateral and posterior dissection of the neck to expose the levator scapulae muscles, and then the images of the levator scapulae muscles were taken using the Nikon digital camera. The levator scapulae muscles were then measured. The initial three trial measurements were taken by the main researcher and the second researcher assisted with the second three trial measurements, giving a total of six trials by two researchers. These trials were applied for all muscle distances, individual muscle slip widths and lengths. The significance of three trials per researcher was to obtain the averages of measurements and increase accuracy.

The distances (mm) of the levator scapulae muscles were done following the edges of the muscle (proximal, distal, anterior and posterior), using a Morphometric geometric (MG) method (using a thin white satin ribbon and pins to trace the edges and lengths of the levator scapulae muscle) and the digital Vernier calliper (to measure the lengths of the satin ribbon used in the MG method). The lengths (mm) of the levator scapulae muscle slips were done by following the middle aspects of individual muscle slips, from their origin to their insertion, using a Morphometric geometric method and the digital Vernier calliper.

The Morphometric geometric method is a multivariate class of techniques for assessing and evaluating object shapes (Polly, 2018). The goal of these morphometric geometric techniques is to preserve geometric information during a study. They offer effective, statistically strong analyses that enable the easy connection of abstract, multivariate results to the physical characteristics of the original specimens (Slice, 2007).

The widths (mm) were taken at the widest points of individual levator scapulae muscle slips, using the digital Vernier calliper only. The collected measurements among the researchers were calculated to obtain average measurements. The correlation of the data collected by each researcher was assessed, as well as the correlation of data between the two researchers. The data was then further analysed using linear regression to determine the relationship between cadaver parameters and ages, as well as Box and Whisker plots to determine the differences in measurements.

A t- test was used to determine the relationship between the left and right parameter (distances, lengths and widths) measurements of levator scapulae muscle, as well as the relationship between the study parameters (distances, lengths and widths) and the sex of the cadavers. The cadaver races versus parameters (distances, lengths and widths) were compared using Analysis of Variance (ANOVA) test, and the variables with significant differences were further analysed using a Turkey's Honestly Significant Difference post-hoc (Turkey's HSD post-hoc) test. The blood and nerve branches to the levator scapulae muscles were observed from the anterolateral aspects of cadavers' necks, the origins of both arteries and nerves were traced and the findings were recorded.

3.2.2 MRI study

The retrospective record review data were obtained from the MRI records, extracted from patients at a Roman Catholic Hospital (RCH). The collected MRI scans went through random sampling to obtain the final number of MRI scans used in the current study. The individual scans were analysed in terms of quality and the presence of the muscle of interest, the levator scapulae muscle. Finally, the scans were analysed for the presence of levator scapulae muscle accessory attachments, and the findings were recorded.

3.3 Sample

3.3.1 Cadaveric Study.

Twenty-one available formalin-embalmed adult cadavers were used in this research project to obtain adequate data. This research was based at the School of Medicine, University of Namibia (UNAM). All the specimens used during the research were donated to the Anatomy department (University of Namibia) and each cadaver was pre-embalmed via the right common carotid artery with a mechanical pump infusion over twelve hours. All the cadavers were dissected on the right and the left side to expose both the levator scapulae muscles and the neurovasculature.

3.3.3 MRI study

Simple random sampling was done on the patient records between January 2017- April 2022. The sample size (n = 167) that was calculated was based on a total of 293 patients who received axial scans during this period. The sample size was calculated with a confidence interval of 95.00% and with a 5.00% margin of error. The MRI sample size was calculated as follows:

The sample size (n) is calculated according to the formula: n = [z2 * p * (1 - p) / e2] / [1 + (z2 * p * (1 - p) / (e2 * N))]

Where: z = 1.96 for a confidence level (α) of 95.00%, p = proportion (expressed as a decimal), N = population size, e = margin of error.

z = 1.96, p = 0.5, N = 293, e = 0.05

n = [1.962 * 0.5 * (1 - 0.5) / 0.052] / [1 + (1.962 * 0.5 * (1 - 0.5) / (0.052 * 293))]

n = 384.16 / 2.3111 = 166.222

n ≈ 167

From a sample size of 167 scans, 121 scan records either had major pathologies, were unclear, or the muscle of interest (levator scapulae muscle) was partially presented or not visible in all the slides. Therefore only 46 MRI scans were subsequently suitable for the current study, made up of 24 females and 22 males.

3.4 Research instruments

The following items were used: a digital Vernier calliper (0-150mm ± 0.1mm), a scalpel, forceps, blades, rubber gloves, a head support block, thin satin ribbon, pins, and a digital camera (Nikon D3500). The calliper was calibrated before the measurements were taken.

3.5 Inclusion criteria

3.5.1 Cadaveric study

This study used a cadaver population aged 18 years and above (adult population) of the available specimens during the study period, at UNAM, School of Medicine. Both bilateral and unilateral dissection were performed during this study. The muscle distance, muscle slip length, and width were included.

3.5.2 MRI study

The MRI record included patient records of 18 years and above, who visited the Roman Catholic Private Hospital (Windhoek) from January 2017 to April 2022. MRI scans with no gross pathologies, trauma, or congenital defects were used.

3.6 Exclusion criteria

3.6.1 Cadaveric study

To have more reliable, uniform, and consistent research, the cadaver population aged below 18 years were excluded from this study, as well as the length and width of neurovasculature. In addition, the cadaver embalmed with a neck flexed to the side was excluded and muscle tissue shrinkage due to embalming was disregarded.

3.6.2 MRI study

The MRI records of patients younger than 18 years were not included in this study, as well as MRI scans with blurry views, gross pathologies, trauma, or congenital defects.

3.7 Procedures

3.7.1 Cadaveric study

"The levator scapulae muscle can be identified between sternocleidomastoid and trapezius posterior to scalenus posterior and anterior to splenius capitis. In the upper cervical spine, the levator scapulae muscle in cross-section migrates anteriorly, lying immediately lateral to splenius capitis, as it passes to its C1–C4 transverse processes attachments" (Au et al., 2016).

A bilateral and unilateral dissection was performed on twenty-one (21) formalin-embalmed adult cadavers provided by the University of Namibia (UNAM). This research study was carried out following the procedures described by Beger et al. (2018) and Smit and Todd (2019).

3.7.1.1 The levator scapulae muscle and its attachments

The normal proximal attachment of the levator scapulae muscle is the tuberosity of transverse processes, while the distal insertion is the superomedial border of the scapula, hence other additional proximal and distal attachments associated with the muscle were considered as accessory muscle slips, with accessory attachments of the levator scapulae muscle. The accessory attachments were traces wising a blunt dissection to avoid further distraction of cadaver tissues. Probes were used to trace the underneath skeletal structures like the cervical vertebral transverse processes, ribs, and the clavicles.

To fully expose the levator scapulae muscle and do the necessary measurements, a delicate dissection was performed. To achieve this, the cadaver was dissected in the prone and supine positions to expose the origin and the insertion of the muscle properly. The measurements were taken, the descriptions were done, and necessary photographs were taken for illustration purposes.

For better levator scapulae muscle exposure, the dissection was performed in two stages: The posterior approach was done to define the insertion of the muscle onto the scapula. The anterolateral approach was done to expose the origin of the muscle from the cervical vertebrae and to expose the neurovasculature to the levator scapulae muscle. The technique used during the dissection was the blunt dissection with fingers and forceps. A scalpel was used for making skin incisions and the scissors for blunt dissection and reflection of neighbouring muscles.

The posterior approach began with the cadaver placed in the prone position. The neck was flexed, and the thorax was lifted by a head support block. Using a disposable surgical scalpel, a midline skin incision was made, from the external occipital protuberance to an imaginary line between the medial borders of the right and left scapula. Both of these landmarks were easily palpated beneath the skin. Two more skin incisions were made perpendicular to the midline incision to reflect the skin. The skin and superficial fascia were reflected laterally to expose the back muscles as shown in Figure 3.1.

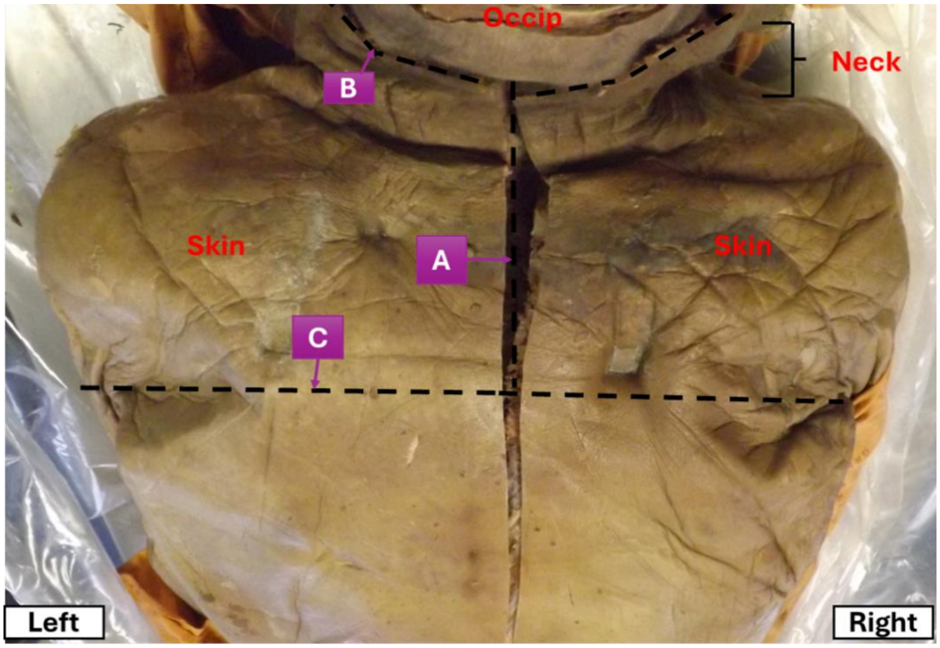

Figure 3.1: A posterior view of the cadaver. Key: A: A midline skin incision from the external occipital protuberance to an imaginary line between the medial borders of the right and left scapula. B and C: Two skin incisions perpendicular to the midline incision to reflect the skin. Occip: occiput.

The trapezius was the first major muscle to be seen. The fascia and fatty tissue of the trapezius were cleared, before reflecting the muscle laterally towards its insertion. The surface of the rhomboids was cleaned to establish a clear inferior end of the LSM insertion. The distal attachment of the levator scapulae muscle to the superomedial border of the scapula and the direction of the muscle towards the cervical vertebrae was exposed as presented in Figure 3.2.

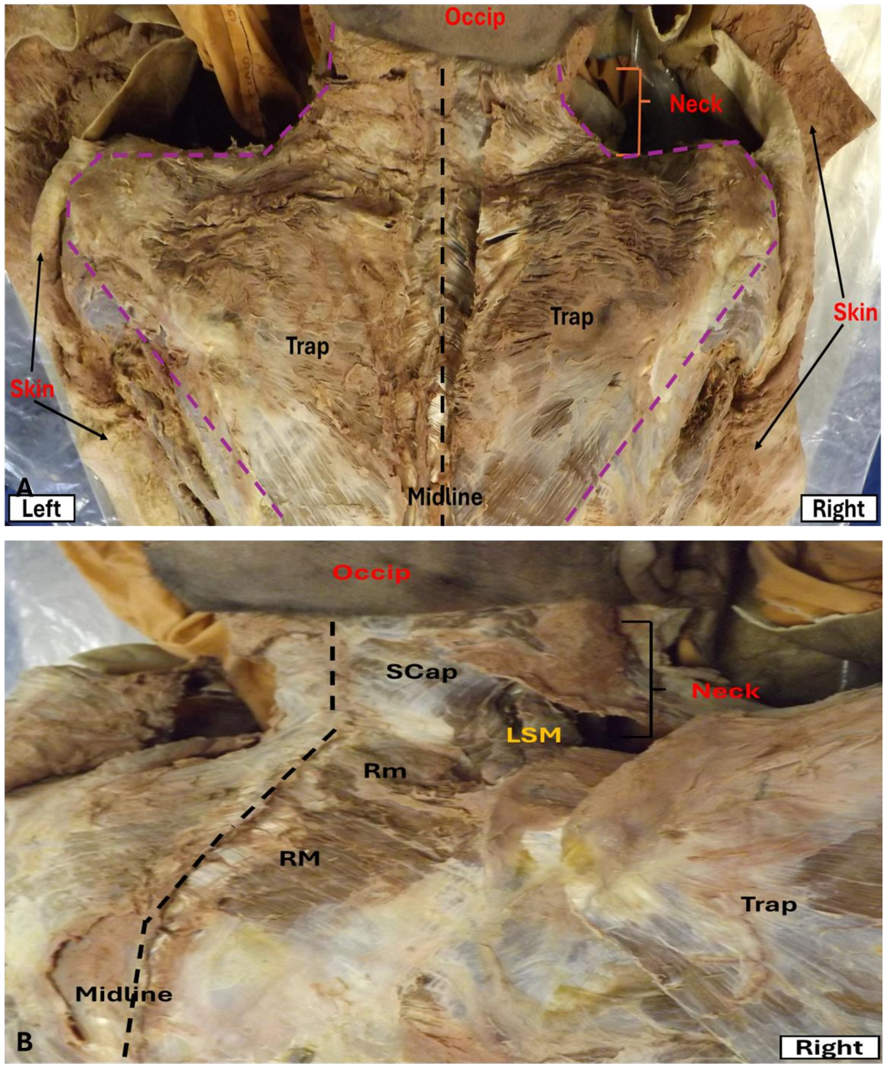

Figure 3.2: Posterior view with exposed and reflected trapezius muscle and rhomboid muscles. Key: A: Exposed trapezius muscle. B: Trapezius muscle reflected laterally to expose the rhomboid major, rhomboid minor and the levator scapulae muscle. LSM: levator scapulae muscle, Occip: occiput, Rm: rhomboid minor, RM: rhomboid major, SCap: splenius capitis, Trap: trapezius.

The levator scapulae muscle was surrounded by substantial amounts of loose connective tissue and dense irregular connective tissue. These were cleared from the muscle to clean and the separate muscle slips near its proximal attachment to the transverse processes of the cervical vertebrae. The splenius capitis was only cleaned without it being reflected to visualise the levator scapula properly. At this point, the number of muscle slips was identified and defined as presented in Figure 3.3. Once the muscle was cleaned, the relevant measurements and pictures were taken.

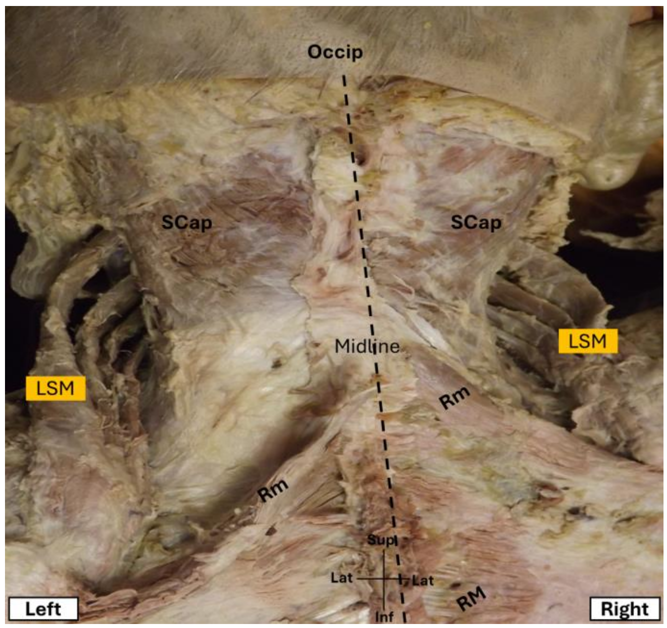

Figure 3.3: Posterior view with exposed levator scapulae muscle and its muscle slips. Key: LSM: levator scapulae muscle, Occip: occiput, Rm: rhomboid minor, RM: rhomboid major, SCap: splenius capitis.

3.7.1.2 Proximal attachment of the levator scapula muscle and its blood and nerve supplies

The proximal attachments of the levator scapulae muscle, its blood and nerve supplies were excess through an anterolateral approach. The cadaver was placed in the supine position and a support block was used to extend the neck, the anterior and posterior triangles of the necks were then dissected. A midline skin incision was made from the chin to the jugular notch. Two transverse incisions were done, one along the inferior border of the mandible towards the mastoid process and the second incision along the clavicle towards the acromion process as presented in Figure 3.4.

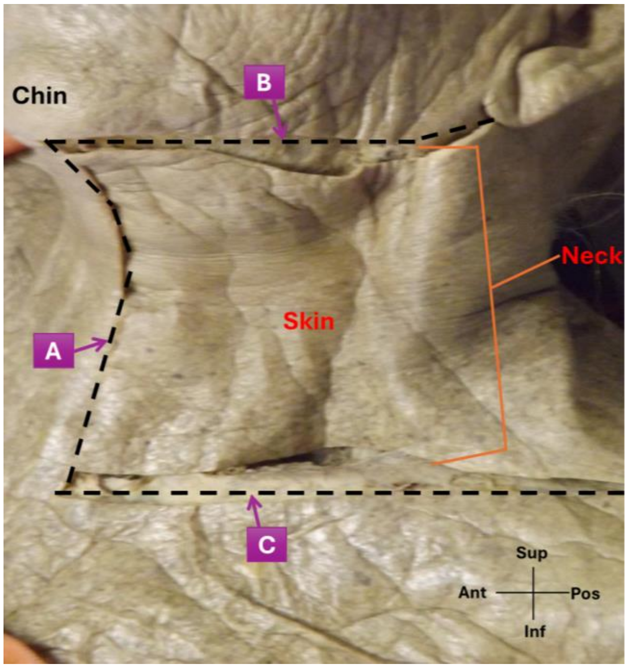

Figure 3.4: An anterolateral view of the neck. Key: A: A midline skin incision from the chin to the jugular notch. B: A transverse incision along the inferior border of the mandible towards the mastoid process. C: A transverse incision along the clavicle towards the acromion process.

Superficial fascia, platysma, and veins were removed. The sternocleidomastoid muscle was reflected towards its attachment to the mastoid process. Now, the levator scapulae muscle was visible within the deep cervical fascia on the floor of the posterior triangle. Once this was done, the delicate process of defining the individual muscle slips and their attachment to the cervical vertebrae was done through blunt dissection (Figure 3.5) The prevertebral layer of the deep cervical fascia surrounding the muscle was carefully removed.

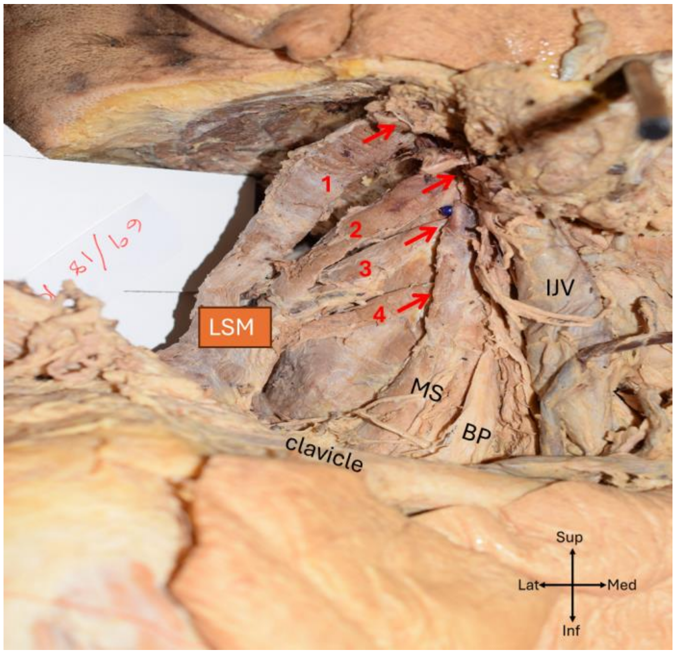

Figure 3.5: Anterolateral view of the neck showing the proximal attachment of the levator scapulae muscle. Key: BP: brachial plexus, IJV: internal jugular vein, Inf: inferior, Lat: lateral, LSM: levator scapulae muscle, Med: medial, MS: middle scalene muscle, Sup: superior.

The blood supply to the levator scapulae muscle was traced from the thyrocervical trunk as well as from the subclavian artery, following the superior aspects of the clavicles laterally. From the thyrocervical trunk, the blood supply to the levator scapula muscle was either the transverse cervical artery or the dorsal scapular artery, which was a collateral branch of the transverse cervical artery. These arterial branches originated from the thyrocervical trunk, extended anteriorly to the anterior scalene and brachial plexus, and bifurcated into two branches. One branch extended deeper to the levator scapulae muscle, while the other branch extended superficial to the levator scapulae muscle.

The dorsal scapulae artery in this case was a branch of the transverse artery, however, it bifurcated from the transverse artery about at the level of the brachial plexus and extended deeper to the levator scapulae muscle. On the other hand, the transverse cervical artery extended superficially to the levator scapula muscle.

Arterial supplies from the subclavian artery were traces slightly deeper to the clavicles. The dorsal scapular artery originated from the subclavian artery, extended deeper or through the brachial plexus and the middle scalene muscle and bifurcated into deep and superficial branches before the levator scapulae muscle. In addition, the fascia of the anterior triangle was well cleaned and additional blood supplies to the levator scapulae muscle, other than from the transverse cervical artery or from the dorsal scapular artery were noted as presented in Figure 3.6.

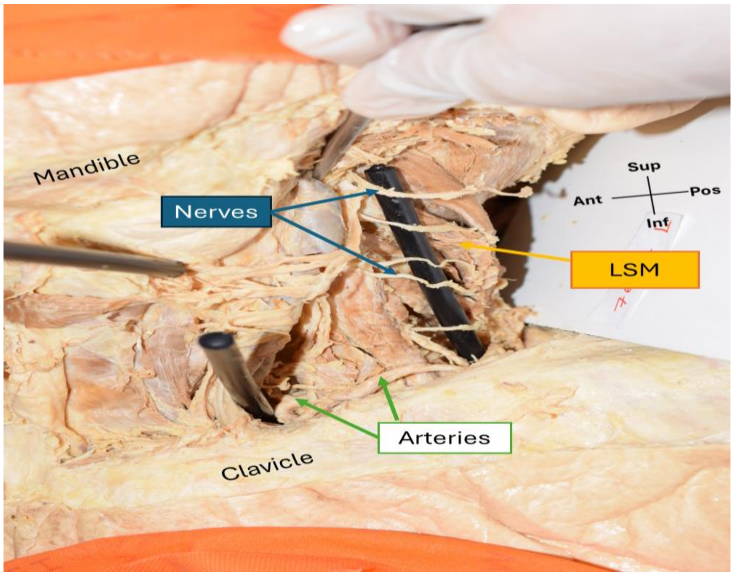

Figure 3.6: An anterolateral view of the neck, showing the exposed levator scapulae and neurovasculature. Key: LSM: levator scapulae muscle.

The anterior rami of the cervical spinal nerves C2, C3 and C4, as well as the dorsal scapular nerve from C5 nerve root to the levator scapulae muscle were identified and cleaned at this point. Twig-like branches to the anterior surface of the levator scapulae muscle were seen from these nerves (Figure 3.7).

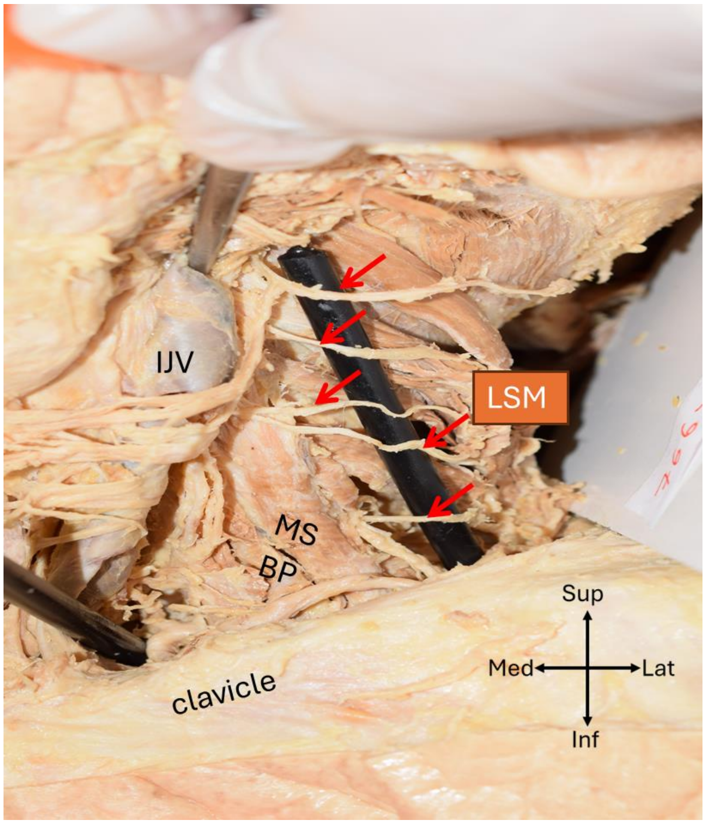

Figure 3.7: An anterolateral view of the neck, showing the exposed nerve supply to the levator scapulae muscle. Key: BP: brachial plexus, IJV: internal jugular vein, Inf: inferior, Lat: lateral, LSM: levator scapulae muscle, Med: medial, MS: middle scalene muscle, Sup: superior.

3.7.1.3 The levator scapulae muscle parameter measurements

Intermuscular planes were used to define the levator scapulae muscle from other muscles on the floor of the posterior triangle. The direction of the muscle and the union of the slips before inserting onto the scapula clearly defined the levator scapulae muscle. The transition from muscle to tendon was observed clearly, and each tendon was followed to its attachment to a vertebra. The measurements related to the origin of the levator scapulae muscle were made accurately and with ease. The measurements were done using a

Morphometric geometric method and a Vernier digital calliper (R.S. Baty metric calliper 0-150mm ±0.1mm) presented in Figure 3.8.

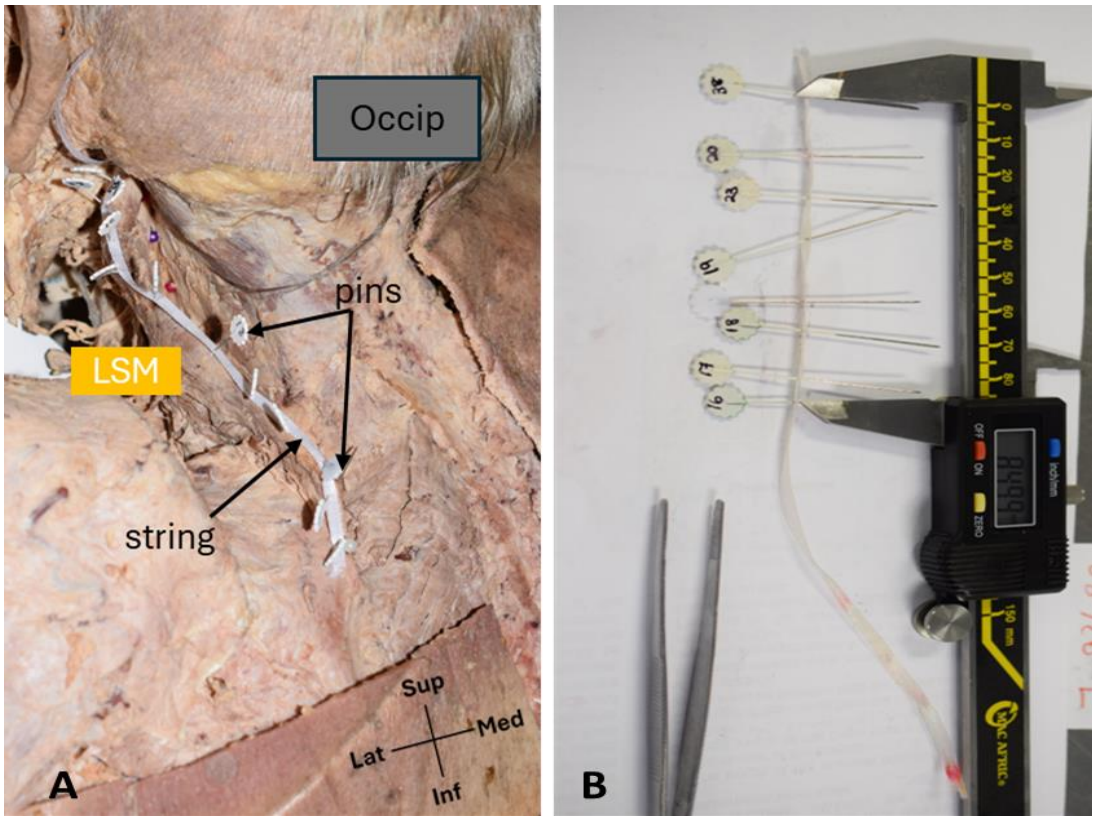

Figure 3.8: Morphometric geometric method and a Vernier digital calliper. Key: A: Posterior view demonstrating a Morphometric geometric method. B: Measurements using a Vernier digital calliper (R.S. Baty metric calliper 0-150 mm ± 0.1 mm).

The following measurements were made:

Measurement 1 (Figure 3.9A):

A: The distance from superior to inferior origin on transverse processes (proximal).

B: The distance of the insertion onto the superomedial border of the scapula (distal).

C: The distance of the muscle from the inferior origin to the insertion onto the superomedial border of the scapula (anterior).

D: The distance of the muscle from the superior origin to the insertion onto the superomedial border of the scapula (posterior).

Measurement 2 (Figure 3.9B):

- Length of individual slips.
- Widest point of individual slips (width).

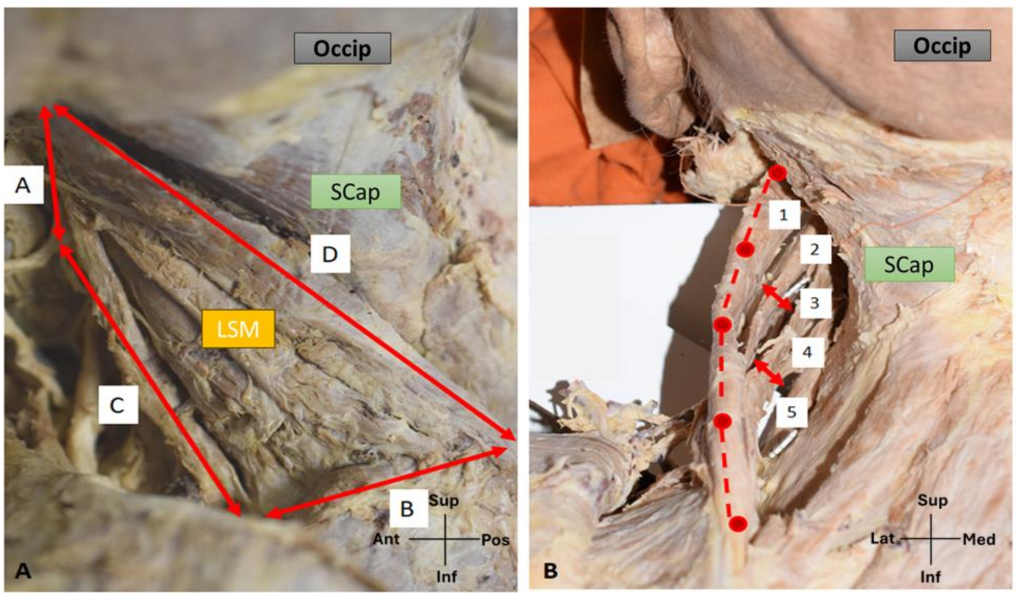

Figure 3.9: Parameters of the levator scapulae muscle. Key: A: Lateral view demonstrating the distances of the levator scapulae muscle (A to D). B: Posterior view demonstrating the individual muscle lengths measured (dotted lines)as well as the widths at the muscle's widest point (arrows). LSM: levator scapulae muscle, Numbers (1-5): muscle slips, Occip: occiput, SCap: splenius capitis.

All measurements were calculated for accuracy. The muscle slips at the origin were counted and recorded. The proximal and distal attachments were traced for possible variations. Furthermore, the nerve and blood supplies to the levator scapulae muscle were traced and recorded as well. A previous study reported that formalin fixation resulted in a 0.50-1.00% reduction of elasticity (Beger et al., 2018), hence, the levator scapulae muscle tissue shrinkage was disregarded.

3.7.2 MRI Study

The second component of the study relied on a retrospective cross-sectional study. This component focused on MRI records of adult patients with neck pain visited the Roman Catholic Hospital (Windhoek), between 2017-2022. Axial T1-weighted spin-echo MR images, between the occiput and T1, were acquired using a 3-Tesla Skyra scanner (Siemens, Erlangen, Germany) with a head and neck coil and stored in the Database. MRI scans offered an excellent opportunity to study the anatomical variations of the levator scapulae muscle (Au et al., 2017). The axial cervical MRI scans collected from the database were assessed, and the levator scapulae muscle and its accessory attachments were traced guided by Au et al. (2016), Dixon et al. (2017), and Ellis et al. (2007). There were no direct contact with patients, and the main researcher was not present during the MRI procedures.

MRI scans with no gross pathologies, trauma, or congenital defects were used. Using alphabetical order, patients' records were searched from the medical data records and their cervical MRIs, age and sex were collected and noted. From a population of 293 patient scans, a sample size of 167 scans was calculated. Since most of the MRI scans had either major pathology, were unclear, or the levator scapulae muscle was partially presented or not visible in all the slides, only 46 MRI scans were subsequently suitable for this study. Twenty-four (24) MRIs were from female patients, while twenty-two (22) were from male patients respectively.

Each patient's record had a certain number of MRI scan slices ranging from occiput to T2. However, the current study focused only on the C2 to T1 region. A Snip tool was then used to crop out the patients' confidential details from all MRI scan slices. Some records had both axial and sagittal cervical MRI scans, whereas some only had the axial cervical MRI scans recorded. The axial MRI scans were then arranged from C2 to T1, complemented by the sagittal scans, to aid with identifying the level of the cervical vertebral column on slides with no labels as presented in Figure 3.10.

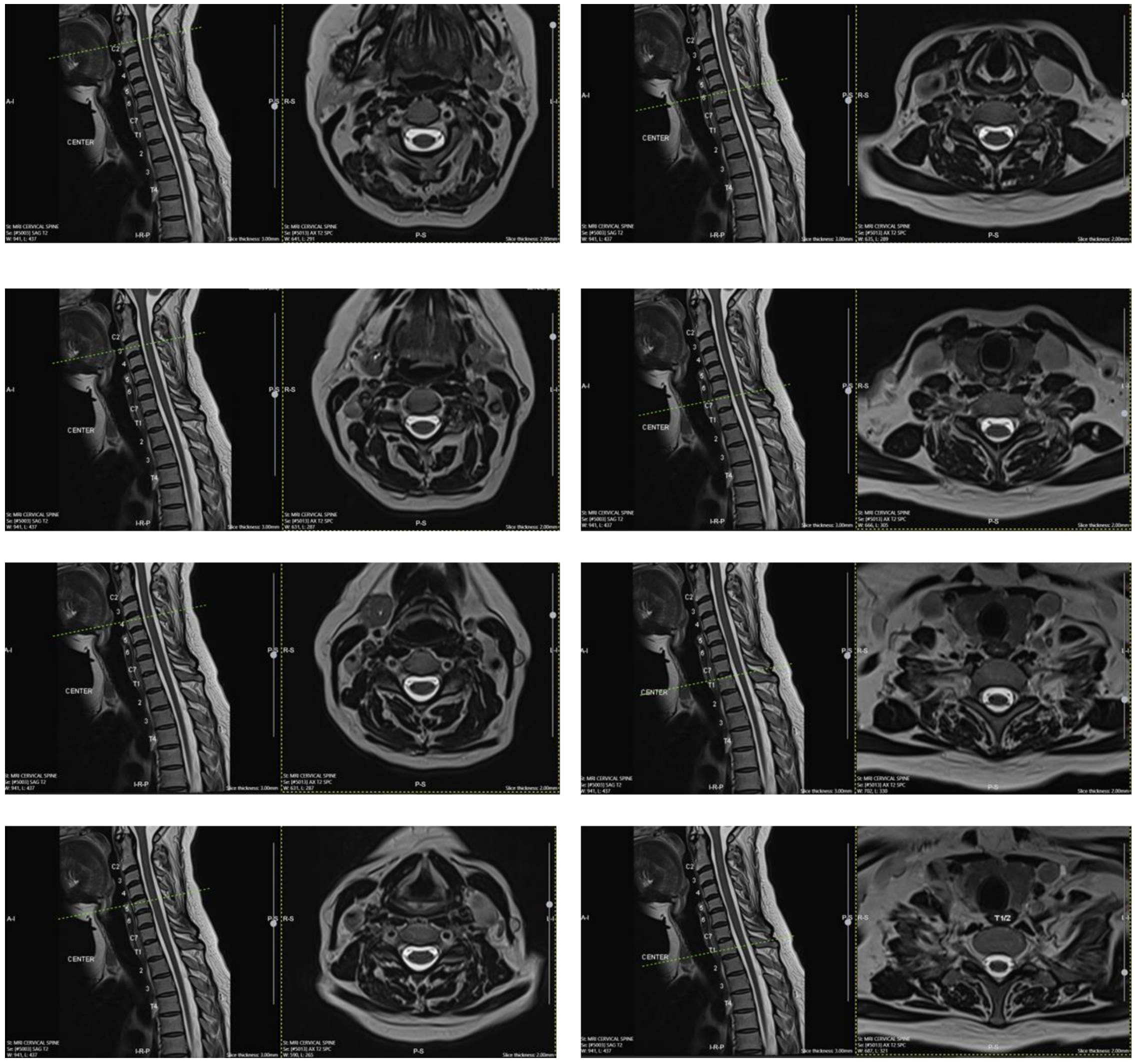

Figure 3.10: Sagittal and axial cervical MRI scans.

Overall, the MRIs with 2 mm, 3 mm, and 4 mm slice thicknesses were used. The MRI slices of every patient were combined, and the images were saved. The sagittal scan parts were later excluded and only the axial scans remained for further observations. The levator scapulae muscle was traced and identified in all axial cervical MRIs, guided by Au et al. (2016), as well as by the *Human sectional anatomy* by Dixon et al. (2017), and Ellis et al.

(2007). The vertebral levels of the slices between C2-T1 were also identified as presented in Figure 3.11.

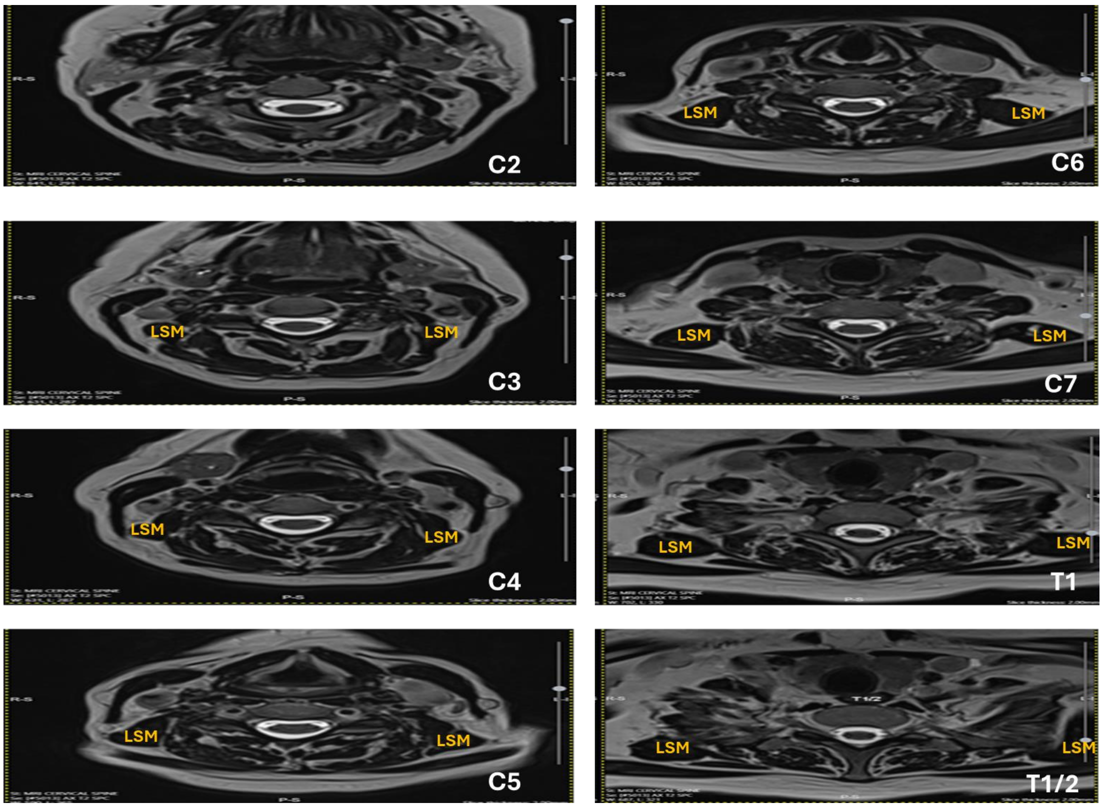

Figure 3.11: The axial cervical MRI scans with identified levator scapulae muscle (LSM). Key: C1-C7: cervical vertebral 1-7, T1: thoracic vertebral 1, T1/2: between thoracic vertebral 1 and 2.

Other muscles closely related to the levator scapulae muscle were also identified. These were the sternocleidomastoid, trapezius and splenius capitis. This made it easier to identify the accessory attachments associated with the levator scapulae muscle as presented in Figure 3.12. Moreover, the patient's age and sex were also recorded for interpretation purposes.

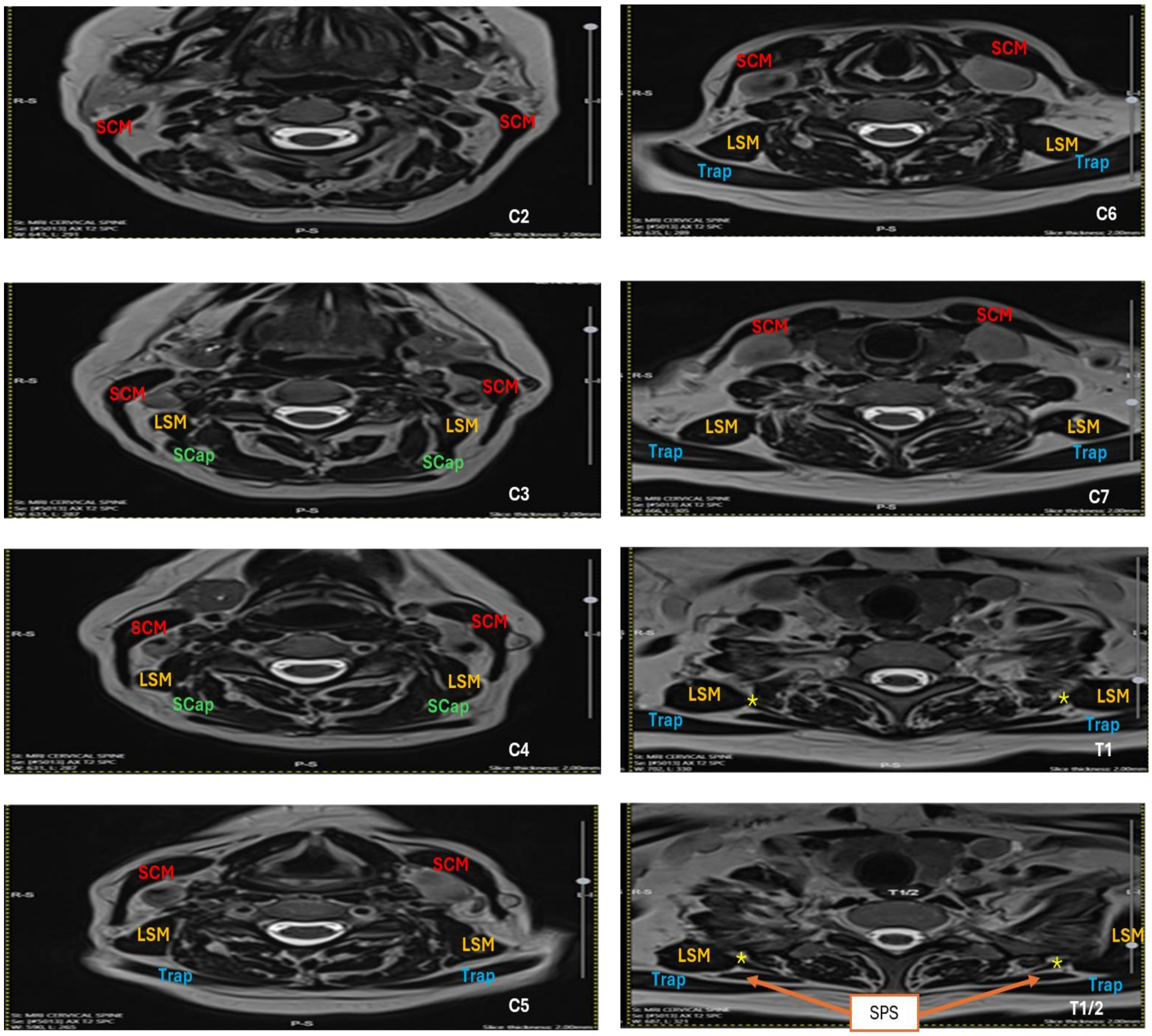

Figure 3.12: Tracing and identification of other muscles associated with the levator scapulae muscle (LSM). Key: C1-C7: cervical vertebral 1-7, SCap: splenius capitis, SCM: sternocleidomastoid, SPS: serratus posterior superior, T1: thoracic vertebral 1, T1/2: between thoracic vertebral 1 and 2, Trap: trapezius, *: accessory attachments od the levator scapulae muscle.

3.8 Data analysis

3.8.1 Cadaveric study

All measurements from the cadaveric dissection were collected in triplicate, the results were expressed as means (± deviation noted), and the statistical analysis was done in the SPSS 22 package.

Following the analysis done by Beger et al. (2018), with slight changes, the digital Vernier calliper (0.01 mm precision) was used to measure the width, length, and distance of muscles. The measurements of levator scapulae muscles were conducted under the same environmental conditions. Two researchers conducted the measurements independently at various times. The mean values of three repetitions belonging to each researcher were calculated. Both Intra-observer reproducibility and inter-observer reproducibility were assessed using intra-class correlation coefficients (ICC).

An independent t-test was conducted to determine significant differences in the measured parameters (distances, lengths and widths) of the levator scapulae muscle, between the left and right sides in cadavers, as well as between parameters and cadaver sex. Analysis of Variance (ANOVA) was used to determine the significance difference within the races of cadavers, followed by the Turkey's test to specifically determine where the significant differences occurred. The relationships of parameters versus age (years) were obtained by simple linear regression. However, the statistical significance level was set as $p < 0.05$.

3.8.2 MRI study

Descriptive statistics were employed on the data collected from the axial scans. This included frequencies of the variations and number of muscular slips about the anatomical side, sex, and age of the individual. The data was presented in a table and was accompanied by MRI scans for description purposes.

3.9 Ethical Considerations

3.9.1 Cadaveric study

For ethical purposes, the cadaveric materials were managed following the Anatomical Donations and Post-mortem Ordinance, No. 12 of 1977 (Namibia). Only the cadaver age, race, and sex were used and linked to the biographical information on the death certificate for interpretation purposes. The cadavers' names were kept anonymous, hence, numbers were assigned to each cadaver for interpretation. The anonymity was ensured by citing only the cadaver number and sex, and all records were restricted and safeguarded within the Division of Anatomy.

Personal information and the data generated during data collection were kept confidential. All specimens used were provided by the Division of Anatomy at the University of Namibia. Each cadaver was embalmed via the right common carotid artery with a mechanical pump infusion for twelve hours. Ethical approval was obtained from University of Namibia Decentralised ethic committee (DEC) (Ethical Clearance Reference Number: SOM0001) as presented in Appendix A. Research permission was granted by the University of Namibia postgraduate research support services (Appendix B).

3.9.2 MRI study

The MRI records of the cervical region done on patients at the Roman Catholic Hospital were obtained. This retrospective study relied on a document review and did not require contact with patients, only their records. The respect and dignity of participants were valued since their anonymity was ensured with assigned numbers (names not used) and their personal information was not managed by the collector.

This study held no risk to any patient's body, emotional, social, or spiritual well-being. Furthermore, future patients might potentially benefit from the proposed study as the data could aid the development of improved approaches to the treatment of cervical neck pain. All patient records were reviewed fairly and equitably.

The captured data was handled and stored with utmost care and privacy away from public reach. No personal details whatsoever (for example, names, addresses, next of kin, etc.) were collected. Transparency from the researcher's side was ensured as all contact details were available for any concerns or queries. Ethical approval was obtained from the superintendent of Roman Catholic Hospital (Appendix C), as well as from the University of Namibia's DEC (Appendix A). Finally, to avoid plagiarism, the information obtained was paraphrased, cited, quoted, and referenced.

3.10 Chapter Summary

In this chapter, the focus was on research methods. The next chapter focused on research results.

CHAPTER 4: CADAVERIC RESULTS

4.1 Introduction

This chapter presents the findings obtained from the cadaveric study. This explored anatomical variations of levator scapulae muscle in terms of its origin, insertion, and morphology (muscle distance, muscle slip width and length). It also explored the arterial supply and nerve supply to the levator scapulae muscle. However, the venous drainage to the levator scapulae muscle was excluded because veins are highly variable and often closer to the skin, which might have increased the chances of being destroyed by students. The results were presented as figures, tables, as well as statistical data. All sample values were presented in two decimal places.

This study was performed on the available cadavers during the research period, hence a total of 21 (n = 21) cadavers were used in this study. Eight cadavers (n = 8) were from the 2021 intake, 10 (n = 10) cadavers from 2020, two (n = 2) cadavers from 2019, and one (n = 1) cadaver from the 2018 intake. The leading causes of death in the cadaver population used in this study were respiratory pathologies (28.57%), natural causes (23.81%), cardiac pathologies (19.05%), renal pathologies (9.52%), brain pathologies (9.52%), liver pathologies (4.76%) and malnutrition (4.76%) respectively.

The average age of the cadavers used was 69.76 ± 16.06 years. The youngest cadaver was 26 years old, and the oldest cadaver was 90 years old respectively. The cadaver population included a total of 11 female cadavers and a total of 10 male cadavers. The bilateral dissection was performed on 19 cadavers, whereas the unilateral dissection was performed on two cadavers, giving a total of 40 levator scapulae muscles.

4.2 The levator scapulae muscle slips

Overall, 40 levator scapulae muscles had two to six muscle slips, with an average of 4.18 ± 1.08 muscle slips. The majority of the levator scapulae muscles had four muscle slips (62.50%) and only two levator scapulae muscle had six muscle slips (5.00%), which was the least in terms of frequency of muscle slips, as shown in Figure 4.1.

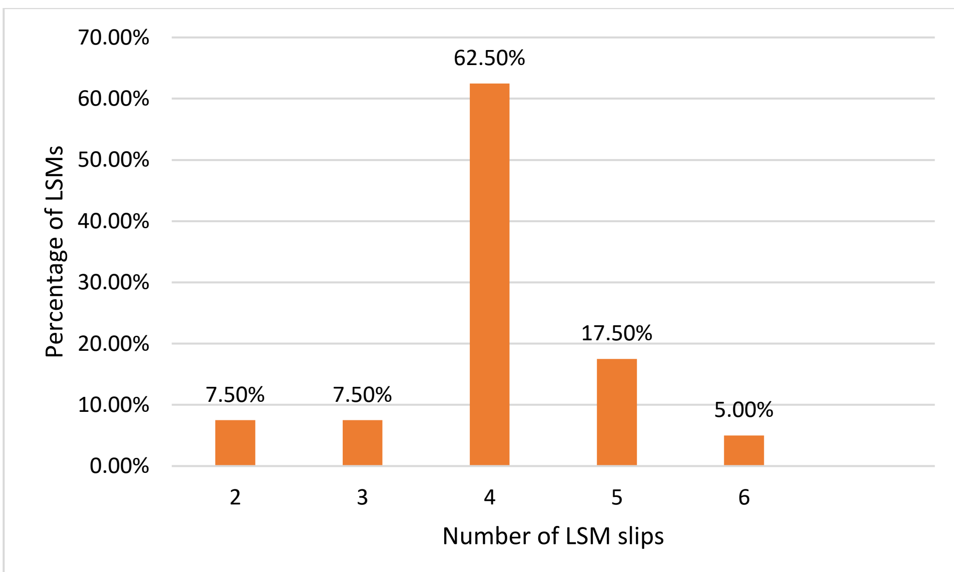

Figure 4.1: Frequency of the levator scapulae muscle slips. Key: LSM(s)- levator scapulae muscle(s)

4.3 The lateral differences in levator scapulae muscle slips

With regards to the differences observed between muscle slips of the right and the left levator scapulae muscles, the muscles with four slips dominated, with 65.00% on the right and 60.00% on the left. The muscles with five slips were observed second highest, with 20.00% on the right and 15.00% on the left side. The lowest occurrence was 5.00%, observed in muscles with two muscle slips (left) and three muscle slips (right) as presented in Figure 4.2.

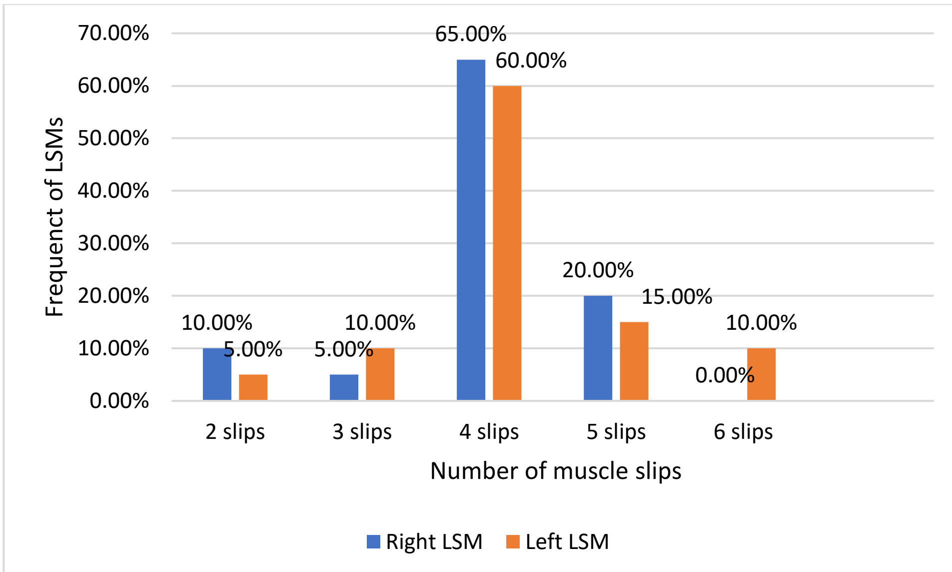

Figure 4.2: The difference in muscle slips between the right and left levator scapulae muscles.

Key: LSM(s)- levator scapulae muscle(s).

The majority (13 of 19) of the bilaterally dissected levator scapulae muscles had equal numbers of muscle slips on both sides (symmetrical). However, there were some cases observed with asymmetric numbers of muscle slips between the two sides (left and right). Out of 19 bilaterally dissected cadavers, six cadavers had different numbers of levator scapulae muscle slips. The laterality differences observed were five slips and four slips which was the most common difference, six slips and four slips, as well as six slips and five slips. An example of a bilateral dissection with asymmetrical six muscle slips on the left side and four muscle slips on the right side is presented in Figure 4.3.

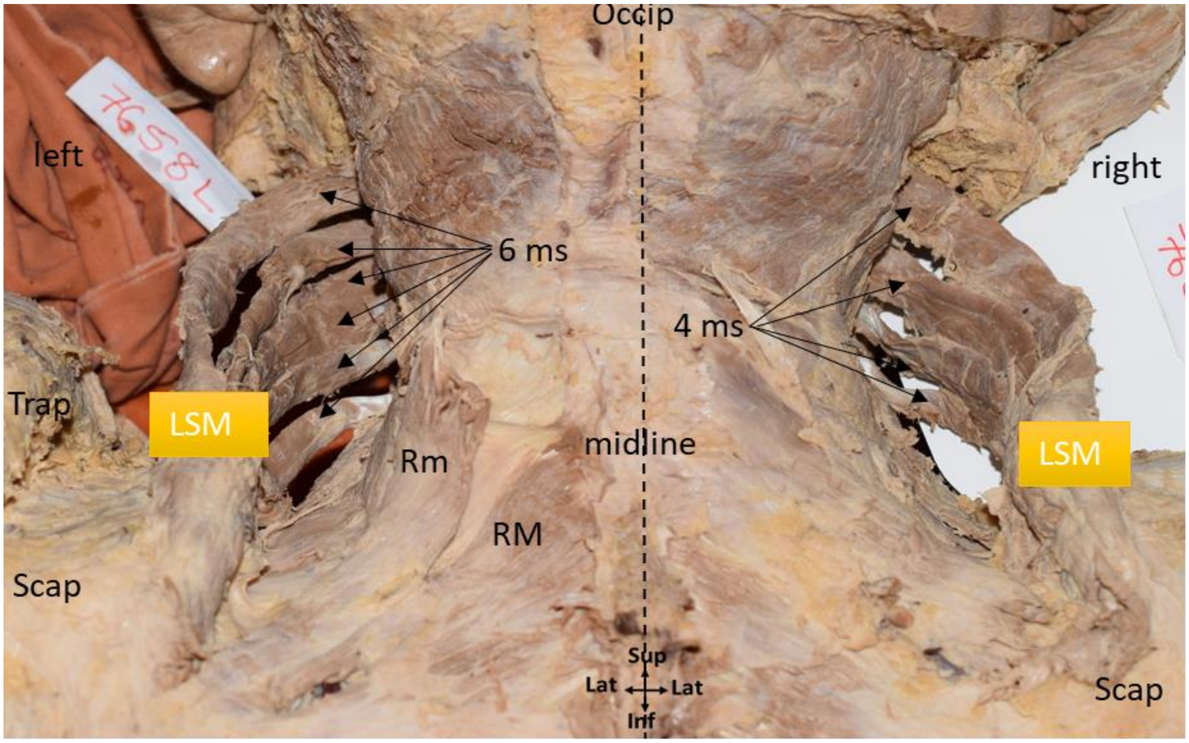

Figure 4.3: Asymmetrical levator scapulae muscle slips within a cadaver. This figure illustrates a posterior view of the left and right levator scapulae muscle of a 60-year-old cadaver (c# 21). Key: LSM- levator scapulae muscle, ms- muscle slips, Rm- rhomboid minor, RM- rhomboid major, and Trap- trapezius. Arrows identify the muscle slips.

4.4 The variations in the number of levator scapulae muscle slips and their attachments

With regards to the variations associated with the individual levator scapulae muscle slips, some of the muscle slips were well-defined whereas others had variations. The first instance of variation presented three cases of levator scapulae with two muscle slips. Two instances were observed bilaterally in a 43-year-old female (c# 9) as presented in Figure 4.4 and one instance was observed unilaterally on the right side of a 71-year-old male cadaver (c#. 19).

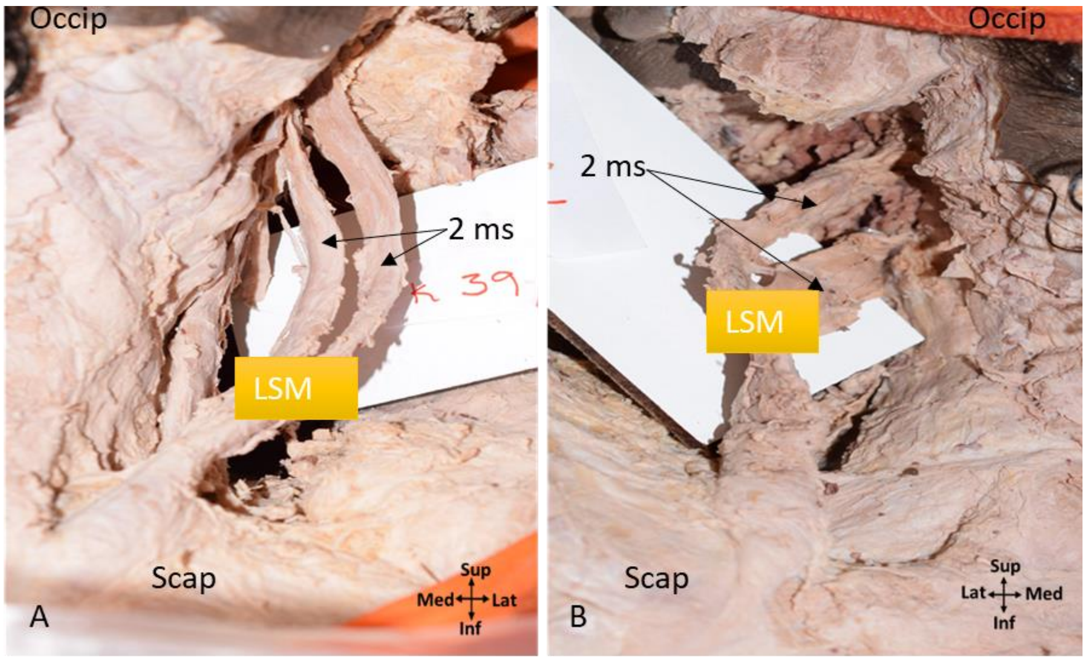

Figure 4.4: The levator scapulae muscle with two muscle slips. Key: A and B- show the right and left levator scapulae muscles with two muscle slips (2 ms) of a 43- year-old mixed-race female cadaver (c# 9). LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, Scap- scapula.

The second observed variation included three levator scapulae muscles with three muscle slips, whereby one was unilaterally observed, and two were bilaterally observed in a 59-year-old male cadaver (c# 18). In both instances, the first muscle lips were proximally attached to C1, whereas the second and third muscle slips were both proximally attached to C2, as presented in Figure 4.5.

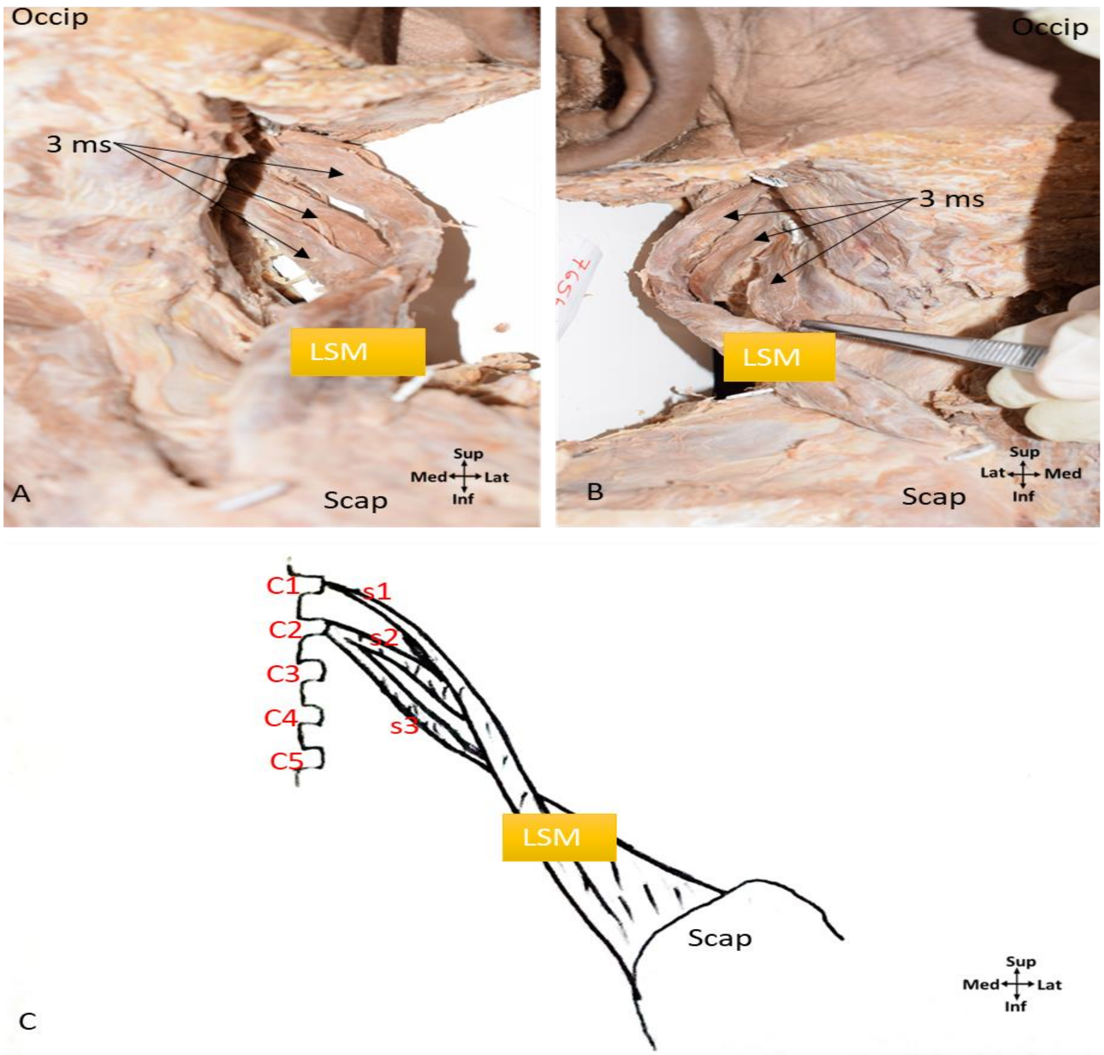

Figure 4.5: The levator scapulae muscle with three muscle slips (C2 shared). Key: A and B- The right and left posterior view of the levator scapulae muscle of a 59-year-old white male cadaver (c# 18). C- A clear diagrammatic presentation of the right levator scapulae muscle slips. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, s- slip, Scap- scapula.

The third type of variation was found with four muscle slips, which dominated in terms of the number of muscle slips. The four muscle slip variations were observed in twenty-three (23) levator scapulae muscles. Although most of them (91.30%) were well-defined, there were some (8.70%) four-slipped muscles with accessory slips observed. A great example of well-defined four muscle slips was found on the left side of a 68-year-old white female cadaver (c# 17) and the right side of a 90-year-old cadaver (c# 12) as presented in Figure 4.6.

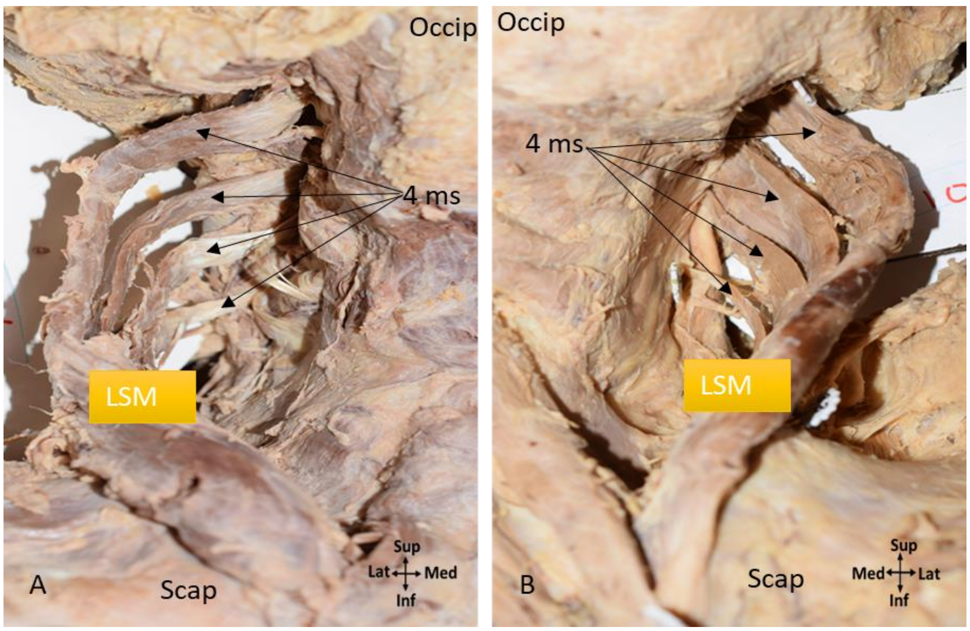

Figure 4.6: The levator scapulae muscle with four well-defined muscle slips. Key: A- A left posterior view of the levator scapulae muscle of a 68-year-old white female cadaver (c# 17) with four well-defined muscle slips. B- A right-side posterior view of the levator scapulae muscle of a 90-year-old cadaver (c# 12). LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, Scap- scapula.

The fourth observed variation had five muscle slips, which was the second dominant in terms of frequency of muscle slips. Similar to the third variation, some levator scapulae muscles had five well-defined muscle slips, whereas others had additional attachments and accessory muscle slips. Examples of five well-defined slips were observed in a 73-year-old white female cadaver (c# 15), as well as in an 86-year-old white female cadaver (c# 20). The muscle slips were proximally attached to C1-C5, as presented in Figure 4.7.

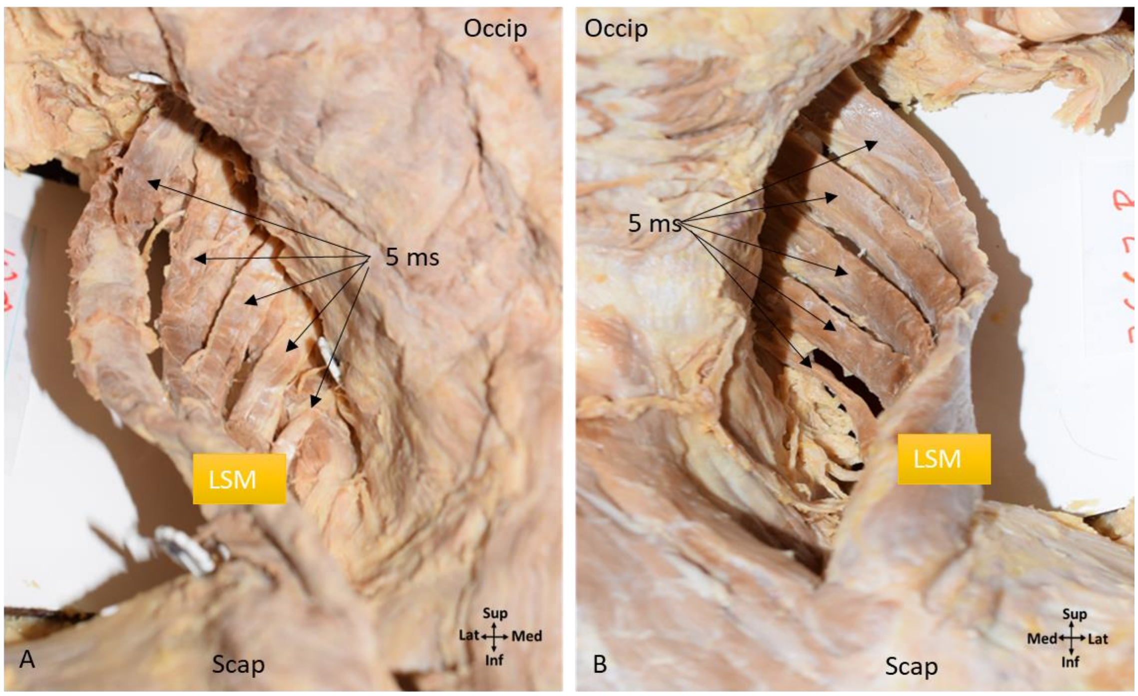

Figure 4.7: The levator scapulae muscle with five well-defined muscle slips. Key: A- A left posterior view of the levator scapulae muscle of a 73-year-old white female cadaver (c# 15). B- A right posterior view of the levator scapulae muscle of an 86-year-old white female cadaver (c# 20). C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, Scap- scapula.

The fifth instance of variation observed had six muscle slips. These muscle slips were observed unilaterally in two levator scapulae muscles. The first six-muscle slip instance was observed on the left muscle of a 26-year-old black male cadaver (c# 14). In this instance, the first three muscle slips were individually attached to C1-C3, the fourth and the fifth muscle slips were both proximally attached to C4, and the sixth muscle slip was proximally attached to C5. All six muscle slips converged before inserting to the superomedial border of the scapula, as presented in Figure 4.8.

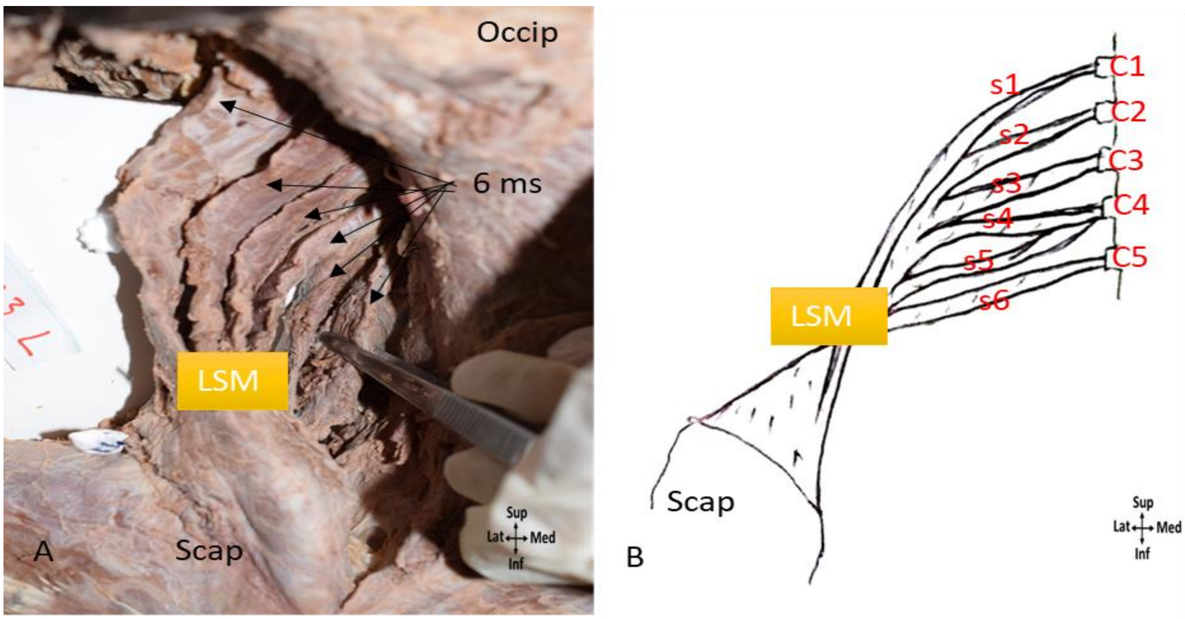

Figure 4.8: The levator scapulae with six muscle slips (C4 shared). Key: A- Posterior view of the levator scapulae muscle with six slips, found in a 26-year-old black male cadaver (c# 14). B- A clear diagrammatic presentation of the levator scapulae muscle with six muscle slips. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, s- slip, Scap- scapula.

The second six muscle-slip instance was observed on the left side of a 60-year-old female cadaver (c# 21). The first muscle slip was proximally attached to C1. The second and third were both proximally attached to C2. The fourth, fifth, and sixth were individually attached to C3, C4, and C5. All six muscle slips were distally attached to the superomedial borders of the scapula, as presented in 4.9.

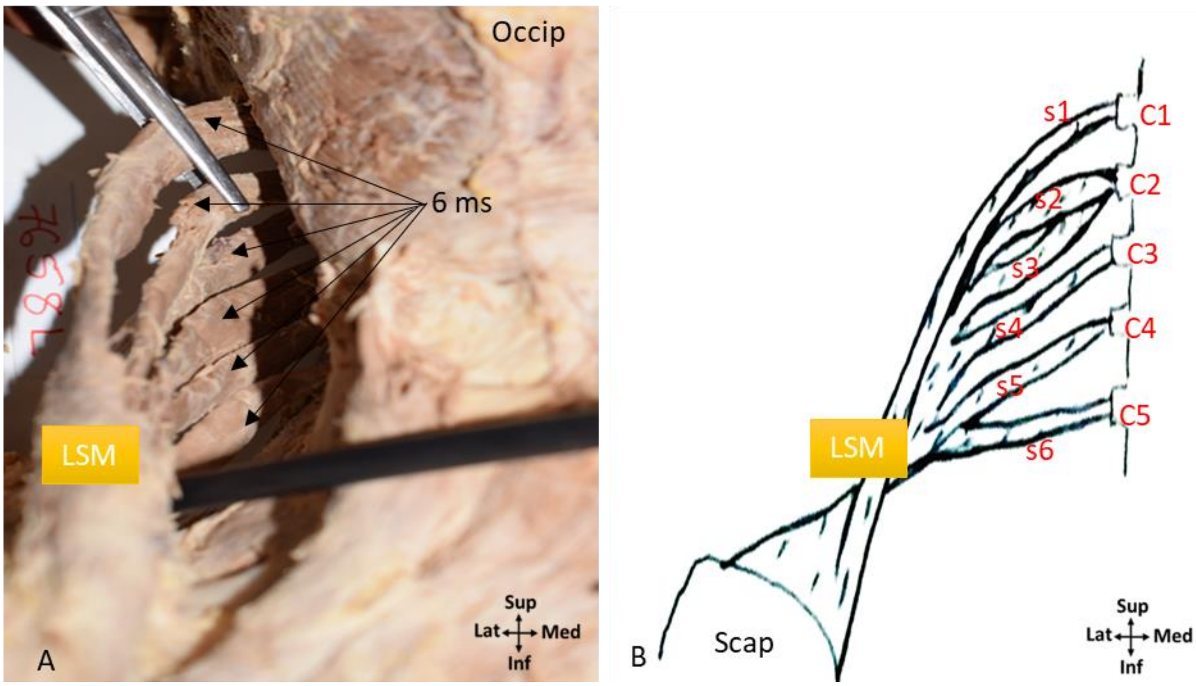

Figure 4.9: The levator scapulae muscle with six muscle slips (C2 shared). Key: A- Posterior view of the levator scapulae muscle with six slips, found on the left side of a 60-year-old female cadaver (c# 21). B- A clear diagrammatic presentation of the levator scapulae muscle slips. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, s-slip, Scap- scapula.

Moreover, the sixth variation observed on the left levator scapulae muscle of a 54-year-old male cadaver (c# 11). The levator scapulae muscle had three muscle slips, whereby the first slip originated from C1, the second slip originated from C2, and the third slip originated from C4. Interestingly, there was no muscle slip attached to C3. Nevertheless, all the slips converged before they were distally inserted onto the superomedial border of the scapula as presented in Figure 4.10.

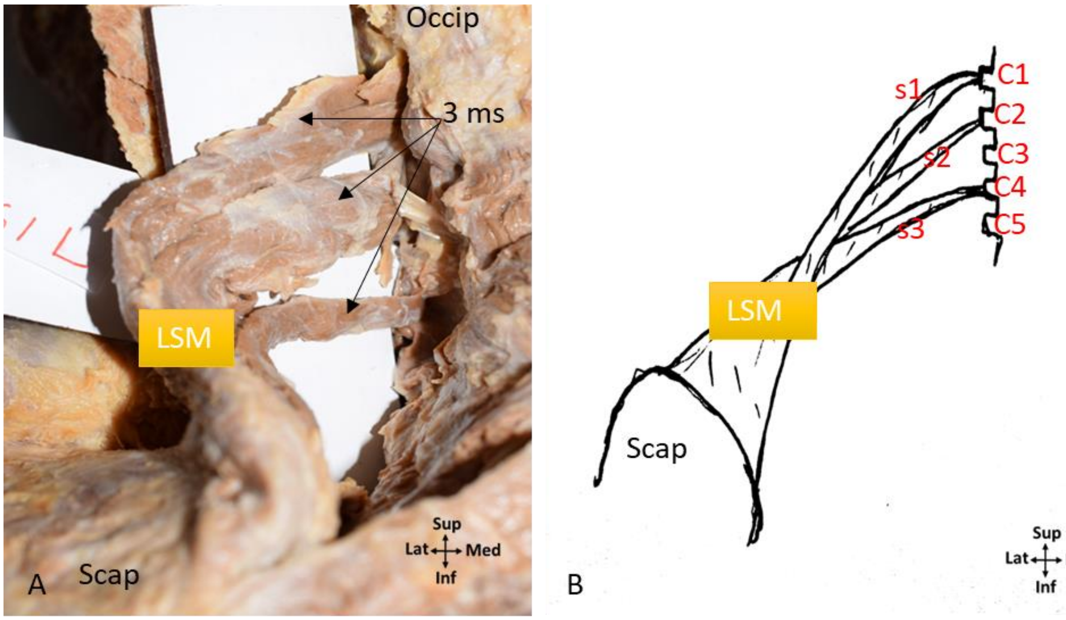

Figure 4.10: The levator scapulae muscle with three muscle slips. Key: A- A left posterior view of the levator scapulae muscle of a 54-year-mixed-race male cadaver (c# 11) with three muscle slips (3ms). B- A clear diagrammatic presentation of the levator scapulae muscle slips with their origins and insertions. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, s- slip, Scap- scapula.

4.5 The levator scapulae muscle with accessory muscle slips and attachments

The levator scapulae muscle is well known to originate from the cervical transverse processes of the vertebral column and inserts onto the superomedial border of the scapula (Au et al., 2017; Beger et al., 2018; Naik & Lokanadham, 2019; Smit & Todd, 2019).

However, this study has observed variations associated with the origins and insertions of the levator scapulae muscles. Overall, a total of seven levator scapulae muscles were observed with accessory attachments. Six of them were from the four-muscle-slipped category, whereas one was from the five-muscle-slipped category.

With regards to the origins (proximal attachment), majority of the levator scapulae muscles had well-defined muscle slips that originated from the transverse processes. Most of the levator scapulae muscle had muscle slips individually attached to the cervical transverse processes, whereas a few levator scapulae muscles had muscle slips sharing proximal attachments. Concerning the insertions (distal attachments) of the levator scapulae muscles, most of the muscles were distally inserted on the superomedial borders of the scapula. However, there were few variant insertions observed in this study.

A first type of variation in terms of origin and insertion was observed unilaterally in two cadavers. One instance was observed on the left levator scapulae muscle of an 84-year-old white male cadaver (c# 8), while another instance was observed on the left levator scapulae muscle of a 79-years-old female cadaver (c# 7). In both instances, the two levator scapulae muscles had four muscle slips, with four well-defined muscle slips, proximally originating from the cervical transverse processes of C1-C4.

However, there was an accessory muscle slip with a common proximal attachment (C2) as the second muscle slip (Lengths = 128.97 mm and 117.22 mm, widths = 9.32 mm and

5.64 mm). The accessory muscle slip extended superficially and distally inserted onto the anterolateral surfaces of the first and second ribs, as presented in Figure 4.11.

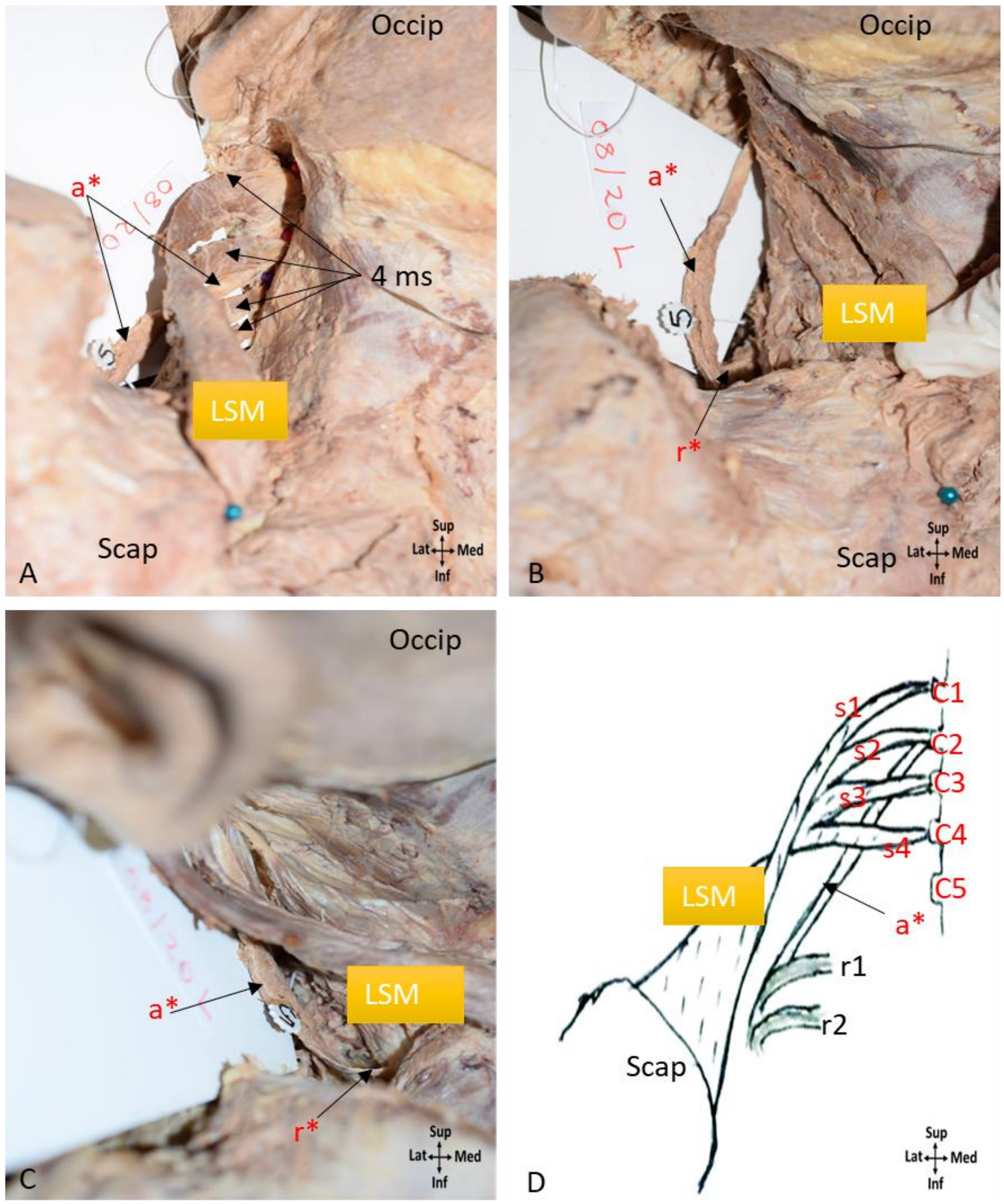

Figure 4.11: The levator scapulae muscle with a four muscle slips and an accessory muscle slip. Key: A- A posterior view of the left levator scapulae muscle of an 84-year-old white male cadaver (c# 8). B- A posterior view of a levator scapulae muscle demonstrating the nature of the

accessory muscle slip (a*). C- A Posterior view of the accessory muscle slip (s5). D- A clear diagrammatic presentation of the levator scapulae muscle slips. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slips, Occip- occiput, r*- the accessory muscle slip tendon at a level of the first rib, r1 and r2- first and second ribs, s: slip, Scap: scapula.

The second form of variation concerning the origin and insertion was found on the left levator scapulae muscle of an 80-year-old white female cadaver (c# 5). The levator scapulae muscle had four muscle slips, proximally originating from the cervical transverse processes of C1-C4 and inserted onto the scapula. However, two accessory muscle slips were also observed. The first (superior) accessory muscle slip bifurcated from the third muscle slip at about 39.89 mm from its origin (C3) and had an average width of 6.83 mm and a length of 41.55 mm from the point of bifurcation to its distal insertion.

The second (inferior) muscle slip bifurcated from the fourth muscle slip at about 25.63 mm from its point of origin (C4), with an average width of 5.66 mm and an average length of 40.30 mm from its point of bifurcation. Both accessory muscle slips extended superficially and distally inserted on the anterolateral aspects (surface fascia) of the first and second ribs as presented in Figure 4.12.

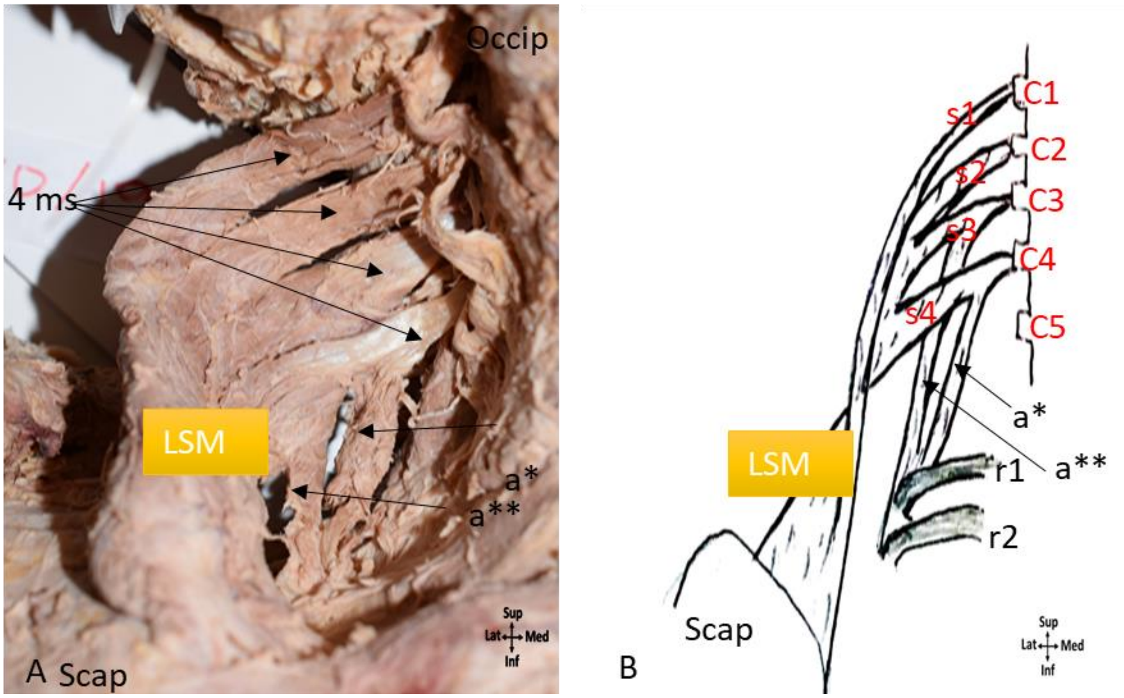

Figure 4.12: The levator scapulae muscle four muscle slips and two accessory muscle slips. Key: A- A posterior view of the left levator scapulae muscle of an 80-year-old white female cadaver (c# 5), with four muscle slips and two accessory muscle slips (a* and a**). B- A clear diagrammatic presentation of the muscle slips with their origins and insertions. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slips, Occip- occiput, r1 and r2- first and second rib, s- slip, Scap- scapula.

The third variation was observed on the right levator scapulae muscle of a 79-year-old female cadaver (c# 7). The muscle had four well-defined muscle slips, proximally originating from the first four cervical transverse processes (C1-C4) and distally inserted onto the superomedial border of the scapula. However, this levator scapulae muscle was observed with a single accessory slip, that shared a common proximal attachment with the fourth muscle slip and distally inserted onto the middle scalene muscle. The accessory muscle slip had an average width of 4.54 mm as presented in Figure 4.13.

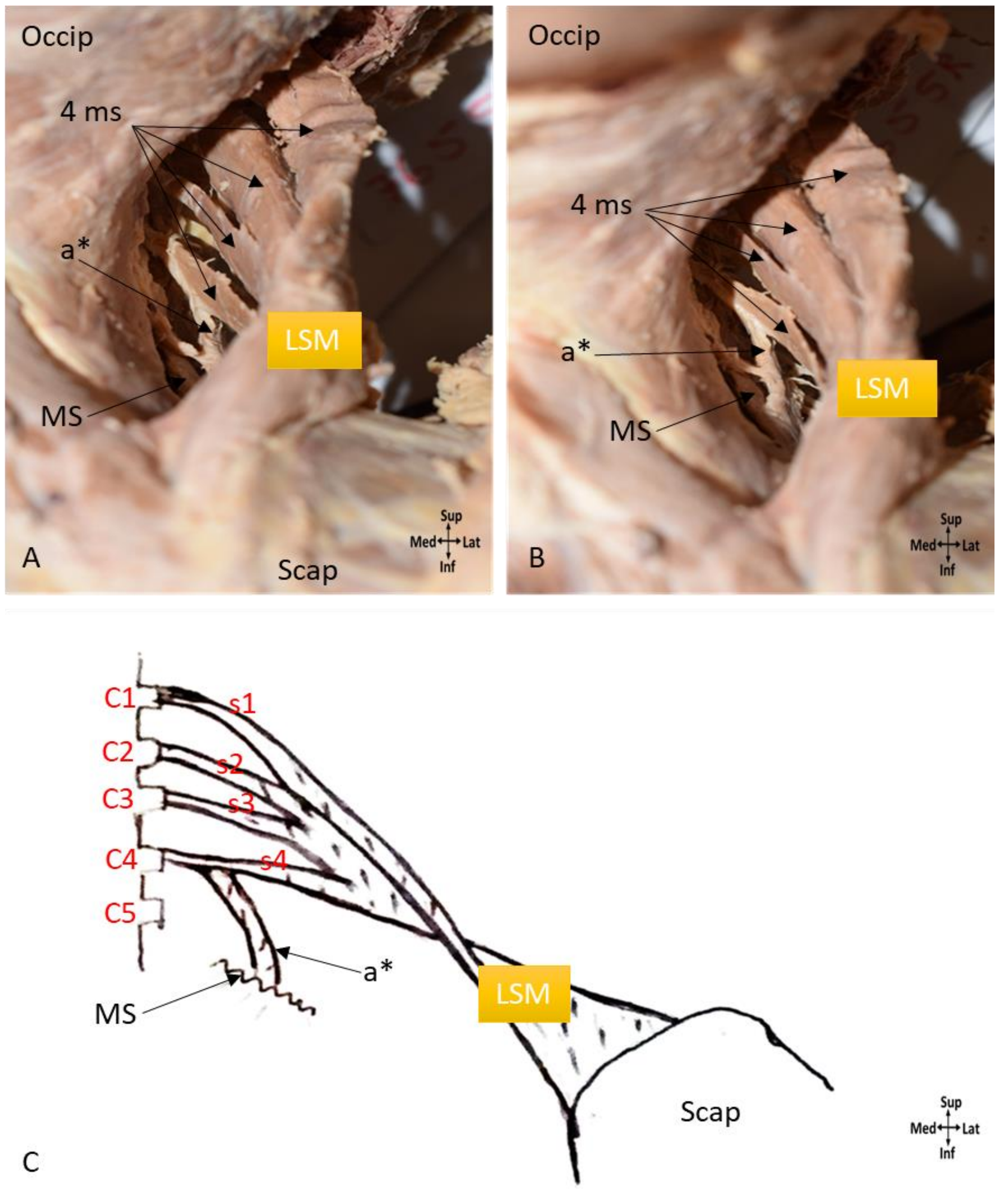

Figure 4.13: The levator scapulae muscle with four muscle slips and an accessory muscle slip . Key: A and B- Posterior views of the levator scapulae muscle of a 79-year-old female cadaver (c# 7), with four slips and an accessory muscle slip (a*), distally attached to the middle scalene

muscle. C- A clear diagrammatic presentation of the levator scapulae muscle slips with their attachments. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, MS- middle scalene, ms- muscle slip, Occip- occiput, s- slip, Scap- scapula.

The fourth variation had five muscle slips, with three accessory muscle slips. This instance of variation was only observed in a single levator scapulae muscle of an 80-year-old white female cadaver (c# 5). The five well-define muscle slips originated from the cervical transverse processes (C1-C5) and united before inserting on the scapula. The three accessory muscle slips shared the proximal attachment with the third, fourth, and fifth muscle slips.

The superior accessory muscle slip originated from C3 with the third muscle slip (Length = 98.35 mm, width = 6.16 mm), the middle accessory muscle slip originated from C4 with the fourth muscle slip (Length = 88.56 mm, width = 6.96 mm), and the inferior accessory muscle slip originated from C5 with the fifth muscle slip (Length = 79.13 mm, width = 4.17 mm). These muscle slips extended superficially and were inserted onto the lateral aspects of the first and second ribs, as presented in Figure 4.14.

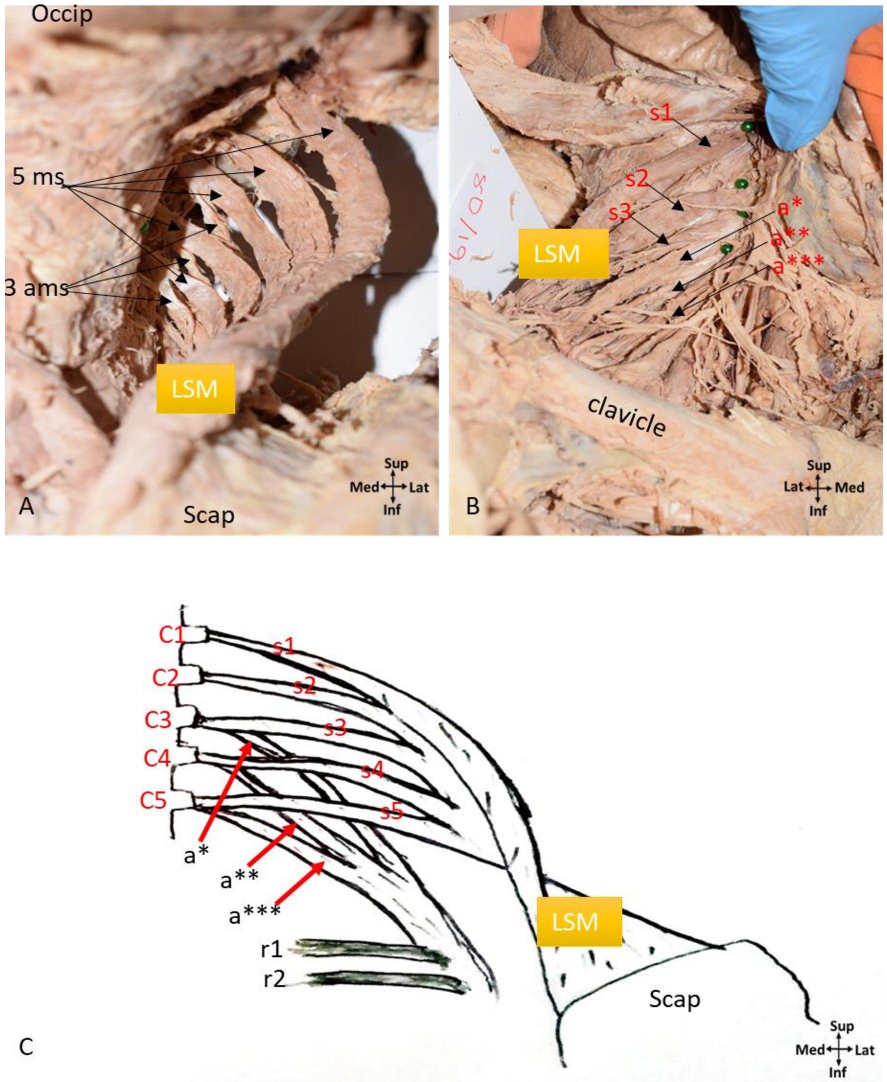

Figure 4.14: The levator scapulae muscle with five muscle slips and three accessory muscle slips. Key: A- A posterior view of the levator scapular muscle with five prominent muscle slips and three accessory muscle slips, was found on the right side of an 80-year-old white female cadaver (c# 5). B- Anterolateral view of the muscle, C- A diagrammatic representation of a posterior view of the levator scapulae muscle slips. C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ams- accessory muscle slips ms- muscle slip, Occip- occiput, a*- superior accessory muscle slip, a**- middle accessory muscle slip, a***- inferior accessory muscle slip, r1 and r2- first and second rib, s- slip, Scap- scapula.

Moreover, a fifth variation with similar minor features was observed in two cadavers. The first instance was found on the left side of a 73-year-old cadaver ((c# 3) while the second instance was also found on the left side of a 79-year-old male cadaver (c# 4). Both levator scapulae muscles in these instances had four muscle slips, proximally originated from the cervical transverse processes (C1-C4), and distally inserted onto the superomedial borders of the scapula.

However, in each instance, there was a muscle slip with an average length of 13.10 mm and an average width of 5.41 mm. These muscle slips proximally bifurcated from the second muscle slips at about 28.13 mm from their proximal origin (C2) and distally joined the middle part of the third muscle slip at about 26.97 mm from the proximal attachment (C3). Nevertheless, all four prominent muscle slips converged before they were inserted on the superomedial border of the scapula as presented in Figure 4.15.

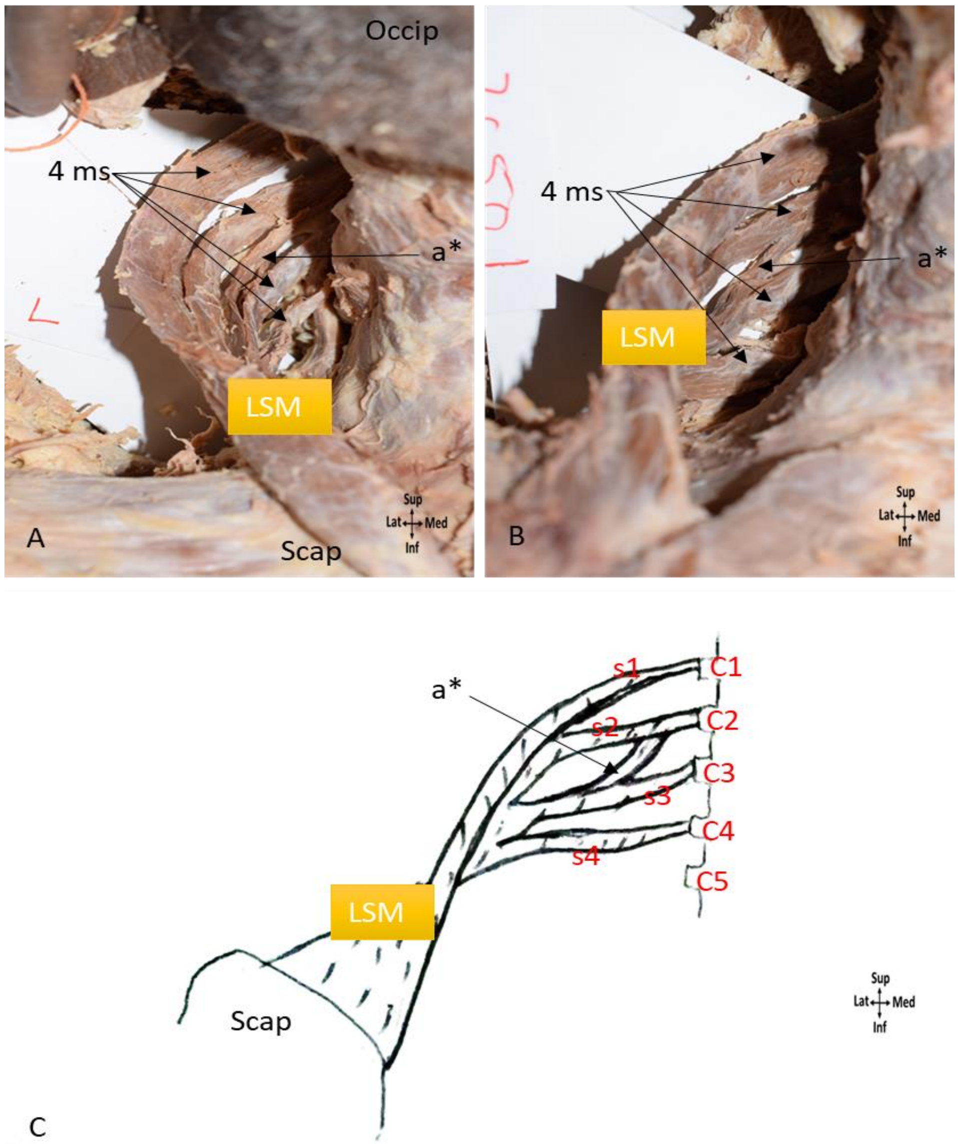

Figure 4.15: The levator scapulae muscle with four muscle slips and an accessory muscle slip. Key: A- A posterior view of the left levator scapulae muscle with four slips of a 73-year-old white male cadaver (c# 3), with four muscle slips originating from C1-C4, and an accessory muscle slip originating from C2 and unite with the third muscle slip. B- A Posterior view of the left levator scapulae muscle with four slips found in a 79-year-old white male cadaver (c# 4). C- A clear posterior diagrammatic presentation of the levator scapulae muscle slips. a*- accessory

muscle slip, C1-C5- cervical vertebrae 1-5, LSM- levator scapulae muscle, ms- muscle slip, Occip- occiput, s- slip, Scap- scapula.

In summary, the levator scapulae muscle is mainly known to have an average of four muscle slips, originating from C1-C4 and inserts onto the superomedial borders of the scapula (Dalley & Agur, 2023; Dixon et al., 2017). As per Anatomy textbooks by Dalley and Agur (2023), Dixon et al. (2017), Ellis et al. (2007), and Netter (2014), the levator scapulae muscles normally originate from the transverses processes of the cervical vertebrae and insert to the superomedial borders of the scapula. Hence, this study regarded muscle slips with additional attachments as accessory muscle slips.

According to the study findings, a total 40 levator scapulae muscles were observed in this study, ranging between two to six muscle slips: three (7.50%) of them had two well-defined muscle slips originating from C1 and C2 and inserted to the superomedial border of the scapula. Another three (7.50%) levator scapulae muscles had three muscle slips: two of these muscles shared a proximal attachment (C2), hence, they were proximally attached to C1 and C2, whereas the other muscle originated from C1, C2, and C4. All three muscle slip instances were distally inserted to the superomedial borders of the scapula.

A total of 25 (62.50%) levator scapulae muscles had four muscle slips: of the 25 muscles, 19 had four well-defined muscle slips originating from C1-C4 and inserted to the superomedial border of the scapula. six of the 25 levator scapulae muscles with four muscle slips had accessory muscle slips: the first instance of the six muscle had an accessory muscle slip originating from C4 and inserted to the middle scalene muscle, two muscles had an accessory muscle slip originating from C2 and inserted to the anterolateral aspects of the first and second ribs, another variation among this category had two accessory muscle slips originating from C3 and C4 and inserted on the anterolateral aspects of the first and second ribs. The last instance in this category was observed in two levator scapulae muscles with an accessory muscle slip originating from C2 and inserted to the middle aspects of the third muscle slip.

Seven (17.50%) of the 40 Levator scapulae muscles had five muscle slips: six of the muscles had five well-defined muscle slips originating from C1-C5 and distally inserted to the superomedial borders of the scapula, whereas one muscle had three accessory muscle slips in addition to the five muscle slips. The accessory muscle slips were proximally attached to C3-C5 and distally inserted to the anterolateral aspects of the first and second ribs.

Lastly two (5.00%) of the 40 levator scapulae muscle had six muscle slips proximally attached to C1-C5 and inserted to the superomedial borders of the scapula. However, in both instances there were two muscle slips sharing a proximal attachment: in one of the instances, the second and third muscle slips both originated from C2, while in the second instance, the fourth and fifth muscle slips both originated from C4. The overall cadaveric results in terms of the levator scapulae muscle slips are summarised in Table 4.1.

Table 4.1: Summary of the levator scapulae muscle slips results

Cadaver numbers	Age	Sex	Race	Number of LSM slips	
				Right	Left
1	56	M	B	4	4
2	64	M	W	4	4
3	73	M	W	4	4* (1 accessory slip from C2 to 3rd slip)
4	79	M	W	4	4* (1 accessory slip from C2 to 3rd slip)
5	80	F	W	5*(3 accessory slips from C3-C5 to r1 and r2)	4* (2 accessory slips from C3-C4 to r1 and r2)
6	82	F	W	4* (1 accessory slip from C2 to r1 and r2)	4
7	79	F	N/S	4* (1 accessory slip from C4 to middle scalene)	5
8	84	M	W	4	4*(1 accessory slip from C2 to r1 and r2)
9	43	F	C	2	2
10	85	F	E	4	4
11	54	M	C	x	3*
12	90	M	W	4	4
13	64	F	W	5	5
14	26	M	B	5	6*
15	73	F	W	4	5
16	83	M	W	4	4
17	68	F	W	4	4
18	59	M	W	3*	3*
19	71	M	W	2	x
20	86	F	W	5	4
21	60	F	N/S	4	6*

Key: B- black, C- coloured, F- female, M- male, N/S- not specified, W- white, x- LSM absent, * - variations in terms of muscle slip attachments.

4.6 Blood supply to the levator scapulae muscle

In this study, out of 40 levator scapulae muscles observed, only 27 muscles had arterial blood supply kept intact, while blood supplies to the 13 muscles were destroyed by medical students. Nevertheless, this study followed the three blood supply types based on the branch of origin and mode of birth as described by Bulbul et al. (2019); Ikka et al. (2016); Manyacka Ma Nyemb et al. (2018), stated that Type I: Both dorsal scapular artery and transverse cervical artery originated from a common trunk stemming from the subclavian artery, in Type II: dorsal scapular artery originated directly from subclavian artery while transverse cervical artery originated from thyrocervical trunk, whereas in Type III: Both dorsal scapular artery and transverse cervical artery are collateral branches of the thyrocervical trunk.

According to this study's findings, out of 27 levator scapulae muscles, seven (25.93%) levator scapulae muscles received two arterial branches. One of the branches came from the transverse cervical artery, a branch of the thyrocervical trunk, while the second branch was from the dorsal scapular artery, which branched off from the transverse cervical artery (Type III). Another seven (25.93%) levator scapulae muscles received two arterial branches, one branch from the transverse cervical artery a branch of the thyrocervical trunk, and another one from dorsal scapular arteries, a branch of the subclavian arteries (Type II) Figure 4.16.

Six (22.22%) levator scapulae muscles were supplied by the dorsal scapular artery, a branch of the subclavian arteries. Five (18.52%) levator scapulae muscles were supplied by arterial branches from the transverse cervical artery only. Two (7.41%) levator scapulae muscles were also supplied by two arterial branches from the transverse cervical artery as well as from the ascending cervical artery, all branching from the thyrocervical trunk respectively, as presented in Figure 4.16.

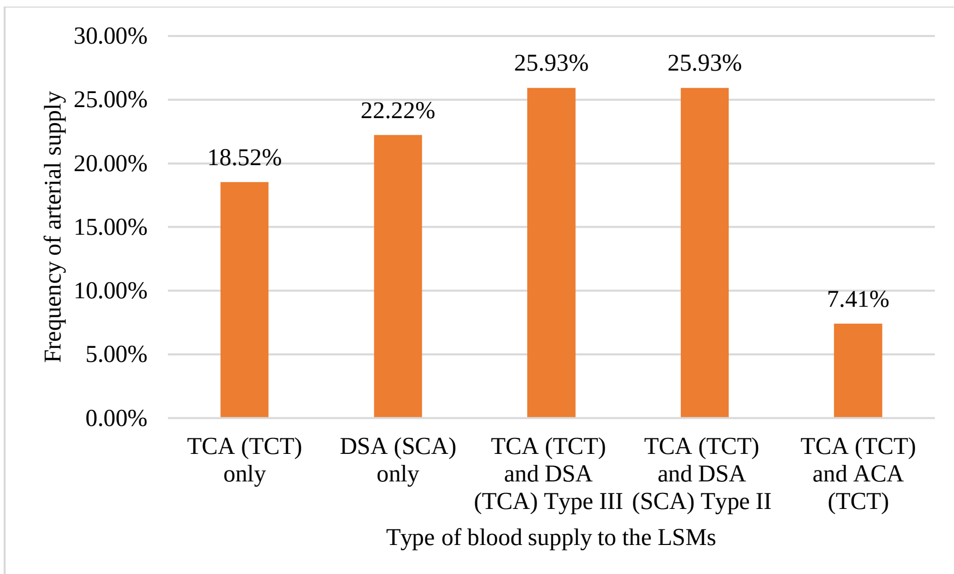

Figure 4.16: The sources of arterial branches to the levator scapulae muscles. Key: ACA- ascending cervical artery, SCA- subclavian artery, TCA- transverse cervical artery, TCT- thyrocervical trunk.

4.6.1 The variations of blood supply to the levator scapulae muscle

The levator scapulae muscle is known to be supplied mainly by the dorsal scapular artery, which usually originates from the subclavian, or as a collateral branch of transverse cervical artery (Beger et al., 2018; Fakoya et al., 2020; Netter, 2014). The transverse cervical artery is also known to supply the levator scapulae muscle (Netter, 2014; Reiner & Kasser, 1996).

The first fascinating variation instance of arterial supply to the levator scapulae muscle was observed on the left sides of 56-year-old (c# 1) and 90-year-old (c# 12) male cadavers, these levator scapulae muscles received blood from two main sources, both stemming from the thyrocervical trunk. The first branch was the transverse cervical artery, which bifurcated into two collateral branches, one of them extended towards and supplied the superficial distal part of the levator scapulae muscles, while the other collateral branch extended towards and supplied the deeper aspects of the levator scapulae muscles. On the other hand, the second arterial branch was the ascending cervical artery, which gave off a collateral branch towards the superficial middle parts of the levator scapulae muscles respectively, as presented in Figure 4.17.

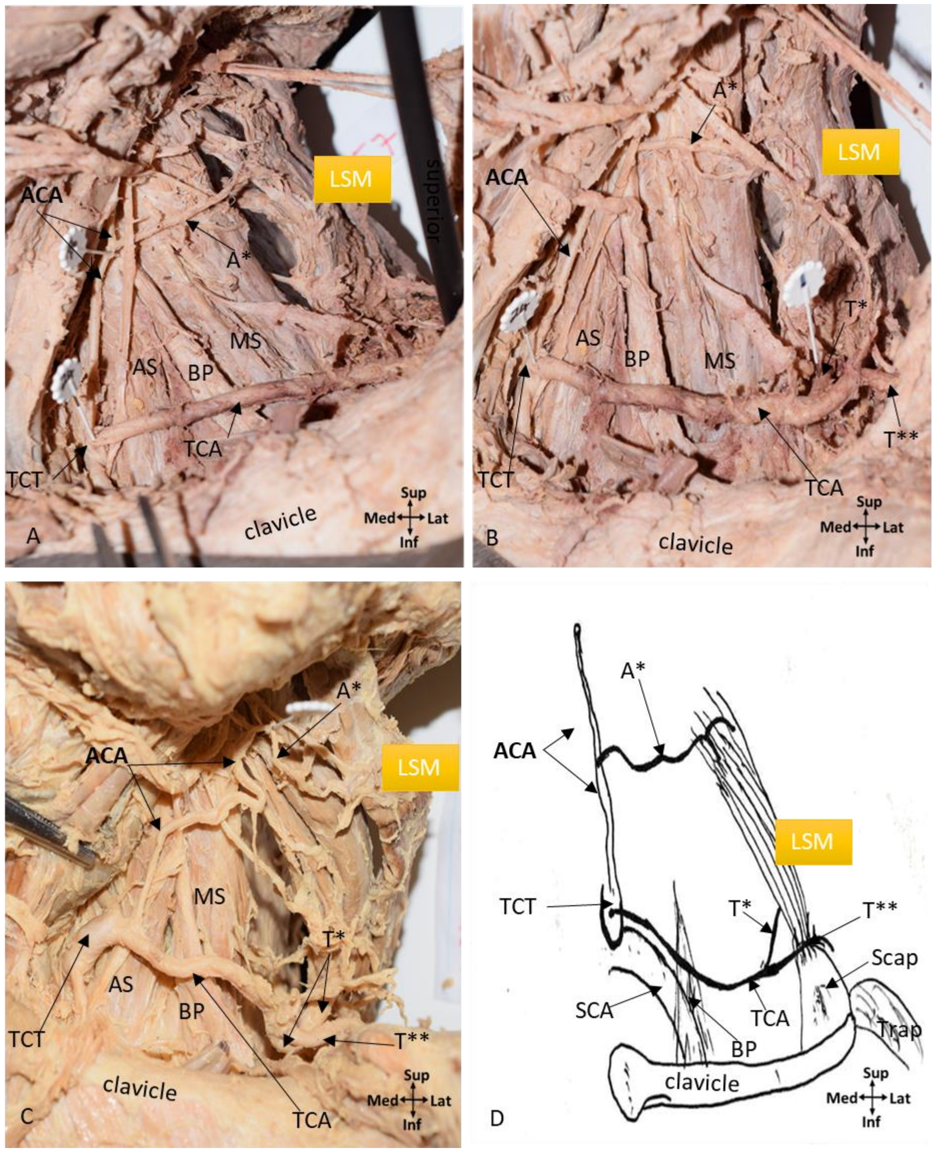

Figure 4.17: Blood supply to levator scapulae muscles from transverse cervical artery and ascending cervical artery. Key: A and B- The left anterolateral cervical view of blood supply to the levator scapulae muscle of a 56-year-old male cadaver (c# 1). C- Left anterolateral cervical view of a 90-year-old male cadaver (c# 12). D- A diagrammatic drawing of an anterolateral view of the neck. ACA- ascending cervical artery, AS- anterior scalene, A*- an arterial branch from the ascending cervical artery, BP- brachial plexus, MS- middle scalene, LSM- levator scapulae muscle, TCA- transverse cervical artery, TCT: thyrocervical trunk, T* and T**: first and second collateral branches of the transverse cervical artery.

The second variation in terms of arterial supply was observed in seven levator scapulae muscles. These levator scapulae muscles were supplied by two collateral branches of the transverse cervical artery, as well as two collateral branches of the dorsal scapular artery. The transverse cervical artery branched stemmed the thyrocervical trunk, while the dorsal scapular artery stemmed from the subclavian artery. The first collateral branches from the transverse cervical artery and the dorsal scapular artery extended towards the deeper aspects of the levator scapulae muscle, while the second collateral branches of the transverse cervical artery and the dorsal scapular artery extended towards the superficial distal part of the levator scapulae muscles as presented in Figure 4.18.

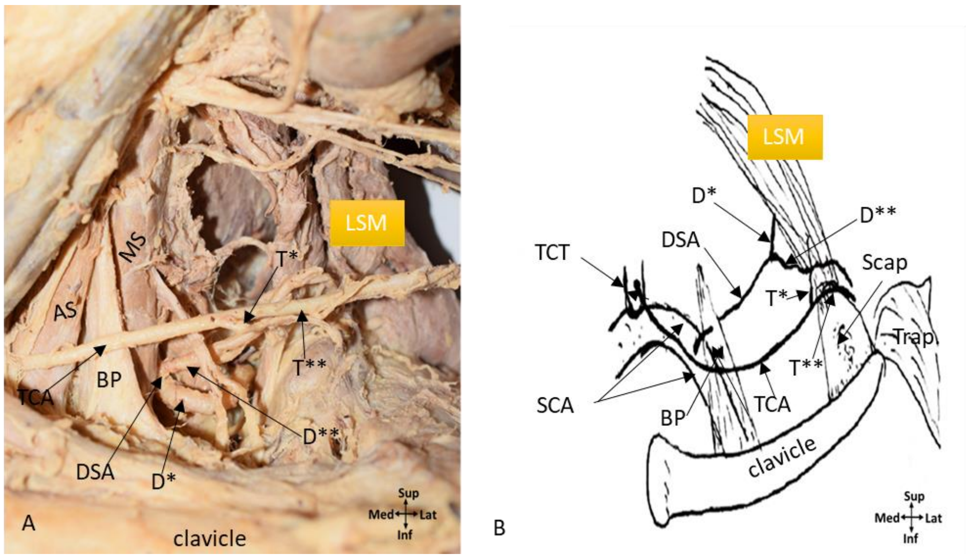

Figure 4.18: Blood supply to levator scapulae muscle from dorsal scapular artery and transverse cervical artery (Type II). Key: A- An anterolateral view of the left side of a 64-year-old male cadaver (c# 2). B- A Diagrammatic drawing of an anterolateral view illustrating two arterial branch supplies to the levator scapulae muscles. BP- brachial plexus, MS- middle scalene, DSA- dorsal scapular artery, D* and first and second collateral branches of the dorsal scapular artery,

LSM- levator scapulae muscle, SCA- subclavian artery, TCA- transverse cervical artery, TCT- thyrocervical trunk, T* and T**- first and second collateral branches of the transverse cervical artery.

A third case was observed in a total of six levator scapulae muscles. These levator scapulae muscles received arterial blood from the collateral branches of the dorsal scapular artery only, a branch of the subclavian artery. One of the collateral branches extended towards the deeper aspects of the levator scapulae muscles, while the other collateral branch extended towards the superficial distal aspects of the levator scapulae muscles. An example of this variation is presented in Figure 4.19.

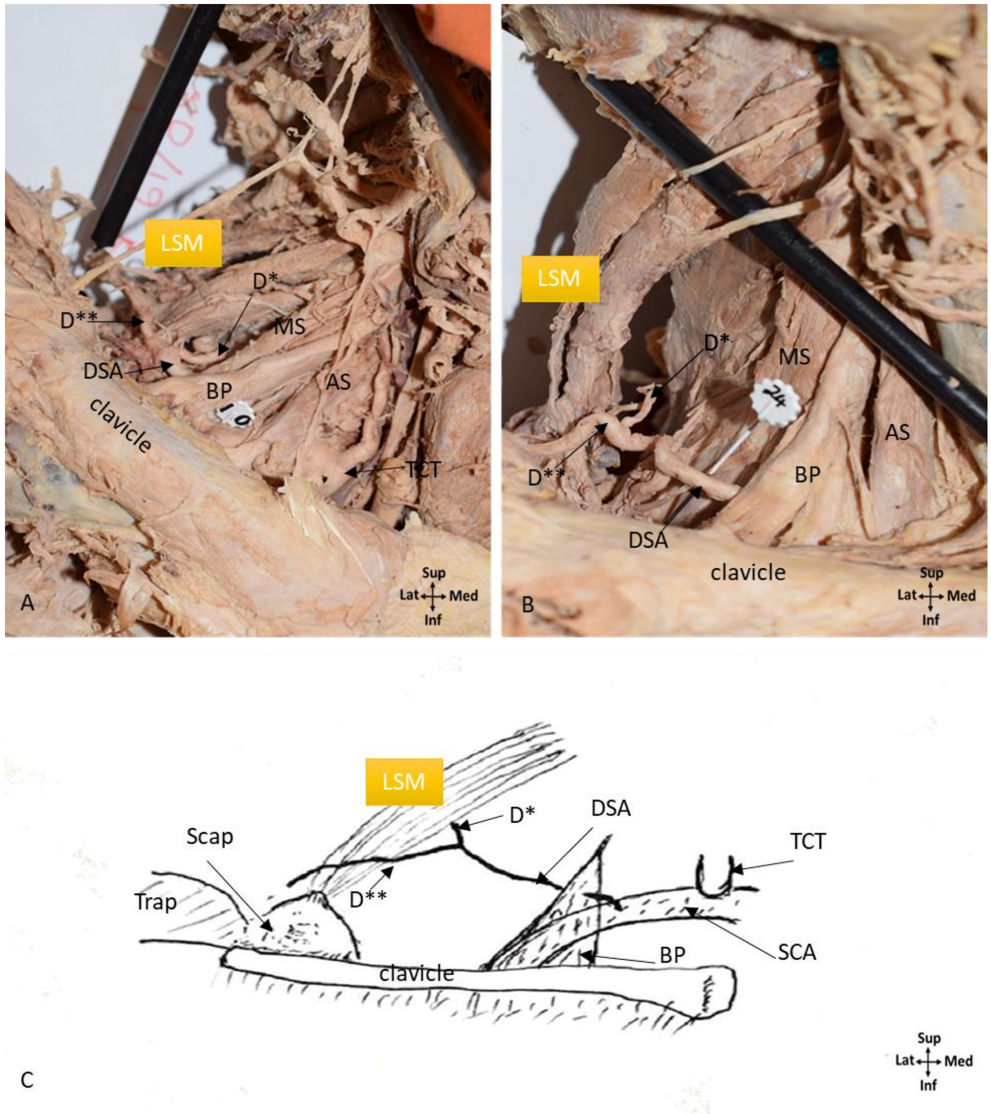

Figure 4.19: Blood supply to levator scapulae muscle from the dorsal scapular artery only. Key: A and B- An anterolateral view of the right side of an 80-year-old female cadaver (c# 5) and an 82-year-old female cadaver (c# 6). C- A diagrammatic drawing of an anterolateral region of the neck showing arterial supplies from the dorsal scapular artery to the levator scapulae muscle. BP- brachial plexus, MS- middle scalene, DSA- dorsal scapular artery, D* and D**- collateral branches of the dorsal scapular artery, LSM- levator scapulae muscle, SCA- subclavian artery.

Moreover, a fourth variation observed was found in a total of 12 levator scapulae muscles. These muscles were supplied by the transverse cervical artery and the dorsal scapular artery. However, in this instance, the transverse cervical artery stemmed from the thyrocervical trunk, while the dorsal scapular artery stemmed from the transverse cervical artery. The transverse cervical artery extended from the thyrocervical trunk towards the superficial distal aspects of the levator scapulae muscles, while the dorsal scapular artery extended from the transverse cervical artery towards the deeper aspects of the levator scapulae muscles. The bifurcation of the dorsal scapular artery from the transverse artery in this instance began at the level of the brachial plexus as presented in Figure 4.20.

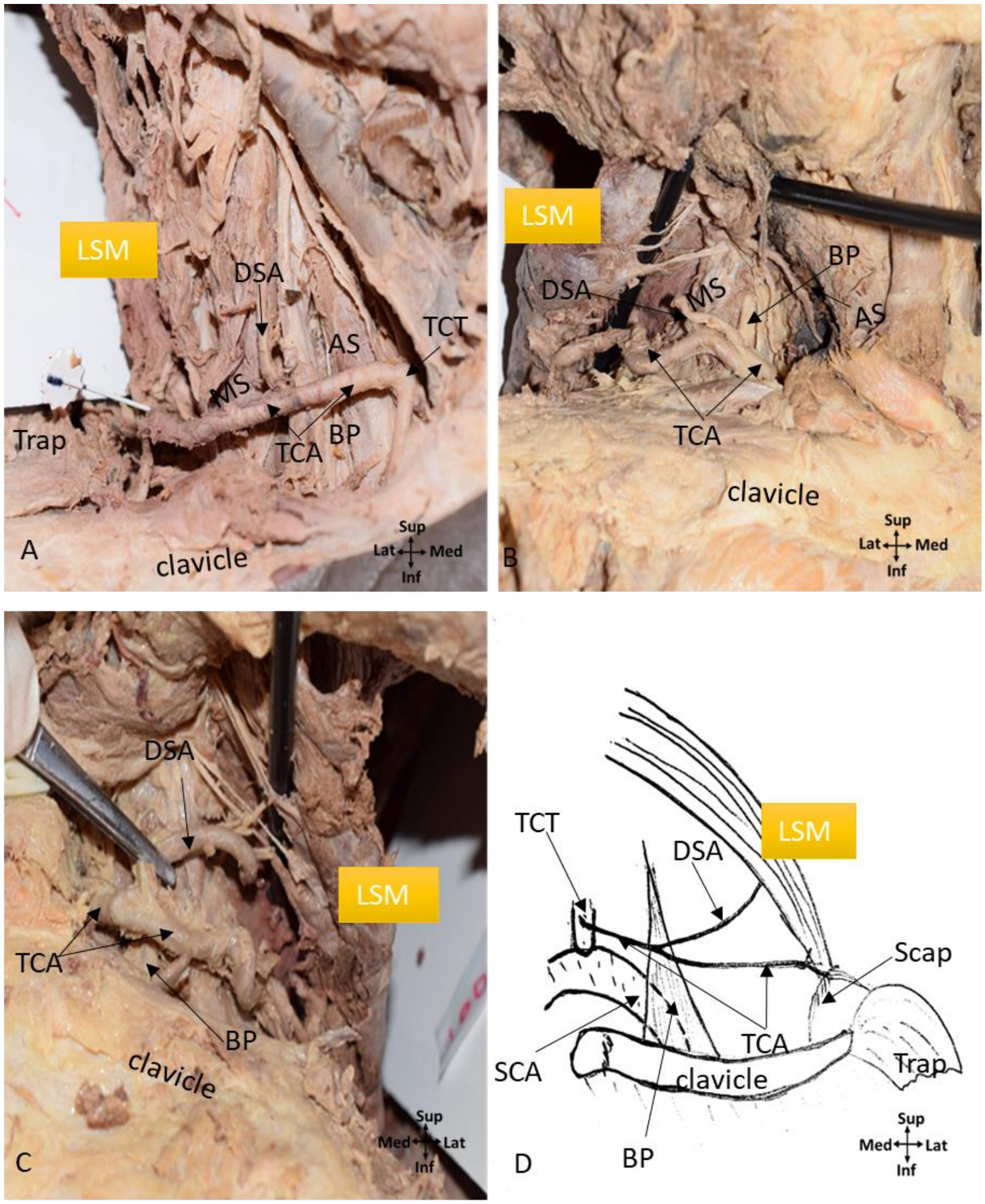

Figure 4.20: Blood supply to levator scapulae muscle from the transverse cervical artery and its branch, the dorsal scapular artery, stemming from the thyrocervical trunk (Type III). Key: A- An anterolateral view of the right side of a 56-year-old male cadaver (c# 1) and B and C- Right and left anterolateral view of an 83-year-old male cadaver (c1# 6). D- Diagrammatic drawing of the arterial supply of the left levator scapulae muscle. BP- brachial plexus, MS- middle scalene, DSA- dorsal scapular artery, LSM- levator scapulae muscle, TCA- transverse cervical artery, TCT- thyrocervical trunk.

In summary, the levator scapulae muscles in this study were mostly supplied by Type II and Type III. The rest of the levator scapulae muscles were only observed with a single blood supply: from the transverse cervical artery (TCA), a branch of the thyrocervical trunk, and the dorsal scapular artery, a branch of the subclavian artery. In addition, the levator scapulae muscle rarely received blood supply from the ascending cervical artery, a branch of the thyrocervical trunk (Table 4.2).

Table 4.2: Summary of arterial blood supply to the levator scapulae muscle

Cadaver numbers	**Age**	**Sex**	**Race**	**Source of arterial branches to the LSMs**	
				Right	**Left**
1	56	M	B	TCA (TCT) and DSA (TCA) Type III	TCA (TCT) and ACA (TCT)
2	64	M	W	DSA (SCA) only	TCA (TCT) and DSA (SCA) Type II
3	73	M	W	TCA (TCT) and DSA (TCA) Type III	DSA (SCA) only
4	79	M	W	TCA (TCT) and DSA (SCA) Type II	TCA (TCT) and DSA (SCA) Type II
5	80	F	W	DSA (SCA) only	TCA (TCT) only
6	82	F	W	DSA (SCA) only	TCA (TCT) and DSA (SCA) Type II
7	79	F	N/P	TCA (TCT) only	TCA (TCT) and DSA (SCA) Type II
8	84	M	W	TCA (TCT) and DSA (SCA) Type II	x
9	43	F	C	x	TCA (TCT) only
10	85	F	E	x	x
11	54	M	C	-	x
12	90	M	W	TCA (TCT) and DSA (TCA) Type III	TCA (TCT) and ACA (TCT)
13	64	F	W	TCA (TCT) and DSA (SCA) Type II	TCA (TCT) only
14	26	M	B	x	x
15	73	F	W	TCA (TCT) only	x
16	83	M	W	TCA (TCT) and DSA (TCA) Type III	TCA (TCT) and DSA (TCA) Type III
17	68	F	W	x	TCA (TCT) and DSA (TCA) Type III
18	59	M	W	DSA (SCA) only	x
19	71	M	W	x	-
20	86	F	W	DSA (SCA) only	TCA (TCT) and DSA (TCA) Type III
21	60	F	N/P	x	x

Key: ACA: ascending cervical artery, B: black, C: coloured, DSA: dorsal scapular artery, F: female, M: male, N/P: not specified, SCA: subclavian artery, TCA: transverse cervical artery, TCT: thyrocervical artery, W: white, x: arterial supply destroyed.

4.7 Nerve supply to the levator scapulae muscle

The levator scapulae muscles used in this study were innervated by up to six nerve branches that vary in terms of their origins, as well as in terms of the number of nerve branches from each nerve root. Since this study was performed on the same cadavers used by medical students, out of 40 levator scapulae muscles, only 29 levator scapulae muscles had nerve branches kept intact, whereas nerves supplying the remaining 11 levator scapulae muscles were destroyed.

A range of 1-6 nerve branches were observed to innervate a single levator scapulae muscle, with an average number of 3.45 ± 1.35. This study found that 37.93% of the 29 levator scapulae muscles were innervated by four nerve branches, 17.24% were supplied by two nerve branches, 17.24% were supplied by five nerve branches, 13.79% were supplied by three nerve branches, 10.34% were supplied by a single nerve branch and 3.45% of the levator scapulae were supplied by six nerve branches as presented by Figure 4.21.

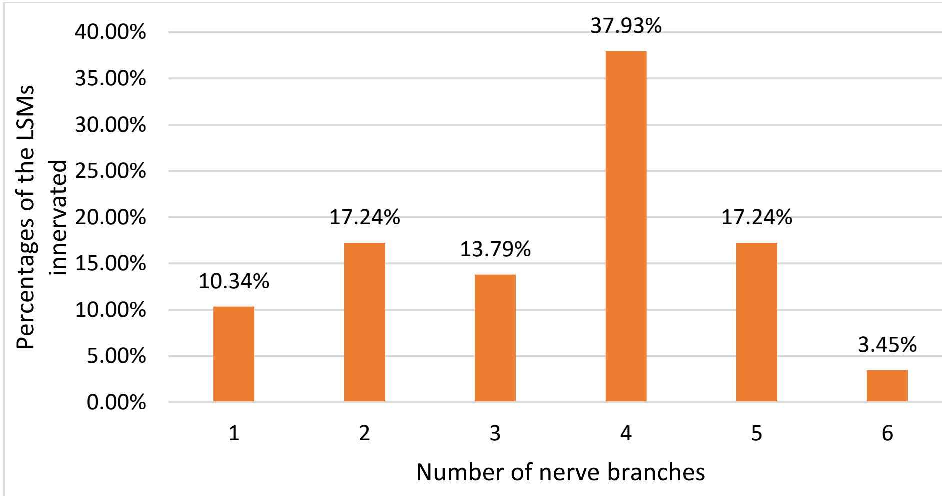

Figure 4.21: The percentage of nerve branches to the levator scapulae muscles (LSMs).

4.7.1 The variations of nerve supply to the levator scapulae muscle

The first instance of variation associated with the number of nerve supply was observed on the right levator scapulae muscle of a 64-year-old female cadaver (c# 13), with a total number of six nerve branches. This levator scapulae muscle received two nerve branches originating from the C2 nerve root, three nerve branches from the C3/C4 nerve root, and one nerve branch from the C5 nerve root. The C2 nerve branches extended towards the proximal aspects of the first superior muscle slip of the levator scapulae muscle, the C3/C4 root nerve branches extended towards the middle part of the levator scapulae muscle, while the C5 root nerve branch is known as a dorsal scapular nerve, as pierced through the middle scalene muscle (Fakoya et al., 2020; Nguyen et al., 2016; Som & Laitman, 2017), and extended towards the distal aspects of the levator scapulae muscle as presented by Figure 4.22.

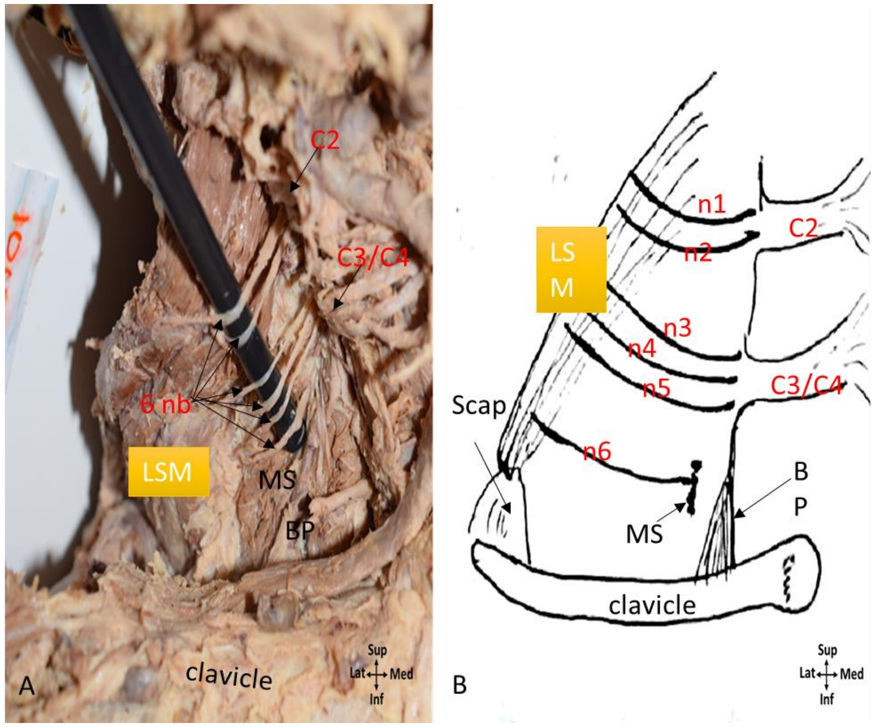

Figure 4.22: Six nerve branches to the levator scapulae muscle. Key: A- An anterolateral view of the six nerve branches to the levator scapulae muscle of a 64-year-old female cadaver (c# 13). B- A diagrammatic presentation of six nerve branches to the levator scapulae muscle. BP- brachial plexus, (C2-C5)- cervical nerve root 2-5, LSM- levator scapulae muscle, MS- middle scalene, (n1-n6)- nerve number 1 – 6, 6 nb- 6 nerve branches.

The second observed variation in the nerve supply was observed symmetrically in a 90-year-old female cadaver (c# 12) and an 86-year-old female cadaver (c# 20). The levator scapulae muscles in these cadavers were innervated by two nerve branches from the C2 nerve root, two nerve branches from the C3/C4 nerve root, and a single nerve branch from the C5 nerve root, giving a total of five nerve branches to these levator scapulae muscles. Two nerve branches from C2 nerve root extended towards the proximal aspects of the first superior muscle slip of the levator scapulae muscle, another two nerve branches from

C3/C4 nerve roots extended towards the middle aspects of the levator scapulae muscle and one nerve branch from C5 root, pierced through the middle scalene and extended to the distal aspects of the levator scapulae muscles as presented in Figure 4.23.

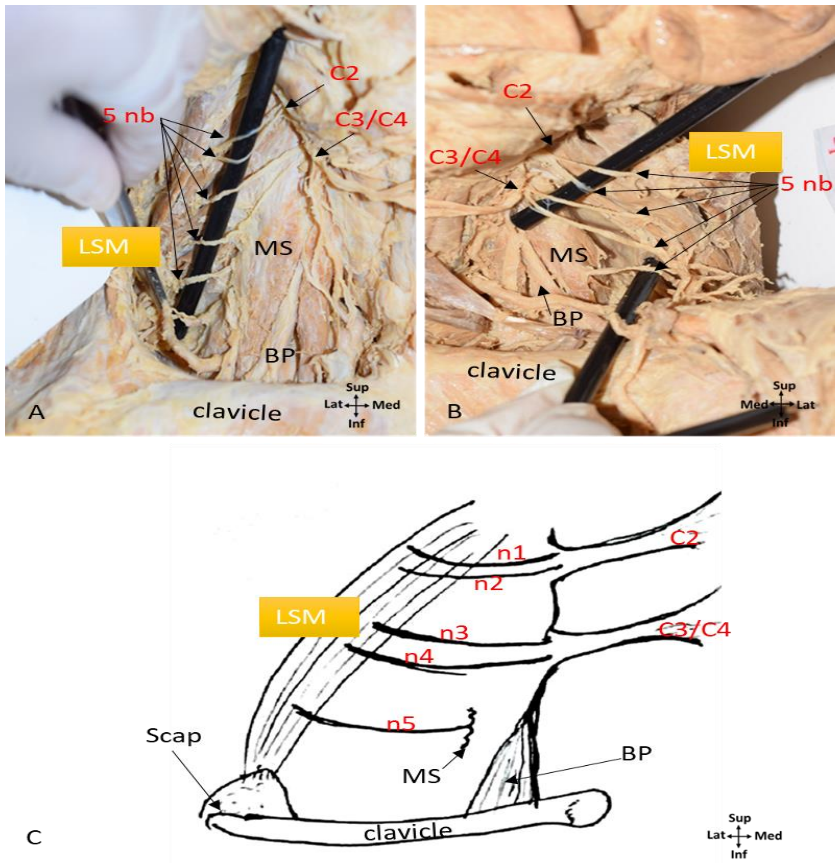

Figure 4.23: Five nerve branches to the levator scapulae muscle. Key: A- An anterolateral view showing five nerve branches to the right levator scapulae muscles, of an 86-year-old female cadaver (c# 20). B- shows the left levator scapulae muscle of a 90-year-old male cadaver (c# 12). C- A diagrammatic illustration of the nerve supply to the levator scapulae muscle. BP- brachial plexus, C2-C5- cervical nerve root 2-5, LSM- levator scapulae muscle, MS- middle scalene, n1-n5- nerve number 1 – 5, 5 nb- 5 nerve branches.

A third instance of nerve supply variation was observed on the left levator scapulae muscle of a 73-year-old female cadaver (c# 15), on the right levator scapulae muscle of a 68-year-old female cadaver (c# 17), and the right levator scapulae muscle of a 79-year-old female cadaver (c# 7). This instance variation demonstrated a total of four nerve branches to the levator scapulae muscle, which was made up of a single nerve branch from the C2 nerve root, two nerve branches from the C3/C4 nerve roots, and another single nerve branch from the C5 nerve root.

Similar to the previous instances, the C2 nerve branch extended to the proximal aspects of the levator scapulae muscle, the C3/C4 nerve branches extended towards the middle aspects of the levator scapulae muscle, whereas the C5 nerve branch pierced through the middle scalene before inserting on the distal aspects of the levator scapulae muscle as shown in Figure 4.24.

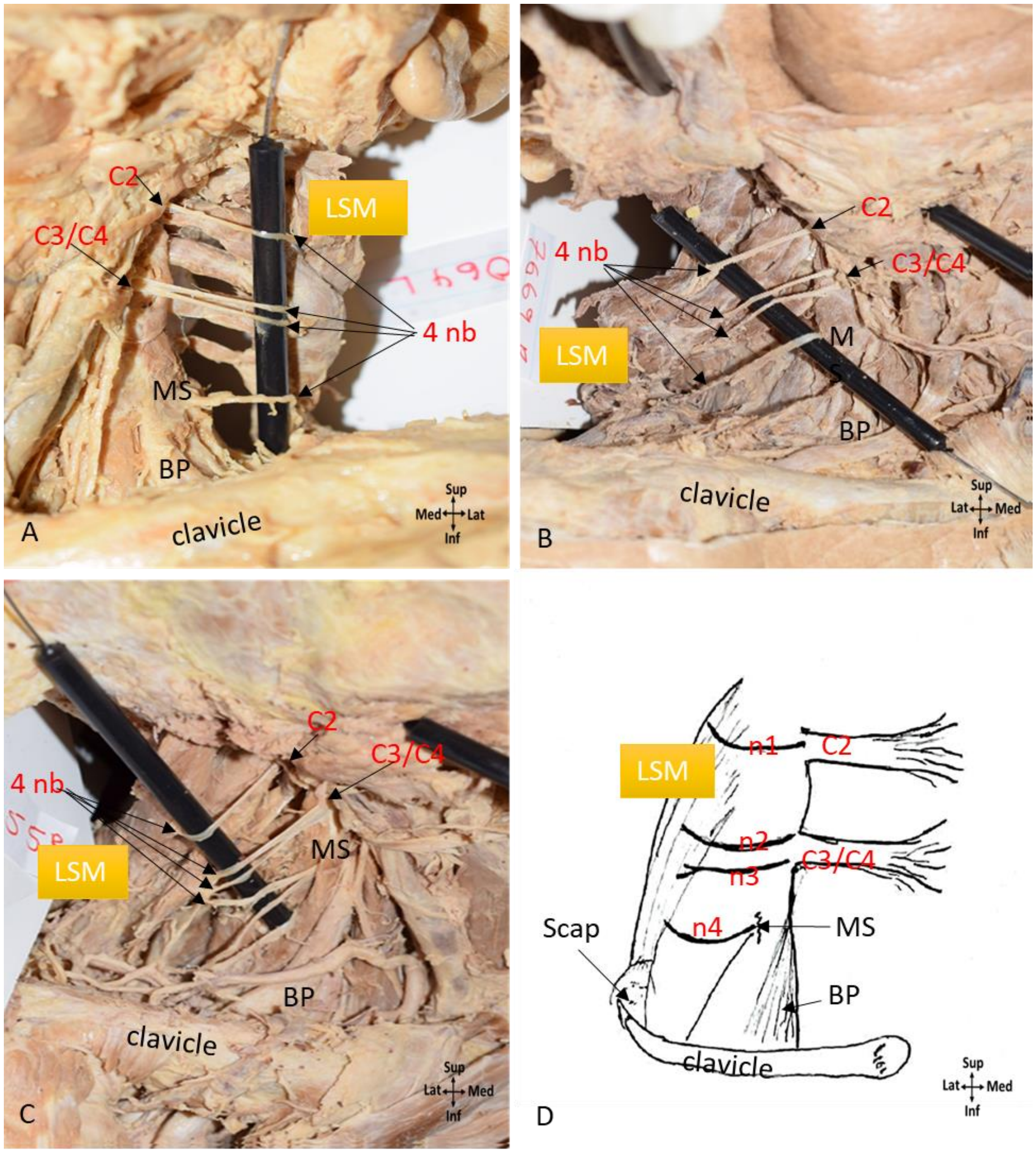

Figure 4.24: Four nerve branches to the levator scapulae muscle. Key: A, B, and C- Left anterolateral view of a 73-year-old female cadaver (c# 15), right levator scapulae muscle of a 68-year-old female cadaver (c# 17), and right levator scapulae muscle of a 79-year-old female cadaver (c# 7). D- A clear diagrammatic presentation of the four nerve branches to the levator scapulae muscles. BP- brachial plexus, C2-C5- cervical nerve root 2-5, LSM- levator scapulae muscle, MS- middle scalene, n1-n4- nerve number 1 – 4, 4 nb- 4 nerve branches.

Similar to the third observed variation, the fourth variation also presented a total of four nerve branches to the levator scapulae muscle. However, this variation consisted of a single nerve branch originating from C2 and another single nerve branch from C3/C4 nerve root and two nerve branches originating from C5 root as presented in Figure 4.25.

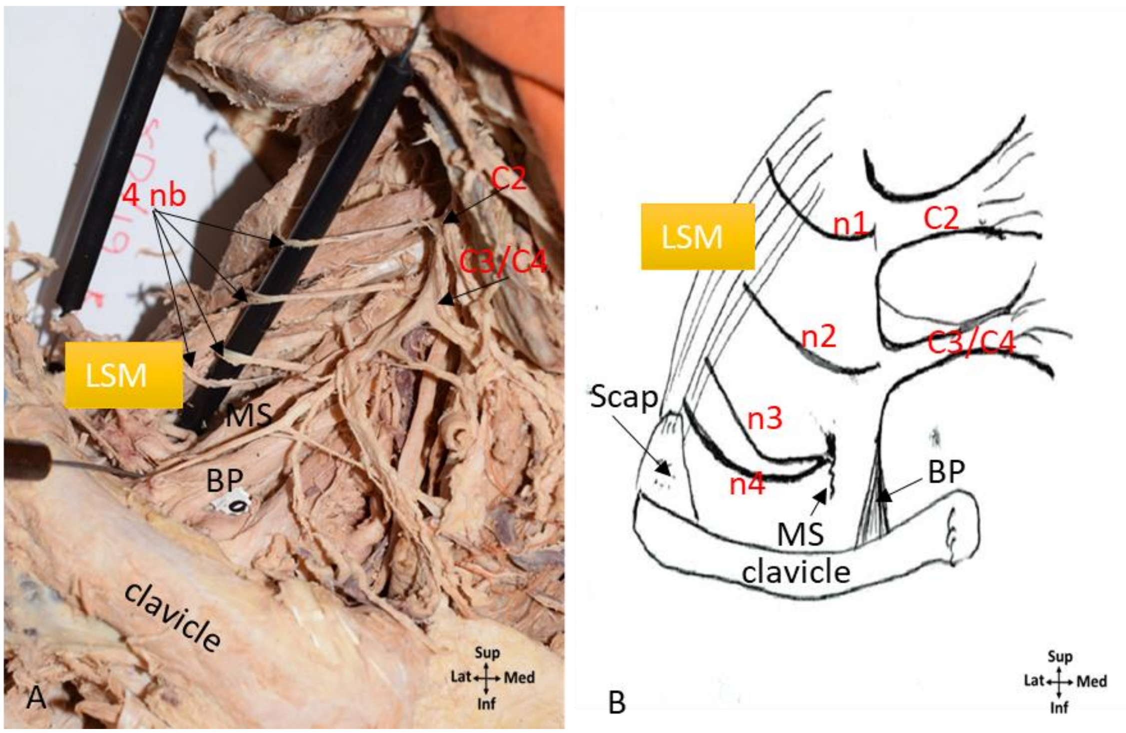

Figure 4.25: Four nerve branches to the levator scapulae muscle. Key: A- A right anterolateral view of an 80-year-old female cadaver (c# 5). B- A clear diagrammatic illustration origin of nerve branches. BP- brachial plexus, C2-C5- cervical nerve root 2-5, LSM- levator scapulae muscle, MS- middle scalene, n1-n4- nerve number 1 – 4, 4 nb- 4 nerve branches.

Lastly, the fifth variation was found on the right side of a 79-year-old male cadaver (c# 4). This variation indicated a single nerve branch from the C2 nerve root, a single nerve branch from the C3/C4 root, and another single branch from the C5 nerve root, hence, giving a total of three nerve branches to the levator scapulae muscle. These nerve branches extended similarly to the fore-presented instances. The C2 nerve branch is attached to the superior proximal aspects of the levator scapulae muscle, the C3/C4 nerve is attached to the middle aspects of the levator scapulae muscle, while the C5 nerve is attached to the distal aspects of the levator scapulae muscle presented in Figure 4.26.

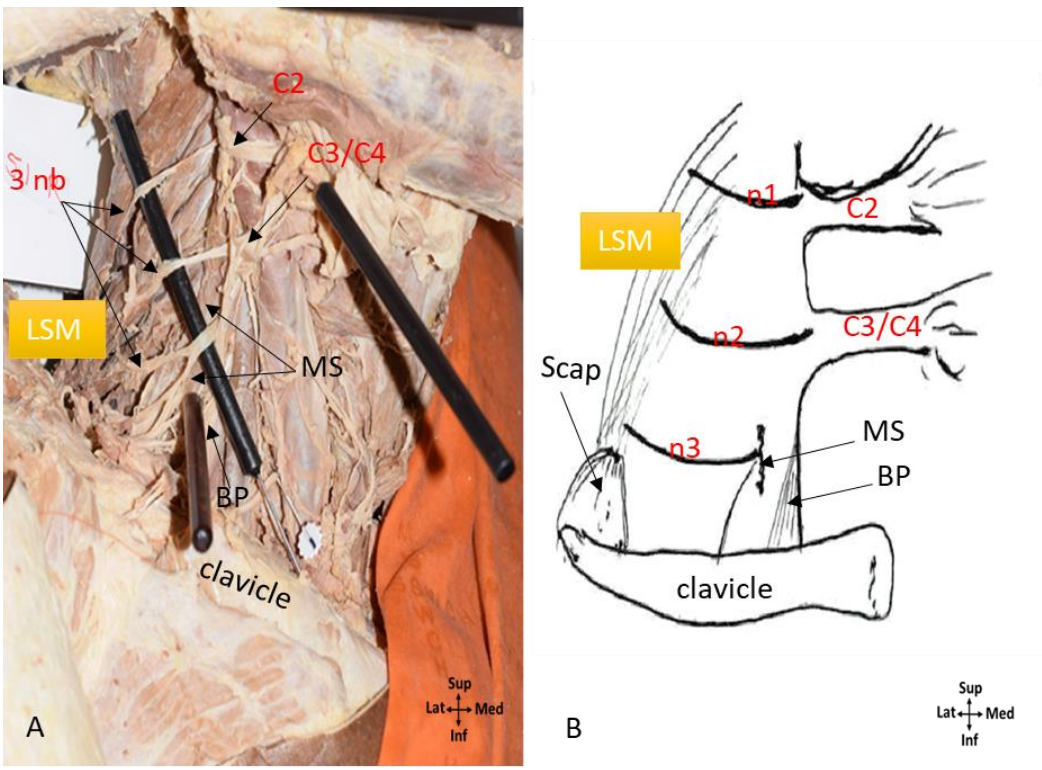

Figure 4.26: Three nerve branches to the levator scapulae muscle. Key: A- Shows a cadaveric image of the levator scapulae observed on the right side of a 79-year-old male cadaver (c# 4). B- A diagrammatic presentation illustrating three nerve branches to the levator scapulae muscle. BP- brachial plexus, C2-C5- cervical nerve root 2-5, LSM- levator scapulae muscle, MS- middle scalene, n1-n3- nerve number 1 – 3, 3 nb- 3 nerve branches.

In summary, the levator scapulae muscle is mostly known to receive innervation from the dorsal scapular nerve, usually the first branch of C5 (Fakoya et al., 2020; Nguyen et al., 2016; Som & Laitman, 2017). The muscle was however reported by Taira et al. (2003) that it received innervation from C2-C5 nerve roots.

In the current cadaveric study, the levator scapulae muscles were innervated by nerve branches of C2, C3/C4, and C5 nerve roots. The C2 nerve root had the potential to give off up to two nerve branches to the levator scapulae muscle, the C3/C4 nerve root had the potential to give off up to three nerve branches, while the C5 had the potential to give up to two nerve branches to the levator scapulae muscle. In terms of nerve branch distributions, the C2 nerve branches extended and attached to the proximal aspects of the levator scapulae muscles, the C3/C4 nerve branches extended and attached to the middle part of the levator scapulae muscles, while the C5 nerve branches extended and attached to the distal aspects of the levator scapulae muscles (Table 4.3).

Table 4.3: Summary of nerve supply to the levator scapulae muscles

Cadaver Numbers	Age	Sex	Race	Total number of nerve branches to LSM		C2 nerve root		C3/4 nerve root		C5 nerve root	
				R	**L**		**L**	**R**	**L**	**R**	**L**
1	56	M	B	x	1	x	X	x	x	x	1
2	64	M	W	x	3	x	x	x	2	x	1
3	73	M	W	1	4	x	1	x	2	1	1
4	79	M	W	3	4	1	1	1	2	1	1
5	80	F	W	4	5	1	2	1	1	2	2
6	82	F	W	2	2	1	1	1	1	x	x
7	79	F	N/P	4	2	1	1	2	1	1	x
8	84	M	W	4	4	1	1	2	2	1	1
9	43	F	C	x	x	x	x	x	x	x	x
10	85	F	E	x	x	x	x	x	x	x	x
11	54	M	C	x	x	x	x	x	x	x	x
12	90	M	W	5	5	2	2	2	2	1	1
13	64	F	W	6	x	2	x	3	x	1	1
14	26	M	B	1	4	x	1	x	2	1	1
15	73	F	W	2	4	1	1	x	2	1	1
16	83	M	W	3	4	2	2	1	2	x	x
17	68	F	W	4	3	1	x	2	2	1	1
18	59	M	W	4	2	1	2	2	x	1	x
19	71	M	W	x	x	x	x	x	x	x	x
20	86	F	W	5	5	2	2	2	2	1	1
21	60	F	N/P	x	x	x	x	x	x	x	x

Key: B- black, C- coloured, C2-C5- cervical vertebrae (2-5), F- female, L- left, LSM- levator scapulae muscle, M- male, R- right, N/P- not specified, x- nerve branch absent, W- white

4.8 Statistical analysis of the cadaveric study

The parameters of this study were the levator scapulae muscle distances (posterior distance, anterior distance, distal distance, and proximal distance), the lengths of individual muscle slips, and the widths of the individual muscle slips at the widest points. The research data were statistically analysed to determine the consistency as well as the correlations within the data recorded. The intra-observer reproducibility, inter-observer reproducibility, descriptive statistics, t-test, ANOVA, Tukey's HSD post-hoc, and linear regression tests were used to calculate, describe, compare, summarise, and determine the significance of the research data obtained. The statistical results were expressed in figures and table forms.

4.8.1 Intra and inter-observer reproducibility

Before the data analysis was done, the intraclass correlation coefficient (ICC) was calculated to determine the consistency of the data. The intra-observer reproducibility was done to determine the differences in trial measurements done by each researcher, while the interobserver reproducibility was done to determine the differences in measurements between the two researchers.

Based on the ICC calculation result, the ICC values of intra-observer reproducibility were all greater than 0.90, indicating excellent reproducibility and that there is an agreement between measurement trials of each researcher. On the other hand, most of the measurements (proximal distances, muscle widths, and lengths) gave ICC values of inter-observer reproducibility within 0.75 to 0.90 and >0.90, which indicated a good to excellent reproducibility while few measurements (distal, anterior, and posterior distances) gave ICC values between 0.50 to 0.75, which indicated a moderate reproducibility between measurements of the two researchers. In addition, all values were statistically significant as the p-values in both intra-observer and inter-observer reproducibility were less than 0.05, hence refuting the null hypothesis presented in Table 4.4.

Table 4.4: Intra-observer and inter-observer reproducibility

		Intra-observer reproducibility		**Inter-observer reproducibility**	
Parameters		ICC	Sig	ICC	Sig
Distance	Proximal	1.00	<0.0001	0.96	<0.0001
	Distal	1.00	<0.0001	0.55	0.001
	Anterior	1.00	<0.0001	0.53	0.005
	Posterior	1.00	<0.0001	0.60	0.003
Length	Slip 1	1.00	<0.0001	0.85	<0.0001
	Slip 2	1.00	<0.0001	0.93	<0.0001
	Slip 3	1.00	<0.0001	0.89	<0.0001
	Slip 4	0.85	<0.0001	0.82	<0.0001
	Slip 5	1.00	<0.0001	0.99	<0.0001
	Slip 6	1.00	<0.0001	0.99	0.009
Widths	Slip 1	1.00	<0.0001	0.95	<0.0001
	Slip 2	1.00	<0.0001	0.98	<0.0001
	Slip 3	1.00	<0.0001	0.97	<0.0001
	Slip 4	1.00	<0.0001	0.71	<0.0001
	Slip 5	1.00	<0.0001	0.97	<0.0001
	Slip 6	1.00	<0.0001	1.00	0.004

The result is significant at $p < 0.05$. Key: ICC- Intraclass correlation coefficient, Sig- Significance

4.8.2 Descriptive statistics of the research parameters

4.8.2.1 Proximal distance

The descriptive statistics of the proximal distances of the levator scapulae muscles (between the superior origin and inferior origin on transverse processes) showed that the longest distance was 71.87 ± 4.69 mm found in levator scapulae muscles with six muscle slips, whereas the shortest proximal distance was found in levator scapulae muscles with two muscle slips with an average of 27.43 ± 2.52 mm.

However, the average proximal distance of levator scapulae muscles with three muscle slips was 42.71 ± 23.75 mm, the standard deviation indicating the highest variation amongst others, which could be due to the nature of muscle slip attachments of the levator scapulae muscles. Two of the three instance variations observed having three muscle slips had two muscle slips with common proximal attachment, whereby the first slip originated from C1 while the second and third slips both originated from C2, hence having a shorter distance as presented in Figure 4.5.

Another three muscle slip levator scapulae muscle was observed with differences in proximal attachments. The first muscle slip was attached to C1, the second slip was attached to C2, and the third slip was attached to C4. There was no muscle slip attached to the third cervical vertebrae (C3) as presented in Figure 4.10, hence, resulting in a huge difference in the proximal distance. These instances explained the great differences among the three muscle slip levator scapulae muscles as presented in Table 4.5 and Figure 4.27.

Table 4.5: Descriptive statistics for the proximal distances of the levator scapulae muscles

Statistical Calculations	**Proximal distance: From superior to inferior origin on transverse processes (mm)**				
Number of LSM slips	**2**	**3**	**4**	**5**	**6**
Number of LSMs (frequency)	3	3	25	7	2
Mean (mm) ± SD	27.43 ± 2.52	42.71 ± 23.75	53.17 ± 6.63	64.99± 10.10	71.87 ± 4.69
Minimum value (mm)	25.14	27.25	36.35	47.41	68.55
Maximum value (mm)	30.13	70.05	64.38	75.89	75.18

Key: LSM(s)- levator scapulae muscles, SD- standard deviation

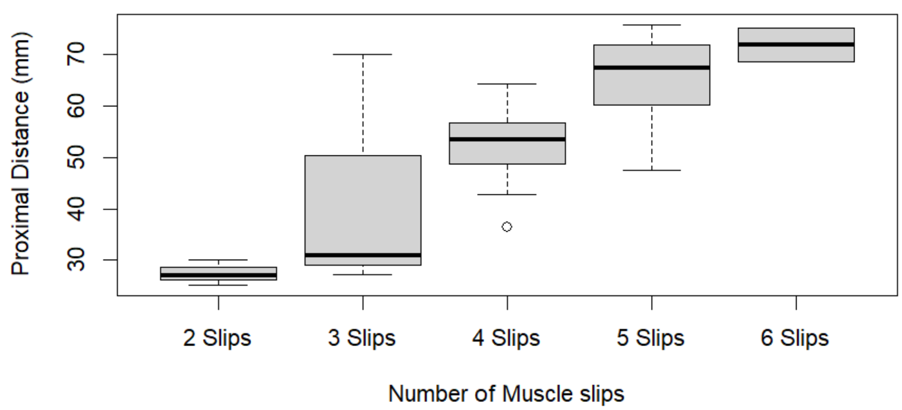

Figure 4.27: Box and whisker plot of proximal distance. Key: LSM- levator scapulae muscle

Overall, for the levator scapulae muscle with well-defined muscle slips, the proximal distance increased with an increased number of muscle slips. However, some of the proximal distances were not correlating with the increased number of muscle slips, due to some muscle slips having common proximal attachments.

4.8.2.2 Distal distance

The distal distance represented the attachment of the levator scapulae muscle to the scapula. The muscles were grouped according to the number of muscle slips and the distance mean was calculated. The calculations demonstrated a huge difference in distal distance within levator scapulae muscles with five muscle slips (60.96 ± 15.38mm). The least difference was observed in levator scapulae muscles with two muscle slips (48.35 ± 3.45 mm) and three muscle slips (61.12 ± 3.35) as presented in Table 4.6. and Figure 4.28.

Table 4.6: The descriptive statistics for the distal distances of the levator scapulae muscles

Statistical Calculations	**Distal distance: Insertion on the medial border of the scapula (mm)**				
Number of LSM slips	**2**	**3**	**4**	**5**	**6**
Number of LSMs (frequency)	**3**	**3**	**25**	**7**	**2**
Mean (mm) ± SD	48.35 ± 3.45	61.12 ± 3.35	60.63 ± 9.06	60.96± 15.38	77.19 ± 9.60
Minimum value (mm)	44.45	57.26	43.42	43.03	70.40
Maximum value (mm)	51.02	63.25	73.70	86.79	83.98

Key: LSM(s)- levator scapulae muscle(s), SD- standard deviation

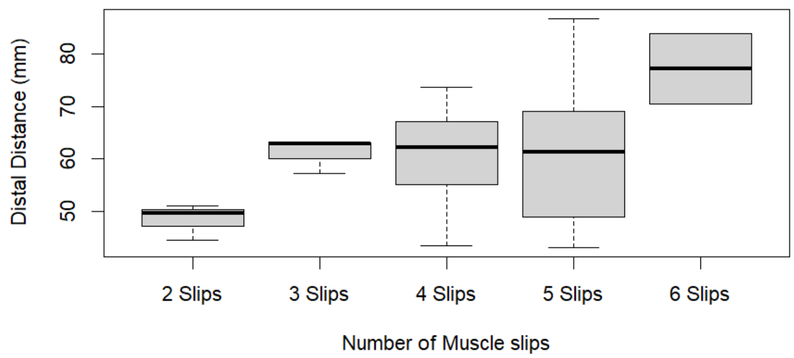

Figure 4.28: Box and whisker plot of distal distance. Key: LSM- levator scapulae muscle

4.8.2.3 Anterior distance

The anterior distance of the levator scapulae muscles extended between the inferior origin on the transverse process and insertion on the medial border of the scapula. The levator scapulae muscles with three muscle slips had the highest mean anterior distance of 102.00 ± 4.31 mm. There was also a great variation in the anterior distance of levator scapulae muscles with two muscle slips (standard deviation of 13.67 mm), as well as in the anterior distance of levator scapulae muscles with five muscle slips, with a mean of 81.15 ± 10.84mm. However, the mean values of anterior distances of the levator scapulae muscles with two muscle slips (86.70 ± 13.67 mm), four muscle slips (87.15 ± 7.32 mm), and six muscle slips (85.49 ± 5.24 mm) appear to be correlating as presented in Table 4.7 and Figure 4.29.

Table 4.7: The descriptive statistics for the anterior distances of the levator scapulae muscles

Statistical Calculations	**Anterior distance: From inferior origin on the transverse process to insertion on the medial border of the scapula (mm)**				
Number of LSM slips	**2**	**3**	**4**	**5**	**6**
Number of LSMs (frequency)	**3**	**3**	**25**	**7**	**2**
Mean (mm) ± SD	86.70 ± 13.67	102.00 ± 4.31	87.15 ±7.32	81.15± 10.84	85.49 ± 5.24
Minimum value (mm)	73.37	99.42	72.18	63.61	81.78
Maximum value (mm)	100.68	106.98	103.19	100.28	89.19

Key: LSM(s)- levator scapulae muscle(s), SD- standard deviation

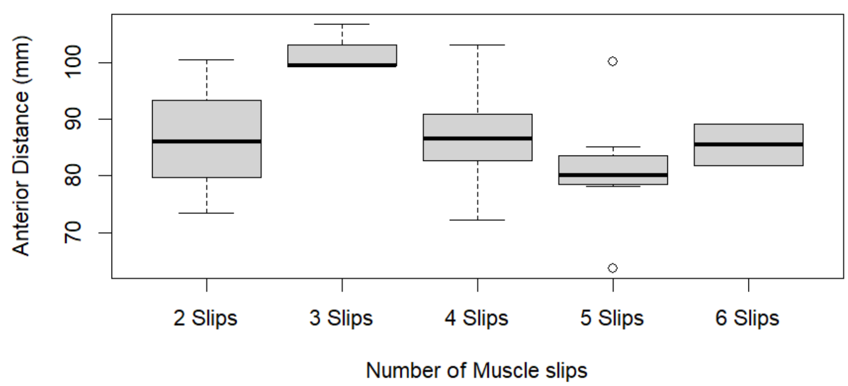

Figure 4.29: Box and whisker plot of anterior distance. Key: LSM- levator scapulae muscle.

Overall, there was a notable difference in anterior distances among the levator scapulae muscles with various numbers of muscle slips. However, the anterior distance in this section only included the muscle slips that were distally inserted on the scapula and excluded the muscle slips and muscle slips that were not distally attached to the scapula.

4.8.2.4 Posterior distance

The descriptive statistics for the posterior distance represented the distance from the superior origin on the transverse process to insertion on the medial border of the scapula. Based on the findings of the study, the mean posterior distance of levator scapulae muscles ranges from 152.99 ± 12.87 mm (2 muscle slips) to 172.73 ± 13.70 mm (6 muscle slips). The levator scapulae muscles with three muscle slips had posterior distances ranging from 141.80 mm to 191.47 mm with a mean of 162.99 ± 25.67 mm, which portrayed the greatest difference in posterior distances among other levator scapulae muscles with three muscle slips (Table 4.8 and Figure 4.30). Another great difference was demonstrated among the levator scapulae with four muscle slips, with a maximum value of 190.47 mm and a minimum value of 126.33 mm, giving a mean value of 159.36 ± 15.60 mm as presented in Table 4.8 and Figure 4.30.

Table 4.8: The descriptive statistics for the posterior distances of the levator scapulae muscles

Statistical Calculations	**Posterior distance: From superior origin on the transverse process of C1 to insertion on the medial border of the scapula (mm)**				
Number of LSM slips	**2**	**3**	**4**	**5**	**6**
Number of LSMs (frequency)	**3**	**3**	**25**	**7**	**2**
Mean (mm) ± SD	152.99 ± 12.87	162.99 ± 25.67	159.36 ± 15.60	149.43± 13.48	172.73 ± 13.70
Minimum value (mm)	145.23	141.80	126.33	133.91	163.04
Maximum value (mm)	167.85	191.54	190.47	168.72	182.41

Key: LSM(s)- levator scapulae muscle(s), SD- standard deviation

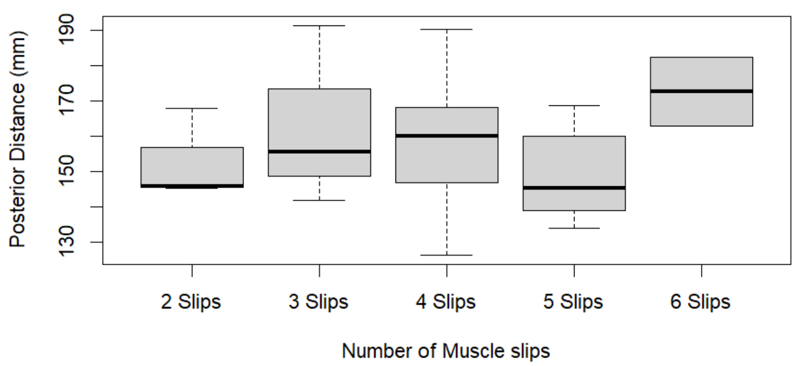

Figure 4.30: Box and whisker plot of posterior distance. Key: LSM- levator scapulae muscle

Overall, there was a great fluctuation associated with the posterior distances, with a standard deviation of 15.08 mm. the longest distance was the posterior distance, followed by the anterior distance. The overall shortest distance was the proximal distance as presented in Table 4.9.

Table 4.9: Total averages of the levator scapulae muscle distances

	Proximal	**Distal**	**Anterior**	**Posterior**
Mean	53.46	60.63	87.10	158.08
Std. Deviation	13.22	10.78	9.27	15.94
Minimum	25.14	43.03	63.61	126.33

Key: Std- standard

4.8.2.5 The lengths of levator scapulae muscle slips

The lengths of individual muscle slips were measured at the middle aspects of each muscle slip. The muscle slips were however numbered from the first to the sixth muscle slip. Since all the levator scapulae muscles in this study had the first and second muscle slips, the highest mean length for the first muscle slip was noted in levator scapulae muscles with six muscle slips, having a mean length of 167.38 ± 13.31 mm, whereas the lowest mean length of the first muscle slip was noted in levator scapulae muscles with two muscle slips having a mean length of 146.63 ± 12.17 mm respectfully.

Similarly, the highest mean length for the second muscle slip was noted in levator scapulae muscles with six muscle slips, having a mean length of 144.14 ± 5.06 mm, while the lowest mean length for the second muscle slip was noted in levator scapulae muscles with two muscle slips, having a mean length of 100.19 ± 9.98 mm. In addition to that, there was a slight difference in mean lengths noted in the first muscle slips among levator scapulae muscles with two muscle slips, four muscle slips, and five muscle slips as presented in Table 4.10.

Table 4.10: The descriptive statistics summary of levator scapulae muscle slip lengths

Muscle slip categories	Statistical Calculations	Lengths of individual muscle slips				
	Number of LSM slips	**2**	**3**	**4**	**5**	**6**
	Number of LSMs (frequency)	**3**	**3**	**25**	**7**	**2**
Slip 1	**Mean (mm) ± SD**	146.63 ± 12.17	158.51 ± 19.41	149.17 ± 18.41	145.07± 1.59	167.38 ± 13.31
	Minimum value (mm)	134.73	140.78	111.14	131.72	157.97
	Maximum value (mm)	159.05	179.25	190.29	159.13	176.79
Slip 2	**Mean (mm) ± SD**	100.19 ± 9.98	127.9 ± 20.36	121.18 ± 16.49	122.85± 15.18	144.14 ± 5.06
	Minimum value (mm)	90.17	114.32	87.03	104.82	140.56
	Maximum value (mm)	110.12	151.31	160.83	149.76	147.72
Slip 3	**Mean (mm) ± SD**		111.47 ± 14.55	102.50 ± 12.78	106.95 ± 8.13	130.04 ± 13.05
	Minimum value (mm)		99.45	73.71	99.40	120.81
	Maximum value (mm)		127.65	133.33	118.18	139.27
Slip 4	**Mean (mm) ± SD**			83.77 ± 10.62	94.11 ± 5.77	113.83 ± 4.54
	Minimum value (mm)			66.60	81.99	110.62
	Maximum value (mm)			110.60	98.91	117.04
Slip 5	**Mean (mm) ± SD**				79.58 ± 9.01	109.02 ± 2.14
	Minimum value (mm)				65.39	107.50
	Maximum value (mm)				93.55	110.53
Slip 6	**Mean (mm) ± SD**					85.32 ± 5.78
	Minimum value (mm)					81.23
	Maximum value (mm)					89.41

Key: LSM(s)- levator scapulae muscle(s), SD- standard deviation

Overall, the was a great difference observed between the minimum and maximum length values of the muscle slip. The first muscle presented the highest average (158.08 ± 15.94 mm) length in comparison to the other muscle slips in all levator scapulae muscles. The lowest value was the average length of the sixth muscle slips (86.12 ± 15.16 mm) as presented in Table 4.11.

Table 4.11 Total average of the levator scapulae muscle slip length

Total	**Slip1_Length**	**Slip2_Length**	**Slip3_Length**	**Slip4_Length**	**Slip5_Length**	**Slip6_Length**
Mean	158.08	149.87	121.55	105.55	87.66	86.12
Std. Deviation	15.94	16.95	17.16	13.40	12.27	15.16
Minimum	126.33	111.14	87.03	73.71	66.60	65.39
Maximum	191.54	190.29	160.83	139.27	117.04	110.53

Key: Std- standard

4.8.2.6 The widths of levator scapulae muscle slips

The levator scapulae muscle slip widths were measured at the widest points. Similar to the length section, the muscle slips in the widths section were also numbered from the first to the sixth muscle slip respectively. All the levator scapulae muscles had the first and the second muscle slips. Hence, the consistency in terms of muscle slip attachments (origin and insertion) was observed among the first and the second muscle slips, whereby the first muscle slips originated from C1, whereas the second slips originated from C2, and they inserted on the superomedial border of the scapula. On the other hand, the rest of the muscle slip categories had no fixed muscle slip origins as well as insertions, due to the presence of variations.

According to the measurements obtained, the first slips were wider among the levator scapulae muscles with four muscle slips (15.63 ± 4.82 mm). The average width of the second slip was dominant in the levator scapulae muscles with three slips (19.17 ± 1.24 mm) and least dominant among the levator scapulae muscles with five muscle slips (6.02 ± 2.76 mm) as presented in Table 4.12.

Table 4.12: The descriptive statistics summary of levator scapulae muscle slip widths

Muscle slip categories	Statistical Calculations	Widths of individual muscle slips				
	Number of LSM slips	**2**	**3**	**4**	**5**	**6**
	Number of LSMs (frequency)	**3**	**3**	**25**	**7**	**2**
Slip 1	**Mean (mm) ± SD**	11.87 ± 2.86	13.56 ± 4.54	15.64 ± 3.39	13.10 ± 3.45	15.08 ± 4.82
	Minimum value (mm)	9.24	10.93	9.74	10.12	11.67
	Maximum value (mm)	14.92	18.81	22.23	19.20	18.49
Slip 2	**Mean (mm) ± SD**	14.95 ± 0.67	19.17 ± 1.24	14.41 ± 3.01	13.03 ± 3.90	12.38 ± 6.66
	Minimum value (mm)	14.33	18.41	9.21	8.98	7.67
	Maximum value (mm)	15.67	20.6	20.56	20.79	17.09
Slip 3	**Mean (mm) ± SD**		8.73 ± 4.38	11.40 ± 3.38	11.50 ± 3.20	11.42 ± 4.04
	Minimum value (mm)		5.68	5.12	8.79	8.56
	Maximum value (mm)		13.75	19.91	18.28	14.27
Slip 4	**Mean (mm) ± SD**			9.89 ± 5.21	9.67 ± 3.90	12.58 ± 1.82
	Minimum value (mm)			4.76	6.14	11.29
	Maximum value (mm)			28.03	17.50	13.87
Slip 5	**Mean (mm) ± SD**				6.02 ± 2.76	11.17 ± 3.08
	Minimum value (mm)				3.45	8.99
	Maximum value (mm)				11.71	13.34
Slip 6	**Mean (mm) ± SD**					14.12 ± 6.24
	Minimum value (mm)					9.71
	Maximum value (mm)					18.53

Key: LSM(s)- levator scapulae muscle(s), SD- standard deviation

The first muscle slips were wider comparing to the inferior muscle slips. Overall, the wideness of the muscle slips decreased inferiorly, from the first to the sixth muscle slip. The total average width ranged of 7.16 mm to 85.32 mm (Table 4.13).

Table 4.13: Total average of the muscle slip widths

Total	Slip1_Width	Slip2_Width	Slip3_Width	Slip4_Width	Slip5_Width	Slip6_Width
Mean	85.32	14.73	14.46	11.20	10.00	7.16
Std. Deviation	5.78	3.56	3.39	3.38	4.80	3.47
Minimum	81.23	9.24	7.67	5.12	4.76	3.45
Maximum	89.41	22.23	20.79	19.91	28.03	13.34

Key: Std- standard

4.8.3 The significant difference in the laterality of the levator scapulae muscle measurements using a t-test

The statistical analysis using a t-test was done, to determine the statistical differences present between the right and the left levator scapulae concerning the measured distances of the levator scapulae muscle, the lengths and widths of the muscle slips. The results indicated that there were no significant differences between the left and right sides proximal distances, distal distances, anterior distances, and posterior distances. There were also no significant differences between the left and right sides regarding the lengths of the first five upper muscle slips (slips 1-5). Moreover, there were no significant differences between the left and right sides regarding the widths of the first three superior muscle slips (slips 1-3), and the fifth muscle slip (slip 5). The results had p-values greater than 0.05 (Table 4.14).

The results suggested that the dimensions and distances of the levator scapulae muscle measurements were symmetrical between the left and right sides. The sixth slips were only present in the left levator scapulae muscles; hence, no significant difference was obtained. However, a significant difference was observed between the right and left widths of the fourth muscle slips (slip 4) of the levator scapulae muscles, with a p-value of 0.01 < 0.05 as presented in Table 4.14.

Table 4.14: The significant difference between right and left levator scapulae muscles

	t-test for Equality of Means						
	t-values	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
						Lower	**Upper**
Distances							
Distal	0.70	38	0.49	2.40	3.43	-4.55	9.34
Proximal	1.35	38	0.19	5.58	4.14	-2.80	13.96
Anterior	0.60	38	0.55	1.77	2.95	-4.21	7.76
Posterior	0.60	38	0.55	3.06	5.08	-7.23	13.35
Lengths							
Slip 1	0.42	38	0.68	2.27	5.42	-8.70	13.24
Slip 2	0.58	38	0.57	3.16	5.47	-7.92	14.24
Slip 3	1.53	35	0.13	6.63	4.33	-2.16	15.41
Slip 4	1.78	32	0.08	7.27	4.07	-1.03	15.57
Slip 5	1.85	9	0.10	21.26	11.48	-4.71	47.22
Slip 6	-1.84	1	0.32	-13.03	7.08	-103.04	76.98
Widths							
Slip 1	0.43	38	0.67	0.49	1.14	-1.82	2.79
Slip 2	0.50	38	0.62	0.54	1.08	-1.65	2.73
Slip 3	1.15	35	0.26	1.28	1.11	-0.97	3.52
Slip 4	2.73	32	0.01	4.12	1.51	1.05	7.18
Slip 5	2.00	9	0.08	3.54	1.77	-0.46	7.54
Slip 6	1.04	1	0.49	7.96	7.64	-89.09	105.02

The result is significant at $p < 0.05$. Key: df- degree of freedom, Sig- significant

4.8.4 The significant difference between cadaver sex using a t-test

An independent t-test was conducted to evaluate potential differences in cadaver measurements based on sex. A significant difference was found in the anterior distance (from the inferior origin on the transverse process to the insertion on the medial border of the scapula) between males and females ($p = 0.01$, less than 0.05), with a mean difference of 7.25 mm, indicating a notable variation between the groups. Additionally, significant differences were observed in the lengths of cadavers with five slips ($p = 0.01$), with a mean difference of 37.22 mm, and in the width of cadavers with two slips ($p = 0.01$), with a mean difference of 2.61 mm. These results suggest that these specific measurements differ significantly based on cadaver sex (Table 4.15).

Conversely, no statistically significant differences were found for several other measurements. For instance, the proximal distance ($p = 0.24$) and distal distance ($p = 0.36$) showed no significant differences, as did the posterior distance ($p = 0.11$). The lengths of Slip 1 ($p = 0.15$), Slip 2 ($p = 0.44$), Slip 3 ($p = 0.85$), and Slip 4 ($p = 0.33$) were also not significantly different. Similarly, no significant differences were observed in the widths of Slip 1 ($p = 0.29$), Slip 3 ($p = 0.16$), Slip 4 ($p = 0.85$), and Slip 5 ($p = 0.91$). These findings indicate no meaningful variation between the groups for these parameters, highlighting that sex does not significantly affect these particular measurements (Table 4.15).

Table 4.15: The significant difference between male and female cadaver measurements

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Proximal	-1.19	38.00	0.24	-5.00	4.21	-13.52	3.52
Distal	0.94	38.00	0.36	3.23	3.45	-3.76	10.22
Anterior	2.63	38.00	0.01	7.25	2.76	1.66	12.84
Posterior	1.63	38.00	0.11	8.15	4.99	-1.96	18.26
Slip1_Length	1.46	38.00	0.15	7.82	5.34	-3.00	18.64
Slip2_Length	0.79	38.00	0.44	4.34	5.52	-6.83	15.51
Slip3_Length	-0.18	35.00	0.85	-0.83	4.51	-9.98	8.32
Slip4_Length	-0.98	32.00	0.33	-4.19	4.28	-12.90	4.52
Slip5_Length	3.28	9.00	0.01	37.22	11.36	11.51	62.93
Slip1_Width	1.08	38.00	0.29	1.23	1.14	-1.07	3.53
Slip2_Width	2.58	38.00	0.01	2.61	1.01	0.56	4.66
Slip3_Width	1.45	35.00	0.16	1.60	1.10	-0.64	3.85
Slip4_Width	0.19	32.00	0.85	0.32	1.70	-3.14	3.78
Slip5_Width	0.12	9.00	0.91	0.32	2.65	-5.67	6.31

The result is significant at $p < 0.05$. df: degree of freedom, Sig: significant

4.8.5 Analysis of Variance test within cadaver race

The results of the ANOVA test revealed several measurements where no significant differences were found between the racial groups. The proximal distance ($p = 0.39$), anterior distance ($p = 0.99$), and posterior distance ($p = 0.35$) showed no significant difference between the racial groups. However, significant differences were observed in the distal distance ($p = 0.00$) (Table 4.16).

Table 4.16: Analysis of variance of levator scapulae muscle distances between racial groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Proximal	Between Groups	543.27	3.00	181.09	1.03	0.39
	Within Groups	5614.66	32.00	175.46		
	Total	6157.93	35.00			
Distal	Between Groups	1352.32	3.00	450.77	5.37	0.00
	Within Groups	2688.35	32.00	84.01		
	Total	4040.67	35.00			
Anterior	Between Groups	6.43	3.00	2.14	0.02	1.00
	Within Groups	3127.81	32.00	97.74		
	Total	3134.24	35.00			
Posterior	Between Groups	696.38	3.00	232.13	1.14	0.35
	Within Groups	6513.87	32.00	203.56		
	Total	7210.25	35.00			

The result is significant at $p < 0.05$. Key: df- degree of freedom, Sig- significance

Similarly, the lengths of Slip 1 (p = 0.27), Slip 2 (p = 0.34), Slip 4 (p = 0.30), and Slip 5 (p = 0.77) did not demonstrate any significant differences. However, the lengths of Slip 3 (p = 0.02) were significantly different within the racial groups (Table 4.17).

Table 4.17: Analysis of variance of levator scapulae muscle slip lengths between racial groups

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	Sig.
Slip1_Length	Between Groups	941.45	3.00	313.82	1.37	0.27
	Within Groups	7309.03	32.00	228.41		
	Total	8250.48	35.00			
Slip2_Length	Between Groups	972.67	3.00	324.22	1.17	0.34
	Within Groups	8894.83	32.00	277.96		
	Total	9867.50	35.00			
Slip3_Length	Between Groups	1169.90	3.00	389.97	3.97	0.02
	Within Groups	2848.14	29.00	98.21		
	Total	4018.05	32.00			
Slip4_Length	Between Groups	320.61	2.00	160.30	1.27	0.30
	Within Groups	3397.98	27.00	125.85		
	Total	3718.59	29.00			
Slip5_Length	Between Groups	52.41	1.00	52.41	0.09	0.77
	Within Groups	3876.92	7.00	553.85		
	Total	3929.33	8.00			

The result is significant at $p < 0.05$. Key: df- degree of freedom, Sig- significant

In addition, the widths of Slip 1 (p = 0.89), Slip 2 (p = 0.39), Slip 3 (p = 0.21), Slip 4 (p = 0.24), and Slip 5 (p = 0.90) were also found to be insignificant across racial groups (Table 4.18).

Table 4.18: Analysis of variance of levator scapulae muscle slip widths between racial groups

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Slip1_Width	Between Groups	8.59	3.00	2.86	0.21	0.89
	Within Groups	427.61	32.00	13.36		
	Total	436.20	35.00			
Slip2_Width	Between Groups	31.64	3.00	10.55	1.04	0.39
	Within Groups	323.16	32.00	10.10		
	Total	354.80	35.00			
Slip3_Width	Between Groups	49.45	3.00	16.48	1.59	0.21
	Within Groups	300.57	29.00	10.36		
	Total	350.02	32.00			
Slip4_Width	Between Groups	66.30	2.00	33.15	1.51	0.24
	Within Groups	593.12	27.00	21.97		
	Total	659.42	29.00			
Slip5_Width	Between Groups	0.08	1.00	0.08	0.02	0.90
	Within Groups	33.26	7.00	4.75		
	Total	33.35	8.00			

The result is significant at $p < 0.05$. Key: df- degree of freedom, Sig- significant

4.8.6 Tukey's HSD post-hoc test

Tukey's HSD post-hoc test was conducted to determine where the significant differences occurred in parameters. For the distal measurement, significant differences were found between Black individuals and several other racial groups. Specifically, the mean distal distance for Black individuals was significantly larger than that for White individuals (mean difference = 17.44 mm, p = 0.006), Coloured individuals (mean difference = 23.96 mm, p = 0.009), and European individuals (mean difference = 22.56 mm, p = 0.037). Conversely, White, Coloured, and European groups did not show significant differences in distal distance among themselves, with p-values above 0.05. These findings indicated that the significant variation in distal measurements is largely driven by differences between Black individuals and other racial groups (Table 4.19).

Table 4.19: Tukey's HSD post-hoc test

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Distal	Black	White	17.44*	4.91	0.01	4.13	30.74
		Coloured	23.96*	7.00	0.01	5.00	42.93
		European	22.56*	7.94	0.04	1.06	44.07
	White	Black	-17.44	4.91	0.01	-30.74	-4.13
		Coloured	6.53	5.58	0.65	-8.59	21.64
		European	5.13	6.72	0.87	-13.07	23.32
	Coloured	Black	-23.96	7.00	0.01	-42.93	-5.00
		White	-6.53	5.58	0.65	-21.64	8.59
		European	-1.40	8.37	1.00	-24.07	21.27
	European	Black	-22.56	7.94	0.04	-44.07	-1.06
		White	-5.13	6.72	0.87	-23.32	13.07
		Coloured	1.40	8.37	1.00	-21.27	24.07

*- The mean difference is significant at the 0.05 level.

4.8.7 Linear regression of research parameters versus age

The relationship between the study parameters (distance, lengths, widths) of the levator scapulae muscles and the ages of the cadavers was obtained by a simple linear regression and presented through scatter plots. The linear analysis was done to determine the significant relationships between the parameters and ages.

4.8.7.1 Linear regression of the muscle distance versus age

The proximal distance gave a p-value of 0.81, the distal distance gave a p-value of 0.07, the anterior gave a p-value of 0.41 and the posterior gave a p-value of 0.81. Therefore, there was no significant relationship between the distance parameters and the ages of cadavers, as the p-values of levator scapulae muscles distances versus age were higher than 0.05. Hence, the scatter plot of the levator scapulae muscles distances versus age indicated that there was no linear regression observed as presented in Figure 4.31.

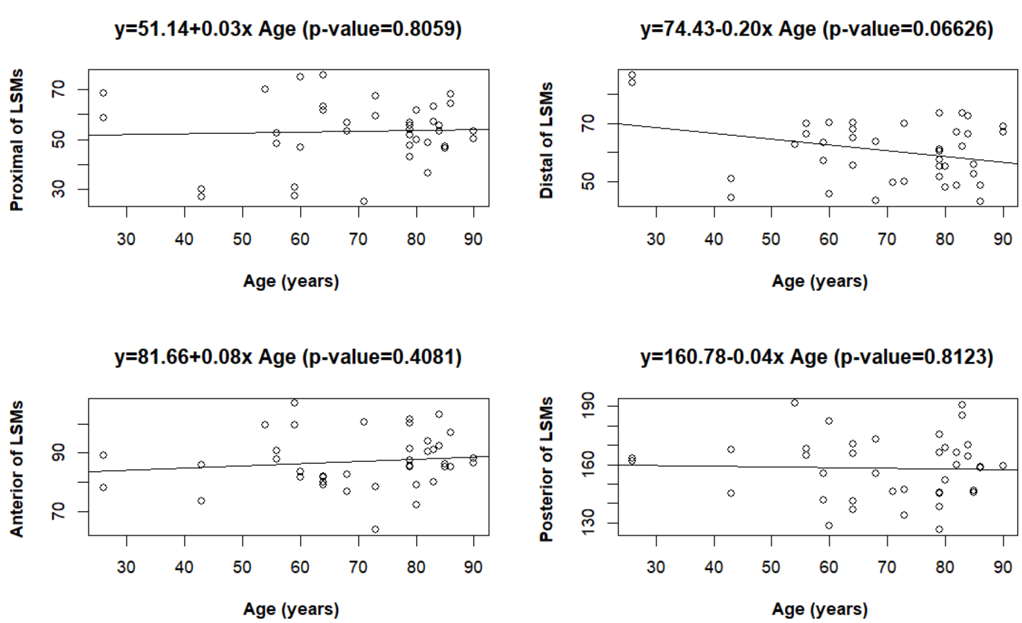

Figure 4.31: A scatter plot of levator scapulae muscle distances versus age. Key: LSM(s)-levator scapulae muscle(s)

4.8.7.2 Linear regression of the muscle slip length versus age

The relationship between the muscle slip lengths and ages of the cadavers was also analysed, which however indicated a non-linear relationship. This was also supported by the p-values obtained from the first to the fifth muscle slips, which were higher than 0.05, as presented in Figure 4.32.

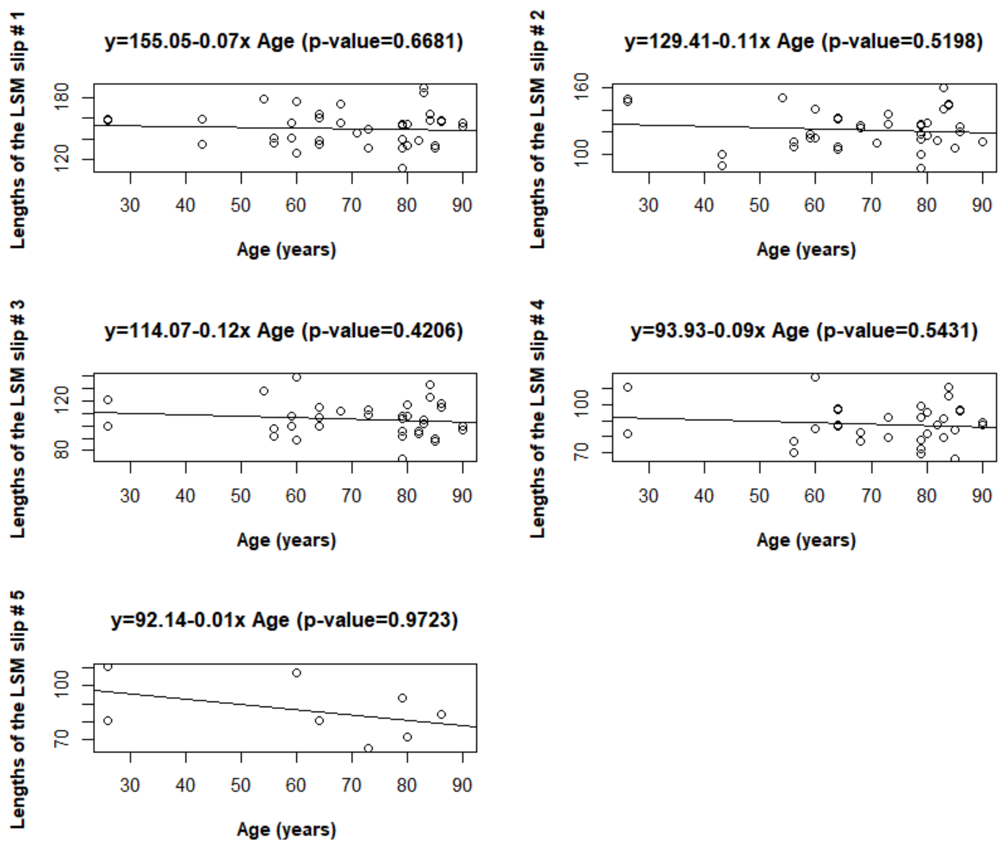

Figure 4.32: A scatter plot of levator scapulae muscle slip lengths versus age. Key: LSM(s)-levator scapulae muscle.

4.8.7.3 Linear regression of the muscle slip width versus age

The relationship between the widths and ages of cadavers was obtained and presented using scatter plots. The mathematical models were done to describe the relationship between the levator scapulae muscle slip widths and the ages of the cadavers. However, a non-linear relationship between the muscle widths and age was portrayed, as the plotted points are scattered rather than following a linear trend. The p-values were also not significant ($p > 0.05$), revealing that age does not affect the widths of the levator scapulae muscle slips (Figure 4.33).

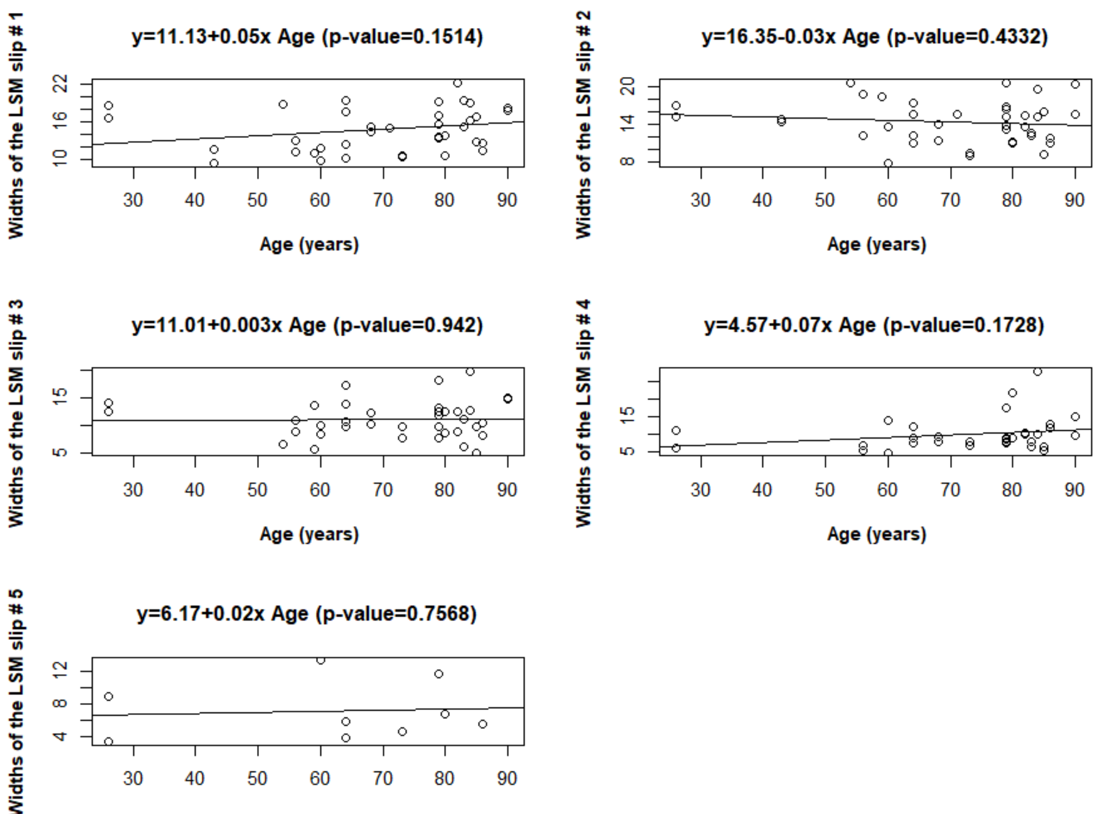

Figure 4.33: A scatter plot of levator scapulae muscle slip widths versus age. Key: LSM(s)- levator scapulae muscle

4.9 Chapter Summary

This chapter focused on the cadaveric results, which included the levator scapulae muscle slips variations, the origins, insertions, and the blood supply and nerve supply to the levator scapulae muscles. The levator scapulae muscle was observed to have two to six muscle slips, and these muscle slips can originate from the first cervical transverse process to the fifth cervical transverse process (C1-C5). In terms of distal insertions, some of the levator scapulae muscles were distally attached to the superomedial borders of the scapula only, whereas some had accessory attachments to the middle scalene as well as to the lateral aspects of the first and second ribs. The average proximal distance of the 40 levator scapulae muscles was 53.46 ± 13.22 mm, distal distance was 60.63 ± 10.78 mm, anterior distance was 87.10 ± 9.27 mm and posterior distance was 158.08 ± 15.94 mm.

In addition to the variations associated with the morphology of the levator scapulae muscle, the muscle was observed to receive blood supply from three main sources, the transverse cervical artery, a branch of the thyrocervical trunk, the dorsal scapular artery which can be a branch of the subclavian artery or a branch the transverse cervical artery and the ascending cervical artery, a branch of the thyrocervical trunk.

Equally important, a single levator scapulae muscle can be supplied by one or two arterial branches. With regards to the nerve supply, the levator scapulae muscle can be innervated by up to six branches of nerves, rooting from C2, C3/C4, and C5 respectively. Furthermore, no significant relationships were observed between the study parameters versus cadaver ages.

The next chapter will focus on the results obtained in the MRI study, which was necessary to observe the levator scapulae muscles from a different angle (axial views).

CHAPTER 5: MRI RESULTS

5.1 Introduction

The MRI study allows internal body organs to be viewed from different angles. This study focused on C2-T1 vertebral levels of the cervical MRI records done on patients at the Roman Catholic Private Hospital, therefore, only variations associated with the levator scapulae muscle within those vertebral levels were included in this study.

One hundred and sixty-seven (n= 167) MRI scans were randomly selected for this study, from a population of 293 patient MRI scans. One hundred and twenty-one scan records either had major pathologies, were unclear, or the muscle of interest (levator scapulae muscle) was partially presented or not visible in all the slides. Therefore only 46 MRI scans were subsequently suitable for the current study, made up of 24 females and 22 males. A total of 92 levator scapulae muscles were thus analysed. Out of 92 levator scapulae muscles, only 54 levator scapulae muscles had visible accessory attachments, while 38 levator scapulae muscles had no accessory attachments visible.

5.2 Frequency of levator scapulae muscle accessory attachments

Some MRI scans had bilateral levator scapulae muscle accessory attachments, whereas some had unilateral accessory attachments. Also, some levator scapulae muscles presented multiple accessory attachments, while some presented single accessory attachments. The prevailing accessory attachments of the levator scapulae muscle observed were to the serratus superior posterior muscles. The second frequent levator scapulae muscle accessory attachment observed was to the serratus anterior. The least common accessory attachments observed were to the rhomboid minor, trapezius, and splenius cervicis as presented in Figure 5.1.

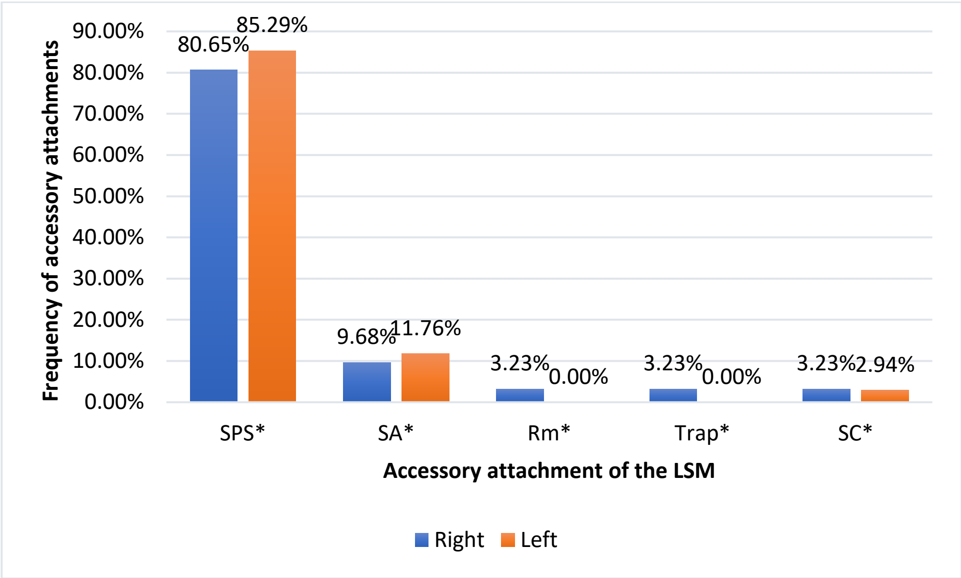

Figure 5.1: Accessory attachments of the levator scapulae muscles. Key: LSM- levator scapulae muscle, Rm*- attachment to the rhomboid minor, SA*- attachment to the serratus anterior, SC*- attachment to the splenius cervicis, SPS*- attachment to the serratus posterior superior, Trap*- attachment to the trapezius muscle.

5.3 The levator scapulae muscle accessory attachment instances

5.3.1 Accessory attachments to the serratus posterior superior only

There were various instances of levator scapulae muscle accessory attachments observed in this study. The first example of the accessory attachment visible in the MRIs was associated with the serratus posterior superior only. This instance was observed bilaterally and unilaterally in a total of forty-six (46) levator scapulae muscles. With regards to the courses of the levator scapulae muscle accessory attachments towards the serratus posterior superior, the extensions were observed routing inferiorly and medially from the medial aspect of the levator scapulae muscles, until they were attached to the serratus posterior superior muscles.

Overall, the levator scapulae muscle extensions to the serratus posterior superior started to be more visible at the level of C6, while the serratus posterior superior muscle itself began to be more visible at the C7/T1 vertebral level, as presented in Figures 5.2-5.6.

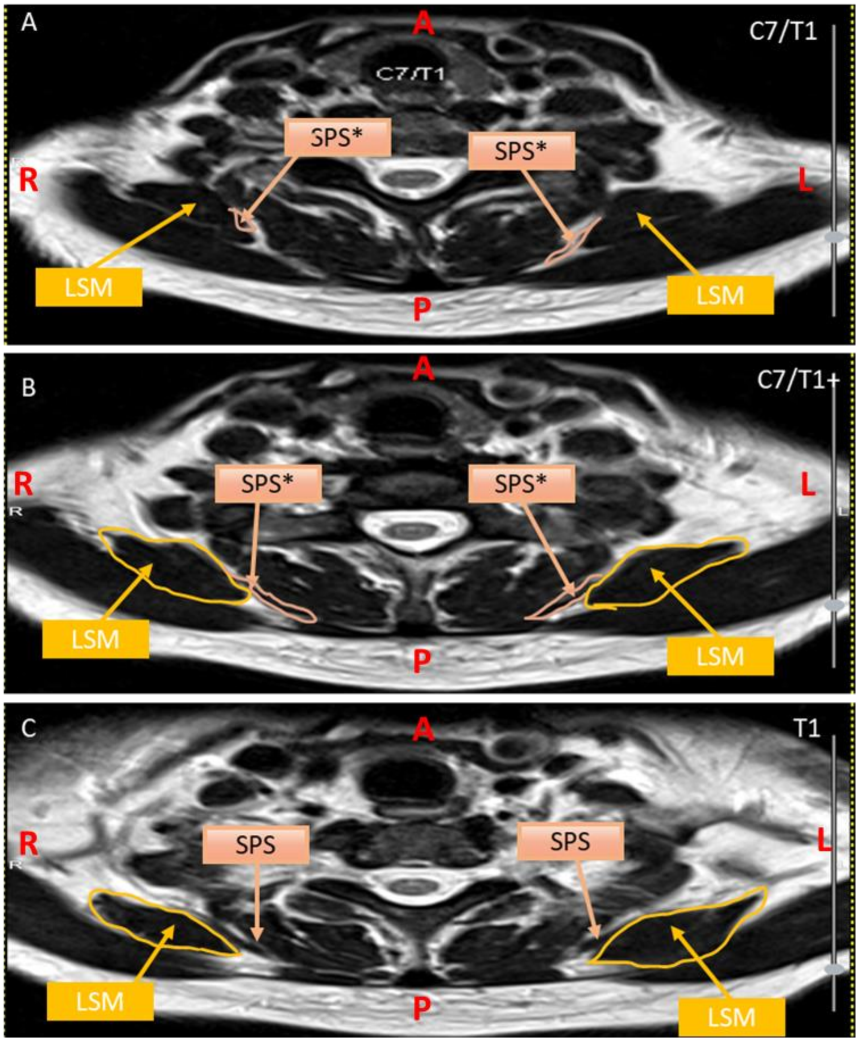

Figure 5.2: The axial cervical MRI scans with serratus posterior superior attachments of the levator scapulae muscle (A to C = Superior to inferior). The MRI scans were obtained from a 53-year-old female patient (p# 3) with bilateral accessory attachments to the serratus posterior superior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SPS*- attachment to the serratus posterior superior, SPS- serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

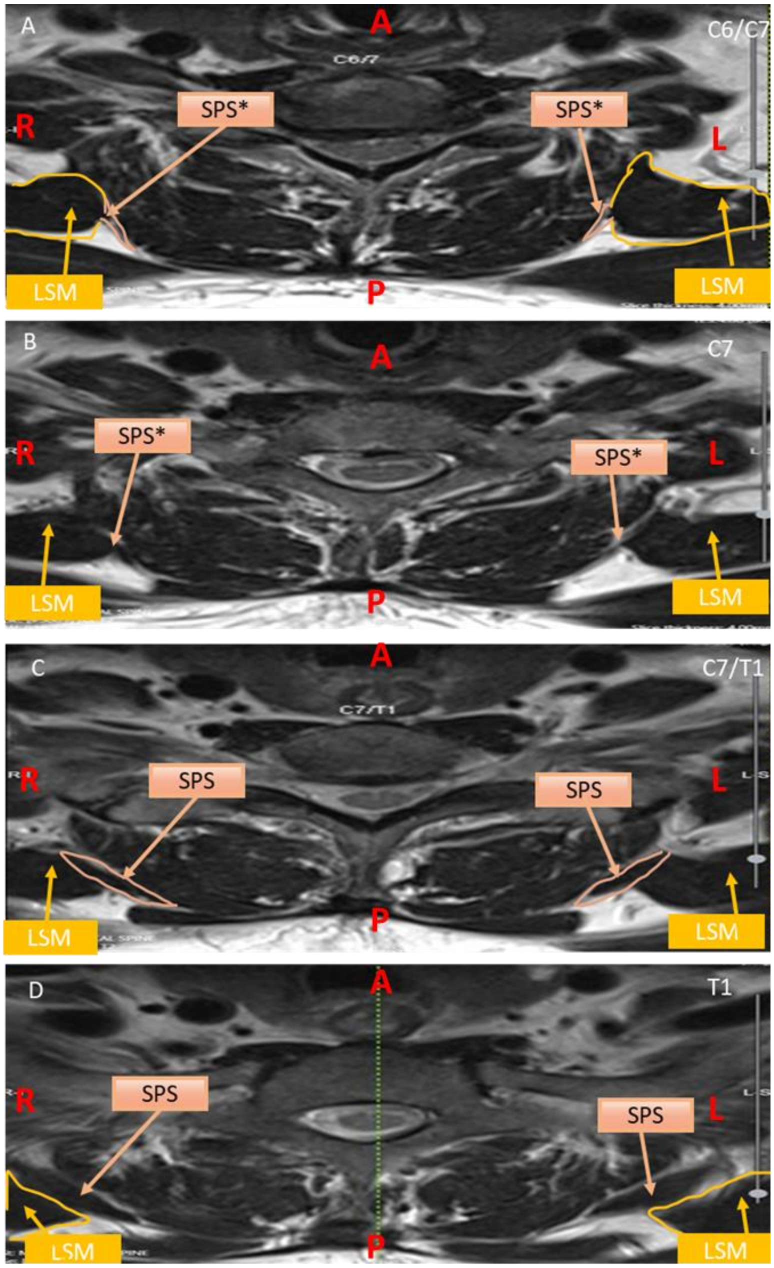

Figure 5.3: The axial cervical MRI scans with serratus posterior superior attachments of the levator scapulae muscle (A to D = superior to inferior). The MRI scans were obtained from a 62-year-old male patient (p# 17), with bilateral accessory attachments to the serratus posterior superior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SPS- serratus posterior superior, SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

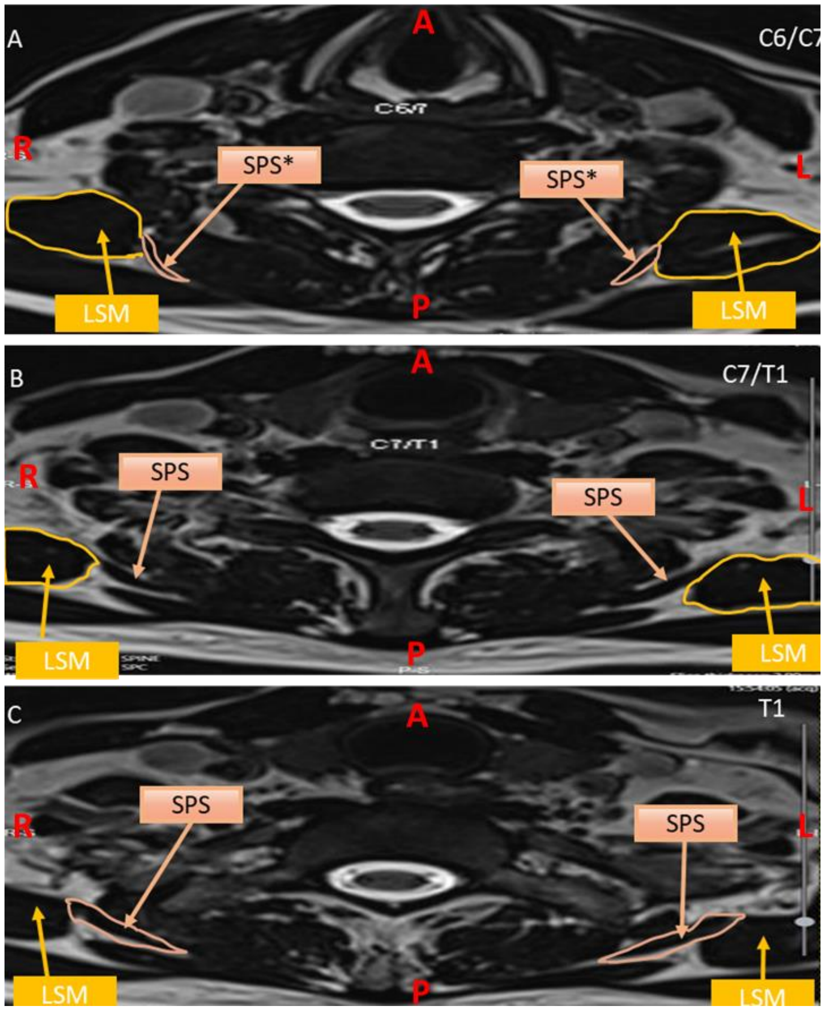

Figure 5.4: The axial cervical MRI scans with serratus posterior superior attachments of the levator scapulae muscle (A to C = superior to inferior). The MRI scans were obtained from a 58-year-old male patient (p# 8) with bilateral accessory attachments to the serratus posterior superior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SPS- serratus posterior superior, SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

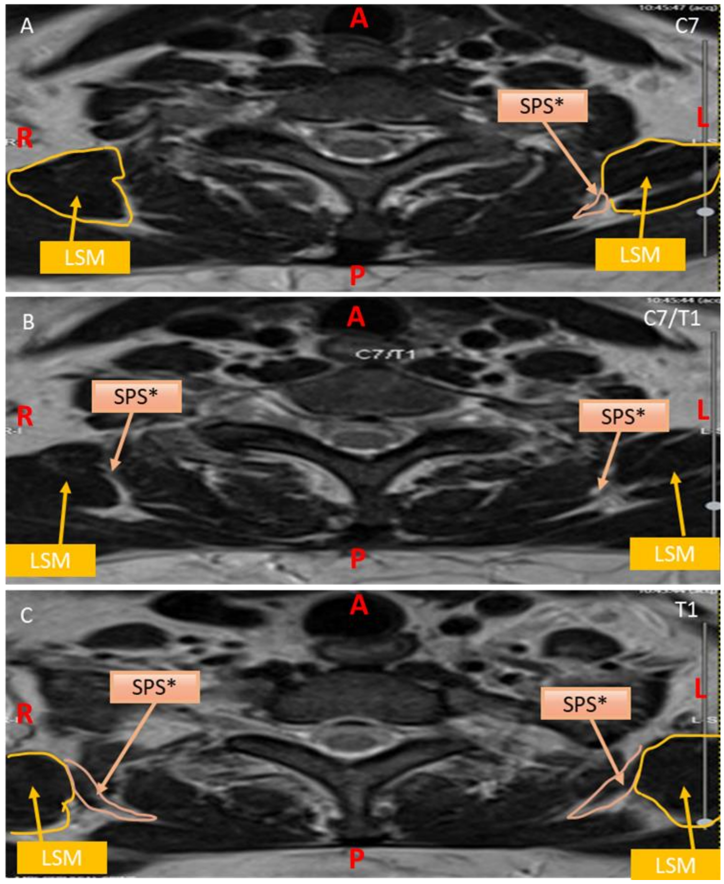

Figure 5.5: The axial cervical MRI scans with serratus posterior superior attachments of levator scapulae muscle (A to C = superior to inferior). The MRI scans were obtained from a 49-year-old female patient (p# 7) with bilateral accessory attachments to the serratus posterior superior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SPS- serratus posterior superior, SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

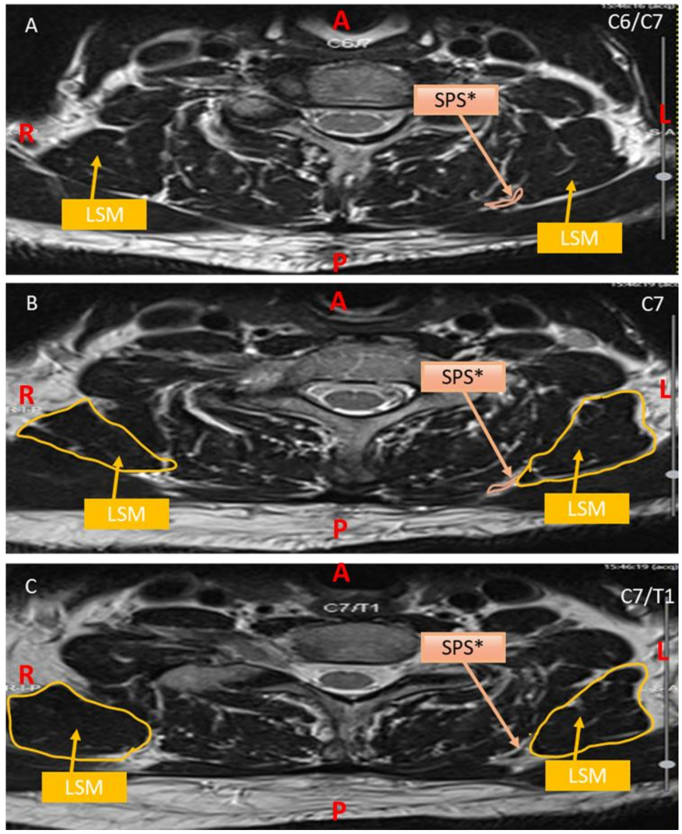

Figure 5.6: The axial cervical MRI scans with serratus posterior superior attachments of levator scapulae muscle (A to C = superior to inferior). The MRI scans were obtained from a 47-year-old male patient (p# 6), with unilateral accessory attachments to the serratus posterior superior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SPS- serratus posterior superior, SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

5.3.2 Accessory attachments to the serratus posterior superior and serratus anterior

The second instance presented the accessory attachments of the levator scapulae muscle to the serratus anterior and serratus posterior superior. This instance was observed bilaterally and unilaterally in a total of four levator scapulae muscles. The routes of the levator scapulae muscle accessory attachments towards the serratus anterior muscles extended inferiorly and laterally from the anterior aspects of the levator scapulae muscle. The levator scapulae muscle began extending to the serratus anterior at C6/7 and C7 vertebral levels, while the serratus anterior muscle became visible at C7/T1 and T1, respectively.

In addition to the accessory attachments to the serratus anterior, the accessory attachments to the serratus posterior superior were also observed in this instance, routing inferior and medially from the medial aspects of the levator scapulae muscles as presented in Figures 5.7 and 5.8.

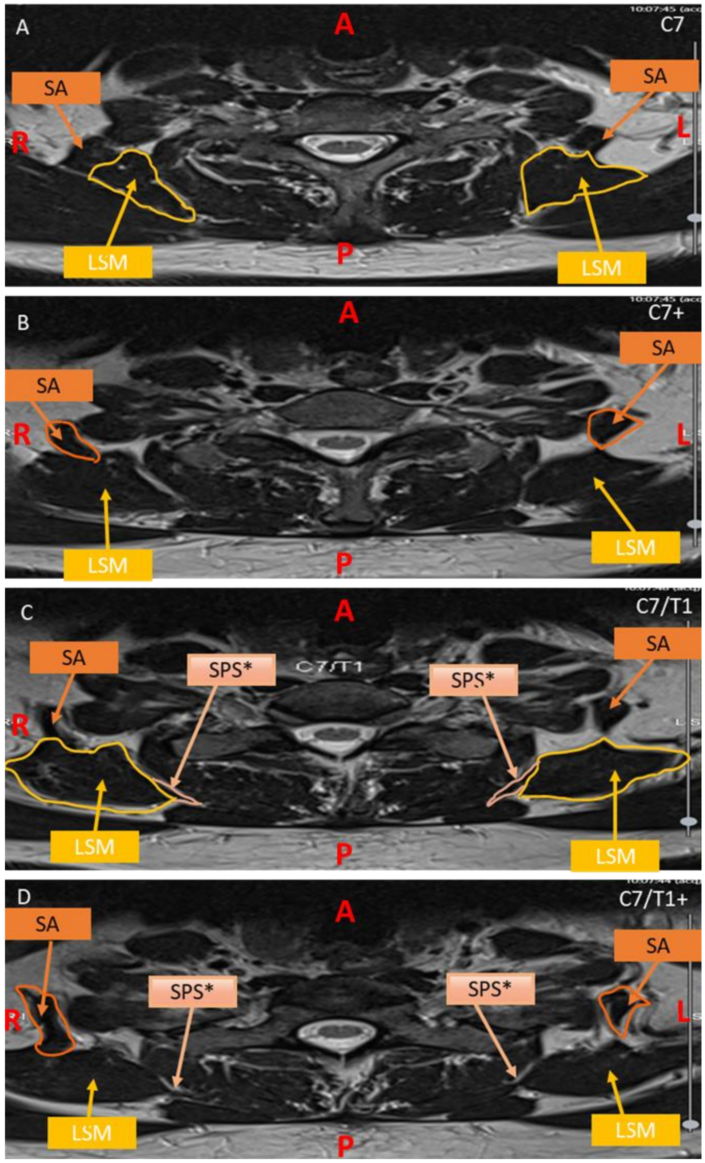

Figure 5.7: The axial cervical MRI scans with serratus posterior superior and serratus anterior attachments of levator scapulae muscle (A to D = superior to inferior). The MRI scans were obtained from a 54-year-old male patient (p# 19) with bilateral accessory attachments to the serratus posterior superior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SA- serratus anterior SA*- attachment to the serratus anterior, SPS*- attachment to the serratus posterior superior, SPS- serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

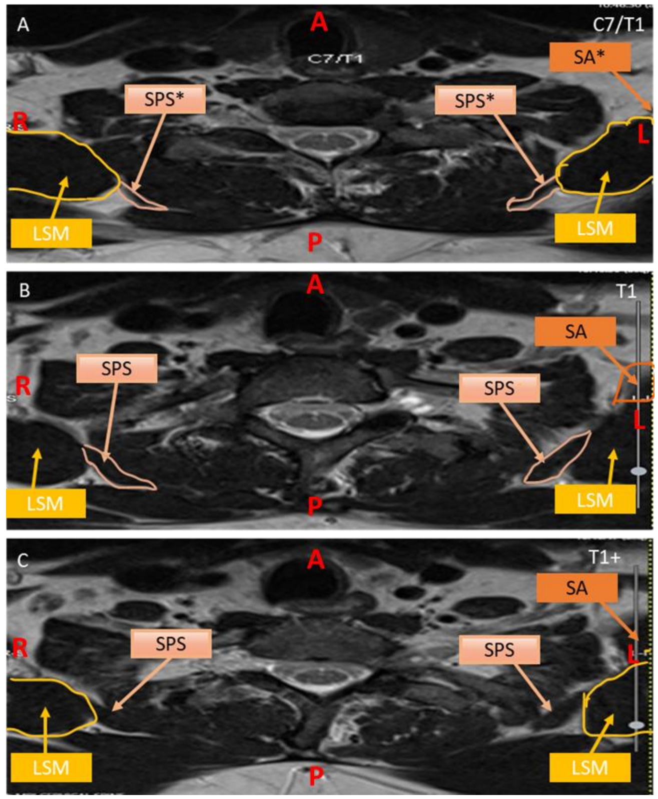

Figure 5.8: The axial cervical MRI scans with serratus posterior superior and serratus anterior attachments of levator scapulae muscle (A to C = superior to inferior). The MRI scans were obtained from a 48-year-old male patient (p# 18) with bilateral accessory attachments to the serratus posterior superior (SPS) and a unilateral accessory attachment to the serratus anterior. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SA- serratus anterior SA*- attachment to the serratus anterior, SPS- serratus posterior superior, SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

5.3.3 Accessory attachments to the serratus posterior superior, serratus anterior, and rhomboid minor

The third instance of levator scapulae muscle accessory attachments was associated with the serratus posterior superior, serratus anterior, and rhomboid minor muscles. This instance was observed in a single levator scapulae muscle. The accessory attachments to the serratus posterior superior were observed extending clearly from C6/C7 and C7/T1, from the medial aspects of the levator scapulae muscles, and coursed inferiorly and medially to the serratus posterior superior.

On the other hand, the accessory attachments to the serratus anterior were observed on C6/C7 and extended inferiorly and laterally to the serratus anterior muscles. In addition to the serratus posterior superior and serratus anterior attachments, a unilateral accessory attachment to the rhomboid minor was also observed on the right levator scapulae muscle. The rhomboid minor attachment originated from the medial aspects of the right levator scapulae muscle and extended inferiorly and medially to the rhomboid minor at C7/T1 as presented in Figure 5.9.

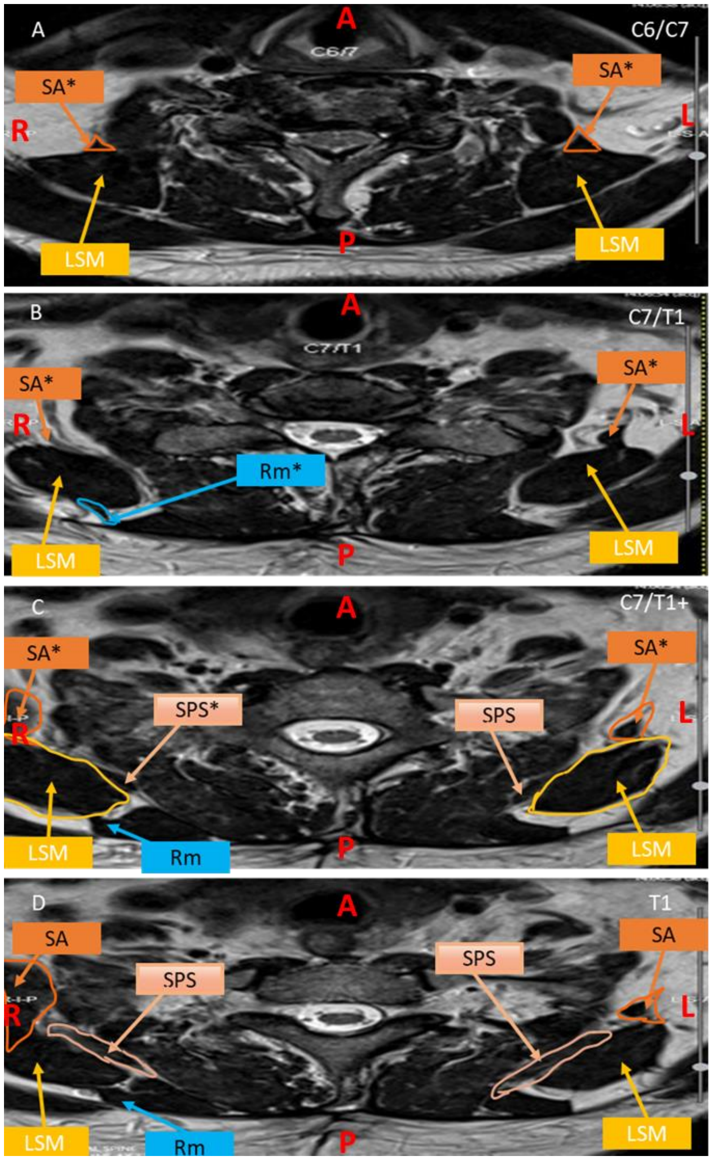

Figure 5.9: The axial cervical MRI scans with serratus posterior superior, serratus anterior, and rhomboid minor attachments of levator scapulae muscle (A to D = superior to inferior). The MRI scans were obtained from a 48-year-old male patient (p# 2) with bilateral accessory attachments to the serratus posterior superior, bilateral accessory attachment to the serratus anterior, and unilateral attachment to the rhomboid minor. Key: C- cervical vertebrae, LSM:- levator scapulae muscle, Rm*- attachment to the rhomboid minor, Rm- rhomboid minor, SA: serratus anterior SA*: attachment to the serratus anterior, SPS- serratus posterior superior, SPS*-

attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

5.3.4 Accessory attachments to the serratus posterior superior, and trapezius

The fourth instance was the attachments of the levator scapulae muscle to the serratus posterior superior and the trapezius muscles. The accessory attachment to the serratus posterior superior was observed extending clearly from C6/C7, from the medial aspects of the levator scapulae muscles, and coursed inferiorly and medially to the serratus posterior superior muscle. The unilateral accessory attachment to the trapezius muscle was observed arising from the lateral aspect of the levator scapulae muscle at the C6/C7 vertebral level and extended laterally to the right trapezius muscle as presented in Figure 5.10.

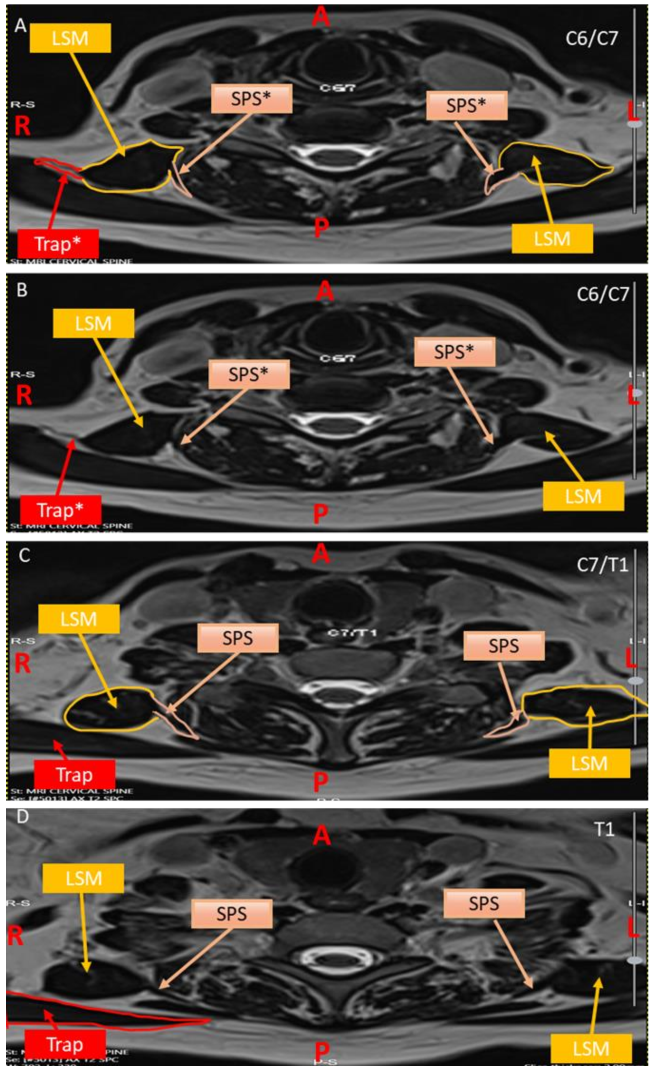

Figure 5.10: The axial cervical MRI scans with serratus posterior superior and trapezius attachments of levator scapulae muscle (A to D = superior to inferior). The MRI scans were obtained from a 52-year-old female patient (p# 4) with bilateral accessory attachments to the serratus posterior superior, and unilateral attachment to the trapezius muscle. Key: C- cervical vertebrae, LSM- levator scapulae muscle, Trap*- attachment to the trapezius muscle, Trap- trapezius muscle, SPS- serratus posterior superior, SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

5.3.5 Accessory attachments to the serratus posterior superior, serratus anterior, and splenius cervicis

The fifth example of levator scapulae muscle accessory attachment was related to the serratus posterior superior, serratus anterior, and splenius cervicis muscles. This instance was observed bilaterally, in a total of two levator scapulae muscles. The accessory attachments to the serratus posterior superior were observed extending clearly from C6/C7 and C7/T1, from the medial aspects of the levator scapulae muscles, and coursed inferiorly and medially to the serratus posterior superior, the accessory attachment to the serratus anterior were observed on C6/C7 and extended inferior and laterally to the serratus anterior muscles, while the attachment to the splenius cervicis was observed arising from the medial aspect of the levator scapulae muscle at the level of C4, but more clearly from the level of C6 and extended inferior-wards to the splenius cervicis at the level of C7/T1, which presented a well-defined attachment of the levator scapulae muscle to the SC as presented in Figure 5.11.

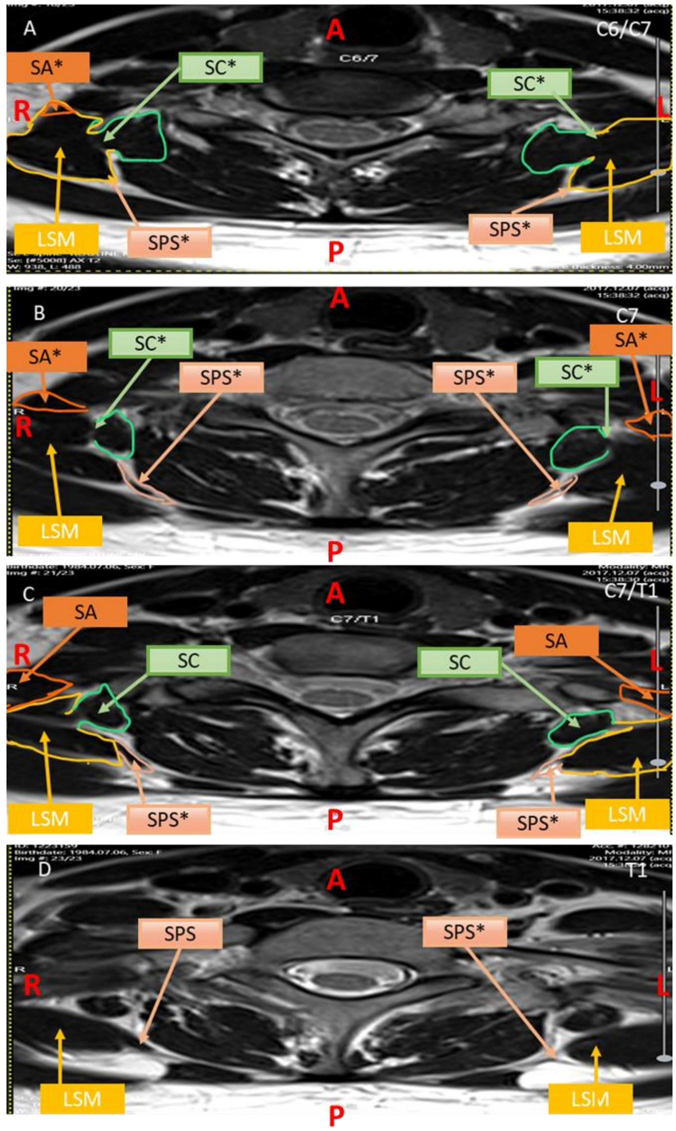

Figure 5.11: The axial cervical MRI scans with serratus posterior superior, serratus anterior, and splenius cervicis attachments of levator scapulae muscle (A to D = superior to inferior). The MRI scans were obtained from a 33-year-old female patient (p# 5) with bilateral accessory attachments to the serratus posterior superior, bilateral accessory attachment to the serratus anterior, and bilateral attachments to the splenius cervicis. Key: C- cervical vertebrae, LSM- levator scapulae muscle, SA- serratus anterior, SA*- attachment to the serratus anterior, SC*- attachment to the splenius cervicis, SC- splenius cervicis, SPS- serratus posterior superior,

SPS*- attachment to the serratus posterior superior, T- thoracic vertebrae. Orientation in red: A- anterior, L- left, P- posterior, R- right.

5.4 Chapter Summary

In the MRI study, the levator scapulae muscle was observed to have accessory attachments to the serratus posterior superior, serratus anterior, rhomboid minor, trapezius, and splenius cervicis. Findings from the current MRI study demonstrate that the levator scapulae muscle was mostly attached to the serratus posterior superior, followed by the attachment to the serratus anterior, and rarely attached to the rhomboid minor, trapezius, and splenius cervicis (Table 5.1). Equally important, there were instances of the levator scapulae muscles with single to multiple accessory attachments. However, due to the quality and focus of some MRI scans, the current study could only report on clear levator scapulae muscle attachments. The next chapter will focus on the discussion of the results obtained in this study and will also consider the existing body of knowledge related to the levator scapulae muscle.

Table 5.1: MRI result summary

MRI numbers	Age /Sex	SPS	SA	Rm	Trap	SC
1	48/F	L	-			
2	48/M	L & R	L & R	R		
3	53/F	L & R	-			
4	52/F	L & R	-		R	
5	33/F	L & R	L & R			L & R
6	47/M	L	-			
7	49/F	L & R	-			
8	58/M	L & R	-			
9	64/M	-	-			
10	51/M	R	-			
11	48/F	L	-			
12	36/F	-	-			
13	43/F	-	-			
14	50/F	L & R	-			
15	18/M	L & R	-			
16	47/M	L & R	-			
17	62/M	L & R	-			
18	48/M	L & R	L			
19	54/M	L & R	L & R			
20	46/F	L & R	-			
21	69/F	L & R	-			
22	42/F	L	-			
23	49/M	-	-			
24	54/F	L & R	-			
25	53/M	-	-			
26	56/F	-	-			
27	58/M	L & R	-			
28	64/M	L & R	-			
29	55/F	-	-			
30	52/F	L & R	-			
31	40/M	L & R	-			
32	47/F	-	-			
33	38/F	-	-			
34	57/F	-	-			
35	57/M	L	-			
36	61/F	R	-			
37	45/M	-	-			
38	55/F	L & R	-			
39	56/F	-	-			
40	40/M	L & R	-			
41	50/F	L & R	-			
42	32/M	-	-			
43	57/M	L	-			
44	36/M	L & R	-			
45	53/F	-	-			
46	52/M	-	-			

Key: F: female, L: left, M: male R: right, Rm: rhomboid minor, SA: serratus anterior, SPS: serratus posterior superior, SC: splenius cervicis, Trap: trapezius.

CHAPTER 6: DISCUSSION

6.1 Introduction

This chapter discussed and interpreted the study findings based on the following study objectives:

1. To examine the existence of the levator scapulae muscles attachment variations, both proximal and distal attachments.
2. To characterise the typology and locality of variations of the levator scapulae muscles
3. To explore the frequency of the muscle slips and attachment variations
4. To explore the frequency of neurovasculature and associated variations
5. To critically appraise the clinical significance of these variations

The highlights of this section include the levator scapulae muscle slips variations, proximal and distal attachments of the levator scapulae muscle, blood supply to the levator scapulae muscle, and nerve supply to the levator scapulae muscle. It also includes the statistical analysis of the measurements of the cadaveric study, followed by the accessory attachments observed and how this relates to the levator scapulae muscle in the MRI study. Moreover, the comparisons of this study's findings to other studies, the significance of the study findings, and the limitations of both cadaveric and MRI studies are included in the chapter.

6.2 The cadaveric study

The cadaveric study focused on the variations associated with the levator scapulae muscles in terms of the number of muscle slips, and its proximal, and distal attachments. Frequently, the levator scapulae muscle is described as having three to five slips (Chotai et al., 2015; Smit & Todd, 2019). The levator scapulae muscles were measured to determine the distances, muscle slip lengths, and muscle slip widths. The measurements were analysed for consistency, efficiency, as well as for correlations. The blood and nerve supply to the levator scapulae muscles were also traced.

This study was based on the available cadavers at the School of Medicine (UNAM) at the time of the research project, and the cadaveric materials were managed following the Anatomical Donations and Post-mortem Ordinance, No. 12 of 1977 (Namibia), however, the cadavers' personal information were kept confidential.

6.2.1 The levator scapulae muscle slip variations and measurements

6.2.1.1 The levator scapulae muscles with four muscle slips

In the current study, 62.50% of the levator scapulae muscles had four muscle slips (Figure 4.1). Most of these muscles were well-defined (Figure 4.6), while few had accessory slips (Figures 4.11, 4.12, 4.13 and 4.15). In addition, 65.00% of the right levator scapulae muscles had four muscle slips, while 60.00% of the left levator scapulae muscles had four muscle slips (Figure 4.2).

These muscle slips were proximally attached to the first four cervical vertebrae (C1-C4), with a proximal distance ranging from 36.35 mm to 64.38 mm. The average proximal distance was 53.17 ± 6.63 mm, which is an approximate distance between C1 and C4 (Table 4.5). In comparison with the available literature, Naik and Lokanadham (2019) obtained proximal distances ranging from 33.70 mm to 54.80 mm, with an average of 47.00 ± 6.30 mm, whereas Smit and Todd (2019) obtained proximal distances ranging from 35.70 mm to 56.80 mm, with an average of 49.00 ± 6.30 mm.

The distal distance of the four muscle-slipped ranged from 43.42 mm to 73.70 mm, the mean distal distance was 60.33 ± 9.06 mm (Table 4.6), which is an approximate insertion distance of the levator scapulae muscle to the superomedial borders of the scapula. In comparison to the distal distances obtained by the available literature, Naik and Lokanadham (2019) obtained distal distances ranging from 33.60 mm to 55.90 mm, with an average of 48.50 ± 5.40 mm, whereas Smit and Todd (2019) obtained distal distances ranging from 36.60 mm to 57.90 mm, with an average of 46.50 ± 5.40 mm. Hence, the current study obtained a slightly high average distal distance.

The anterior distances of these muscles ranged from 72.18 mm to 103.19 mm, with an average of 87.15 ± 7.32 mm (Table 4.7), which is an approximate distance between C4 and the borders of the scapula. However, no literature was found with anterior distance measurements of the levator scapulae muscles.

Moreover, the posterior distance of four muscle slipped levator scapulae muscles ranged from 126.33 mm to 190.47 mm, with an average of 159.36 ± 15.60 mm (Table 4.8), which is an approximate distance between C1 and the scapula. In comparison to the distal distances obtained by the available literature, Naik and Lokanadham (2019) obtained posterior distances ranging from 93.70 mm to 133.50 mm, with an average of 103.30 ± 8.90 mm, whereas Smit and Todd (2019) obtained posterior distances ranging from 98.70 mm to 135.50 mm, with an average of 109.30 ± 8.90 mm. Thus, the current study obtained a higher average posterior distance.

6.2.1.2 The levator scapulae muscles with five muscle slips

In addition to the commonly encountered levator scapulae muscle with four muscle slips, the second dominant variation had five muscle slips. Overall, 17.50% of the total levator scapulae muscles had five muscle slips (Figure 4.1). Regarding the laterality, 20.00% of the total right levator scapulae muscles had five muscle slips, whereas 15.00% of the total left levator scapulae muscles had five muscle slips (Figure 4.2). Six of the levator scapulae muscles had five well-defined muscle slips attached to C1 -C5 (Figure 4.7), while one had three accessory muscle slips that shared proximal attachments on C3, C4 and C5 (Figure 4.14).

The levator scapulae muscle had proximal distances ranging from 47.41 mm to 75.89 mm, with an average of 64.99 ± 10.10 mm (Tables 4.5 and 6.1). This is an approximate distance between C1 and C5, in levator scapulae muscles with five muscle slips. In comparison to the available literature, Naik and Lokanadham (2019) obtained proximal distances ranging from 45.30 mm to 66.30 mm, with an average of 55.90 ± 6.10 mm, whereas Smit and Todd (2019) obtained 46.30 mm to 68.30 mm, with an average of 56.90 ± 6.10 mm.

The distal distance measurements ranged from 43.03 mm to 86.79 mm, with an average of 60.96 ± 15.38 mm (Table 4.6 and 6.1). In comparison to the available literature, Naik and Lokanadham (2019) obtained distal distances ranging from 32.30 mm to 51.40 mm, with an average of 47.30 ± 5.90 mm, whereas Smit and Todd (2019) obtained 35.30 mm to 53.40 mm, with an average of 45.30 ± 5.90 mm.

The anterior distance measurements ranged from 63.61 mm to 100.28 mm, with an average of 81.15 ± 10.84 mm (Table 4.7 and 6.1). This is an approximate anterior distance of the levator scapulae muscles with five muscle slips, from C5 to the superomedial border of the scapula. The anterior distance measurements were excluded in Naik and Lokanadham (2019), and Smit and Todd (2019) studies.

The posterior distance measurements ranged from 133.91 mm to 168.72 mm, with an average of 149.43 ± 13.48 mm (Table 4.8 and 6.1). This is an approximate distance between C1 and the superomedial borders of the scapulae in levator scapulae muscles with five muscle slips. In comparison to the available literature, Naik and Lokanadham (2019) obtained posterior distances ranging from 92.50 mm to 128.70 mm, with an average of 104.40 ± 11.10 mm, whereas Smit and Todd (2019) obtained 94.50 mm to 128.70 mm, with an average of 105.40 ± 11.10 mm.

6.2.1.3 The levator scapulae muscles with three muscle slips

From the total number of the levator scapulae muscles used (40), 7.50% of the muscles had three muscle slips (Figure 4.1). The proximal distances of these muscle slips ranged from 27.25 mm to 70.05 mm, with an average of 42.71 ± 23.75 mm (Table 4.5). This is an approximate distance between C1 and C5, in levator scapulae muscles with five muscle slips. In comparison to the available literature, Naik and Lokanadham (2019) obtained proximal distances ranging from 30.20 mm to 43.00 mm, with an average of 35.60 ± 5.60 mm, whereas Smit and Todd (2019) obtained 30.80 mm to 44.00 mm, with an average of 37.60 ± 5.60 mm.

The distal distance measurements ranged from 57.26 mm to 63.25 mm, with an average of 61.12 ± 3.35 mm (Table 4.6 and 6.1). In comparison to the available literature, Naik and Lokanadham (2019) obtained distal distances ranging from 31.40 mm to 42.80 mm, with an average of 42.40 ± 3.40 mm, whereas Smit and Todd (2019) obtained 34.40 mm to 44.80 mm, with an average of 40.40 ± 3.40 mm. The anterior distance measurements ranged from 99.42 mm to 106.98 mm, with an average of 102.00 ± 4.31 mm (Table 4.7 and 6.1).

The posterior distance measurements ranged from 141.80 mm to 191.54 mm, with an average of 162.99 ± 25.67 mm (Table 4.8 and 6.1). In comparison to the available literature, Naik and Lokanadham (2019) obtained posterior distances ranging from 91.70 mm to 132.90 mm, with an average of 112.60 ± 16.40 mm, whereas Smit and Todd (2019) obtained 92.70 mm to 138.90 mm, with an average of 118.60 ± 16.40 mm.

Overall, the difference in proximal distances and anterior distances could be due to the nature of muscle slip attachments. In some instances, the muscle slips originated from C1 and C2 (Figure 4.5), whereas some originated from C1, C2 and C4 (Figure 4.10). In the first instance, the lower two muscle slips (second and third slip) were proximally attached to C2 with 27.25 mm while in the second instance, the lower muscle slip (third slip) was proximally attached to C4, with 70.05 mm (Table 6.1). This practically made the levator scapulae muscle in Figure 4.5 have a longer anterior distance of 106.98 mm than the levator scapulae muscle in Figure 4.10 with 99.42 mm (Table 6.1).

6.2.1.4 The levator scapulae muscles with two muscle slips

Similar to the frequency of the three muscle lips, another 7.50% of the total levator scapulae had two muscle slips (Figure 4.1), which was the lowest number of muscle slips observed in this study. These muscle slips were proximally attached to C1 and C2 and inserted onto the superomedial border of the scapula. The proximal distances of the two-slipped levator scapulae muscle ranged from 25.14 mm to 30.13 mm, with an average of 27.43 ± 2.52 mm (Table 4.5 and 6.1), which is an approximate average distance between C1 and C2.

The distal distances of the two-slipped levator scapulae muscle ranged from 44.45 mm to 51.02 mm, with an average of 48.35 ± 3.45 mm. The anterior distances of the two-slipped levator scapulae muscle ranged from 72.37 mm to 100.68 mm, with an average of 86.70 ± 13.67 mm. The posterior distances of the two-slipped levator scapulae muscle ranged from 145.23 mm to 167.85 mm, with an average of 152.99 ± 12.87 mm (Table 4.8 and 6.1).

However, the measurements of the levator scapulae muscles with two muscle slips were not presented in the available literature. The levator scapulae with few muscle slips could be associated with weak necks and, hence, could result in tilted heads.

6.2.1.5 The levator scapulae muscles with six muscle slips

Another instance was observed in two levator scapulae muscles, with six muscle slips (5.00%) and both of these muscles originated from C1-C5 (Figure 4.1), whereby in the first instance of variation, the fifth and the sixth muscle slips had the same proximal attachments (C5) (Figure 4.8), while in the second instance, both the second and third muscle slips originated from C2 (Figure 4.9). The proximal distance of the six muscle-slipped ranged from 68.55 mm to 75.18 mm, with an average of 71.87 ± 4.69 mm (Table 6.1), which is an approximate distance between C1 and C5. In comparison to the available literature, both Naik and Lokanadham (2019) and Smit and Todd (2019) had a proximal distance of 79.20 mm, which is an approximate distance between C1 and C6.

The distal distance ranged from 70.40 mm to 83.98 mm, with an average of 79.19 ± 9.60 mm (Table 4.4), while both Naik and Lokanadham (2019), and Smit and Todd (2019) had a distal distance of 41.30 mm. The anterior distance ranged from 81.78 mm to 89.19 mm, with an average of 85.49 ± 5.24 mm (Table 6.1), while Both Naik and Lokanadham (2019), and Smit and Todd (2019) excluded the anterior distance.

The posterior distance of the current study ranged from 163.04 mm to 182.41 mm, with an average of 172.73 ± 4.69 mm (Table 6.1), while, both Naik and Lokanadham (2019) and Smit and Todd (2019) had a posterior distance of 131.40 mm. In addition, six muscle-slipped levator scapulae muscles are generally broad, hence this could be associated with stronger muscle contractions.

Table 6.1: Comparison of the study parameters to the available literature

Muscle slips categories	**Current study**	**Smit and Todd (2019)**	**Naik and Lokanadham (2019)**
	Proximal distance (mm)		
2	27.43 ± 2.52	-	-
3	42.71 ± 23.75	37.60 ± 5.60	35.60 ± 5.60
4	53.17 ± 6.63	49.00 ± 6.30	47.00 ± 6.30
5	64.99 ± 10.10	56.90 ± 6.10	55.90 ± 6.10
6	71.87 ± 4.69	79.20	79.20
	Distal distance (mm)		
2	48.35 ± 3.45	-	-
3	61.12 ± 3.35	40.40 ± 3.40	42.40 ± 3.40
4	60.63 ± 9.06	46.50 ± 5.40	48.50 ± 5.40
5	60.96 ± 15.38	45.30 ± 5.90	47.30 ± 5.90
6	79.19 ± 9.60	41.30	41.30
	Anterior distance (mm)		
2	86.70 ± 13.67	-	-
3	102.00 ± 4.31	-	-
4	87.15 ± 7.32	-	-
5	81.15 ± 10.84	-	-
6	85.49 ± 5.24	-	-
	Posterior distance (mm)		
2	152.99 ± 12.87	-	-
3	162.99 ± 25.67	118.60 ± 16.40	112.60 ± 16.40
4	159.36 ± 15.60	109.30 ± 8.90	103.30 ± 8.90
5	149.43 ± 13.48	105.40 ± 11.10	104.40 ± 11.10
6	172.73 ± 13.70	131.40	131.40

6.2.1.6 The comparison of muscle slip variations to available literature

The current study confirmed variations of the levator scapulae muscle with three, four and five as reported by Naik and Lokanadham (2019), and Smit and Todd (2019). The levator scapulae muscles with four muscle slips highly dominated in the current study with 62.50%, in Smit and Todd (2019) with 60.87%, while in Naik and Lokanadham (2019) it dominated with 59.37% (Figure 4.1 and Table 6.2).

The second dominant variation in levator scapulae muscles had five muscle slips, in the current study it dominated with 17.50%, in the Smit and Todd (2019) study with 21.74%, while in the Naik and Lokanadham (2019) study it dominated with 21.87%. The third dominant variation associated with the levator scapulae muscle had three muscle slips, in the current study it dominated with 7.50%, in Smit and Todd (2019) study with 15.22%, while in Naik and Lokanadham (2019) study it dominated with 15.62%, respectively (Figure 4.1 and Table 6.2).

Table 6.2: Frequency of the levator scapulae muscle categories

	Current study		**Smit and Todd (2019)**		**Naik and Lokanadham (2019)**	
Muscle slips categories	**Number of LSM**	**%**	**Number of LSM**	**%**	**Number of LSM**	**%**
2	3	7.50	-	-	-	-
3	3	7.50	7	15.22	5	15.62
4	23	62.50	28	60.87	19	59.37
5	8	17.00	10	21.74	7	21.87
6	2	5.00	1	2.17	1	3.25

The current study observed the muscle with four well-defined muscle slips proximally attached to C1-C4 (Figure 4.6), agreeing with Naik and Lokanadham (2019), and Smit and Todd (2019). The five well-defined muscle slips observed in the current study were proximally attached to C1-C5 (Figure 4.7), agreeing with Naik and Lokanadham (2019), and Smit and Todd (2019. The current study also observed two instances of levator scapulae muscle with six muscle slips (Figures 4.8 and 4.9), confirming the single cases observed by Naik and Lokanadham (2019), and Smit and Todd (2019) with six muscle slips.

Other confirmations were the proximal attachments of the levator scapulae muscle to the transverse cervical processes of C1-C5, and the distal attachment onto the superomedial border of the scapula (Figure 4.7), as noted by Naik and Lokanadham (2019), and Smit and Todd (2019) amongst others. The accessory attachments to the scalene muscle (middle scalene) (Figure 4.13) and the first two ribs (Figure 4.11 and 4.12) were observed, agreed with (Au et al., 2016; Chotai et al., 2015; Loukas et al., 2006; Naik & Lokanadham, 2019).

Naik and Lokanadham (2019), and Smit and Todd (2019) stated that the levator scapulae muscles with three muscle slips were proximally attached to C1-C3, while the current study the three muscle slips were either proximally attached to C1 and C2, or C1, C2 and C4 (Figure 4.5 and 4.10). Moreover, the current study observed two levator scapulae muscles with six muscle slips proximally attached to C1-C5 (Figures 4.8 and 4.9), while Naik and Lokanadham (2019) and Smit and Todd (2019) observed one levator scapulae muscle with C1-C6 proximal attachments. Equally important, the current study observed two levator scapulae muscles with two muscle slips (Figure 4.4).

The current study did not observe the levator scapulae muscle's accessory attachment to the mastoid process as observed by Chotai et al. (2015), and Fakoya et al. (2020), the muscle slip extensions to the occipital bone, spinous process of the thoracic vertebrae, clavicle, temporal bone and ligamentum nuchae as stated in previous studies (Chotai et al., 2015; Loukas et al., 2006; Naik & Lokanadham, 2019).

6.2.2 The average distances of the levator scapulae muscle

6.2.2.1 Proximal distances

The proximal distance of the levator scapulae presented the distance between the superior transverse cervical process attached (C1) and the inferior transverse cervical process attached by the muscle slips. The common proximal attachments of the levator scapulae muscle slips could generally enhance the strength of the muscle during neck flexions and could support the posture of the cervical vertebral column. The proximal distance measurements are clinically significant as they present the actual length of between C1 and C5. This makes it easier to trace the anterolateral contents of the neck associated with C1 -C5.

6.2.2.2 Distal distances

The distal distance presented the attachments of the levator scapulae muscle on the superomedial borders of the scapula. Overall, the average distal distance ranged between 43.03 mm and 86.79 mm (Table 4.9). This is however significant as it approximates the distal attachment of the levator scapulae muscle to the scapula. In addition, the distal distances were not directly proportional to the number of muscle slips. The distal distances were determined by the nature of muscle fiber extension to the borders of the scapula.

6.2.2.3 Anterior distances

The anterior distances presented the distance between the lower transverse cervical process attached by the muscle slips and the superomedial borders of the scapula. Among the levator scapulae muscle categories, the total average anterior distances ranged from 63.61 mm to 106.98 mm respectively (Table 4.9).

The anterior distance measurements were important, in determining the correlations in anterior distances among muscles from different muscle slip categories. Hence, the gap in anterior distances could be due to the differences in individual cadavers' neck lengths, the point of lower (most inferior) muscle slip attachments on the transverse process, and the muscle fibre attachments to the scapula. The differences could also be due to differences in thoracic cavity broadness, the broader the thorax, the longer the anterior distance.

6.2.2.4 Posterior distances

The posterior distance presents the posterior edges of the levator scapulae muscles, which represent the approximate distance from the first transverse cervical process (C1) to its distal attachment on the scapula. The average posterior distance obtained ranged from 126.33 mm to 191.54 mm (Table 4.9). Hence, the longest among other distances measured. This also explains why the first muscle slips were relatively longer because of the distance between the first cervical process (C1) and the scapula.

6.2.2.5 Muscle slip lengths

The lengths of the muscle slips were taken from the middle aspect of individual slips. The superior muscle slips had a higher average length than the inferior muscle slips. The overall muscle length ranged from 81.23 mm to 176.79 mm (Table 4.11). The length measurements are significant, as they represent the distance between the proximal attachments of each muscle slip and their distal attachments. These measurements could also help determine new attachment sites during levator scapulae muscle slip transfer to assist the functionality of other muscles.

6.2.2.6 Muscle slip widths

The muscle slip widths were taken at the widest point. Not all muscle widths were directly proportional to the order of muscle slips (superior slips to inferior slips). In some instances, the superior muscle slips were wider than the inferior muscle slips. Nevertheless, the overall widths ranged between 3.45 mm and 28.03 mm (Table 4.13).

On the other hand, some inferior muscle slips were wider than the superior muscle slips. For instance, in levator scapulae with two muscle slips (Figure 4.4), the first muscle slip was smaller (11.87 ± 2.86 mm) than the second muscle slip (14.95 ± 0.67 mm) (Table 4.12). Overall, the most superior muscle slips were wide, hence giving the muscle the overall strength to elevate the scapula, lateral flex, and rotate the neck. In addition, the muscle slips of the levator scapulae muscles naturally overlap, hence, the muscle slip widths do not entirely determine the broadness of the levator scapulae muscles.

6.2.2.7 The comparison of muscle parameters obtained to available literature

The current study obtained high posterior distance values compared to other muscle distances measured, similar to the posterior measurements by Naik and Lokanadham (2019), and Smit and Todd (2019).

Overall, this study obtained higher measurement values in comparison to Naik and Lokanadham (2019), and Smit and Todd (2019) due to the measurement method used. Smit and Todd only used a Vernier dial calliper, while the current study used a morphometric geometric method and a digital Vernier calliper (Figure 3.6), thus accommodating the curvatures of the levator scapulae muscle. The current study obtained an average posterior distance of the levator scapulae muscles with four muscle slips of 159.36 ± 15.60 mm, in Smit and Todd (2019) it was 109.30 ± 8.90 mm, while in Naik and Lokanadham (2019) it was 103.30 ± 8.90 mm (Table 6.1).

A huge difference was observed in posterior distances, the current study obtained the highest posterior distance average of 172.73 ± 13.70 mm (Table 6.1), from a category with six muscle slips, while Naik and Lokanadham (2019), and Smit and Todd (2019) obtained 112.60 ± 16.40 and 118.60 ± 16.40 mm, both obtained from a category of three muscle slips.

Unlike Naik and Lokanadham (2019), and Smit and Todd (2019), whose study included posterior, distal, and proximal lengths, the current study pronounced these as distances with an additional anterior distance. The current study also included the lengths and widths of individual levator scapulae muscle slips. However, it showed that the lengths and widths were not dependent on cadavers' age as the study was done on the adult cadaver population, thus, disagreeing with the foetal study by Beger et al. (2018), which demonstrated a relationship between the length versus age and widths versus age, which could be due to an active developmental stage.

6.2.3 The blood supply to the levator scapulae muscles

The dorsal scapular artery and the transverse cervical artery are commonly accepted as the primary blood supply to the levator scapulae muscles (Fakoya et al., 2020; Manyacka Ma Nyemb et al., 2018). Over the years, there has been uncertainty regarding the origin of the dorsal scapular artery, whether it originates from the subclavian artery or the transverse cervical artery (Huelke, 1958; Reiner & Kasser, 1996; Verenna et al., 2016).

According to literature by Bulbul et al. (2019), Ikka et al. (2016), and Manyacka Ma Nyemb et al. (2018), the dorsal scapular artery can arise from three sources; from the transverse cervical artery, from the subclavian artery or as a collateral branch of the thyrocervical trunk, whereas the transverse cervical artery has a potential of arising from the subclavian artery, and from the thyrocervical trunk.

The current study did not focus on how the dorsal scapular artery is associated with the brachial plexus as highlighted by Huelke (1958), and Verenna et al. (2016). However, the current study classified the blood supply to the levator scapulae muscle based on the mode of birth and branch origin (type I, type II and type III) as reported by Ikka et al. (2016), and Manyacka Ma Nyemb et al. (2018), with additional blood supply instances.

In the current study, a single levator scapulae muscle was observed to receive blood supply from up to two arterial branches. According to the findings of the current study, out of 27 levator scapulae muscles, five muscles (18.52%) received a single arterial supply from the transverse cervical artery only. Six (22.22%) muscles originated from the dorsal scapular artery only (Figure 4.19), Seven (25.93%) muscles were supplied by the transverse cervical artery, originating from the thyrocervical trunk, and the dorsal scapular artery, originating from the transverse cervical artery (Type III) (Figures 4.18). Another seven (25.93%) muscles were supplied by the transverse cervical artery, originating from the thyrocervical trunk, and the dorsal scapular artery, originating from the subclavian artery (Type II) (Figure 4.20). Two (7.41%) muscles were supplied by the transverse cervical and the ascending cervical arteries, both originated from the thyrocervical trunk (Figure 4.17).

6.2.3.1 The routes of blood supply to the levator scapulae muscle

The transverse cervical artery originated from the thyrocervical trunk and extended superficially over the scalene muscles, bifurcated into two branches right before it reached the levator scapulae muscle. One of the branches continued towards the distal superficial aspects of the levator scapulae muscles and the rhomboid muscles, while the other branch extended deep towards the middle aspects of the levator scapulae muscles. The dorsal scapular artery in most cases originated from the subclavian artery (Figures 4.18 and 4.19), and bifurcated into two branches, right before the levator scapulae muscles, one of the branches continued towards the distal superficial aspects of the levator scapulae muscles and continued towards the rhomboid muscles, while the other branch extended deep towards the middle aspects of the levator scapulae muscles.

On the other hand, the dorsal scapular artery was also observed branching off from the transverse cervical artery at a point of the brachial plexus (Figure 4.20), the transverse cervical artery in this instance was a branch of the thyrocervical trunk. Nevertheless, the dorsal scapular arteries extended towards the levator scapulae muscles and also bifurcated into two branches, right before the levator scapulae muscles, one of the branches extended superficially towards the distal aspects of the levator scapulae muscles, while the other branch extended deep towards the middle aspects of the levator scapulae muscles. The ascending cervical artery originated from the thyrocervical trunk and gave off a branch that extended towards the superficial middle aspects of the levator scapulae muscles (Figure 4.17).

6.2.3.2 The comparison of blood supply to available literature

Comparing the types of blood supply to the study finding by Ikka et al. (2016), from 50 cases, 38.00% of the dorsal scapular artery was found in type I, 38.00% was a type II and 24.00% was a type III. In their radiology study by Ikka et al. (2016), from 93 cases, 61.30% of both dorsal scapular artery and transverse cervical artery originated from the subclavian artery, with 23.70% of the dorsal scapular artery branched directly from the subclavian artery and transverse cervical artery (type II) and 15.00% of the dorsal scapular artery and transverse cervical artery originated from thyrocervical trunk (type III).

The levator scapulae muscles in the current study were mostly supplied with blood from the transverse cervical artery, a branch of the thyrocervical artery and dorsal scapular artery, a branch of the subclavian artery and transverse cervical artery (Figure 4.16), agreeing with Huelke (1958).

Equally important, in the current study, about 48.15% of the dorsal scapular artery originated from the subclavian artery while 25.93% originated from the transverse cervical artery, agreeing with Reiner and Kasser (1996) who observed 75.00% of the dorsal scapular artery branching from the subclavian artery, 25.00% from the transverse cervical artery, and Verenna et al. (2016) who observed 71.00% of the dorsal scapular artery branching from the subclavian artery, 35.00% from transverse cervical artery.

In addition, this study also observed that 7.41% of the levator scapula muscles received blood supply from the ascending cervical artery (Figure 4.17), agreeing with Grujičić (2022) and Netter (2014) as presented in Figures 4.16 and 4.17.

However, the current study did not observe the transverse cervical artery originating from the subclavian artery, or a Type I, where both the dorsal scapular and the transverse cervical arteries originated from the subclavian artery as reported in Ikka et al. (2016)

6.2.4 The nerve supply to the levator scapulae muscles

The dorsal scapular nerve is known to innervate the levator scapular muscle (Dalley & Agur, 2023; Van De Graaff, 2002). which originates from the upper part of the brachial plexus, from the anterior rami of C5, and usually the first branch of C5 (Fakoya et al., 2020; Nguyen et al., 2016; Som & Laitman, 2017). The C2-C4 nerves are classified as cervical plexus nerves, while C5 nerves are known as dorsal scapular nerves (Fakoya et al., 2020; Nguyen et al., 2016; Som & Laitman, 2017).

In the current study the innervation to the levator scapulae muscle was classified based on the total number of nerve branches to the muscle, and the number of nerve branches per nerve root. About 37.93% of the levator scapulae muscle had four nerve branches, 17.24% had two and five nerve branches, 13.79% had three nerves, 10.34% had a single nerve, while 3.45% had six nerve branches (Figure 4.21).

The levator scapulae muscle in the current study was innervated by up to six nerve branches arising from the nerve root of C2, the nerve plexus of C3/C4 as well as from the nerve root of C5. According to the results, the C2 root had a possibility of giving off up to two nerve branches (Figures 4.22 and 4.23) the plexus nerve root of C3/C4 had a possibility of giving off up to three nerve branches (Figure 4.22), whereas the C5 root had a possibility of giving off up to two nerve branches (Figure 4.25). The C2 nerve branches extended towards the proximal aspects of the levator scapulae muscles, the C3/C4 nerve branches extended towards the middle aspects of the levator scapulae muscles, and the C5 nerve branches extended toward the distal aspects of the levator scapulae muscles.

Moreover, in most instances, the C5 nerve branches pierced through the middle scalene before attaching to the levator scapulae muscle (Figures 4.22-4.26), and only a few instances of C5 nerve branches were observed with the C5 nerve branches extending over the middle scalene muscle.

Having multiple innervations makes it possible for some of the nerve branches to be transferred to the neighbouring muscle in case of nerve injuries. Hypothetically, the levator scapulae muscles with multiple innervations have a high chance of surviving single nerve injuries and could be used in nerve transfer.

6.2.4.1 The comparison of nerve supply to available literature

In the current study, the levator scapulae muscle was innervated by the dorsal scapular nerve arising from the brachial plexus (nerve roots of C5), agreeing with Dalley and Agur

(2023), Fakoya et al. (2020), Nguyen et al. (2016), Som and Laitman (2017), and Van De Graaff (2002). The dorsal scapular nerve was frequently observed piercing through the middle scalene muscle (Figure 4.22-4.26), agreeing with the statements by Nguyen et al. (2016), and Dalley and Agur (2023). The levator scapulae muscle can be innervated by the C3/C4 cervical nerve branches of the cervical plexus (Figure 4.22-4.26), agreeing with Dalley & Agur (2023), and Henry and Munakomi (2022). The overall nerve branches to the levator scapulae muscle originated from C2-C5 (Figure 4.22-4.26), agreeing with Taira et al. (2003).

Martins et al. (2021) stated that about three or four nerve branches of the cervical plexus innervate the levator scapulae muscle, however, the current study observed a possibility of five cervical nerve branches to the levator scapulae, in addition to the dorsal scapular nerve (Figure 4.22). The current study did not focus on the dorsal scapular nerve communications from C4, C6, T1 and long thoracic nerve as described by Nguyen et al. (2016). Equally important, the lengths of the nerve branches to the levator scapulae muscles done by Pinto et al. (2019) were not performed in the current study.

6.2.5 Statistical analysis

The statistical analysis showed that there was a high correlation between the measurements done by each researcher and moderate to strong correlations between the measurements of the two researchers.

In the descriptive analysis, great differences in the proximal distance were observed among the levator scapulae muscles with three muscle slips (42.71 ± 23.75 mm) and five muscle slips (62.59 ± 10.80 mm), the distal distance fluctuations were observed among the levator scapulae muscles with five muscle slips (63.37 ± 13.99 mm), the anterior distance fluctuations were observed among the levator scapulae muscles with two muscle slips (86.70 ± 13.67 mm) and five muscle slips (84.69 ± 12.55 mm), while the posterior distances indicated greater fluctuations among levator scapulae muscle with the same number of muscle slips, however, they were more dominant among the levator scapulae muscles with three muscle slips (162.99 ± 25.67 mm) respectively (Table 6.1).

Regarding the laterality analysis of the levator scapulae muscles, the results suggested that the levator scapulae muscle measurements were fairly symmetrical between the left and right sides. The sixth slips were only present in the left levator scapulae muscles; hence, no significant difference was obtained. However, a significant difference was observed between the right and left widths of the fourth muscle slips of the levator scapulae muscles, with a p-value of $0.01 < 0.05$ (Table 4.14).

The t-test results also indicated that no significant differences were observed between males and females regarding the levator scapulae distances and muscle slip lengths. Except among the fourth slip widths with a p-value of $0.01 < 0.05$ (Table 4.15).

An ANOVA test indicated that there were no significant differences observed in parameters among racial groups, except for the distal distances with a p-value of $0.00 < 0.05$ and in the muscle slip widths of third slips with a p-value of 0.02, which was less than 0.05 (Table 4.16, 4.17 and 4.18). The distal distance was further analysed with Turkey's test, which indicated that the significant differences were between Black individuals versus other racial groups (Whites, Coloured and Europeans) as presented in Table 4.19

A linear regression indicated that there were no relationships between the study parameters and the cadaver ages. Specifically, there were no relationships between the levator scapulae muscle distances (proximal, distal, anterior and posterior) and cadaver ages, between the width of muscle slips and the cadaver ages, and between the lengths and cadaver ages. Hence the parameters were not dependent on age (Figures 4.31, 4.32 and 4.3).

6.2.6 Limitations

The current study only included and relied on the available adult population of cadavers, aged 18 and above during the research period. The cadaveric dissection only included superficial variations found between the external occipital protuberance and the inferior borders of the right and left scapula. Also, the anterior distances of the levator scapulae muscle excluded the muscle slips and accessory slips attached to the middle scalene and the first and second rib, hence, only those attached on the superomedial borders of the scapula were regarded. The sixth slips were excluded in some statistical calculations as they were only present in two levator scapulae muscles. Moreover, no deep detailed dissection was done, to avoid maximum destruction of other anatomical structures necessary for students, hence the removal of fat, fascia and blunt dissection methods was used to trace deep accessory attachments of the levator scapulae muscles.

6.3 The MRI study

The current section focused on the anatomical variations of levator scapulae muscle, using MRI scans. The MRI study was done only on patients who visited the Roman Catholic Hospital between the year 2017-2022. The axial scans were used, from the C2 to the T1 level of the vertebrae. The MRI scans were randomly selected for the current study and due to the quality and content focused on the MRI scans, the number of the MRI scans with visible features of interest declined. Therefore, out of 46 visible feature scans, only 31 had accessory attachments.

The MRI study observed various accessory attachments of the levator scapulae muscle, this included the attachment to the serratus posterior superior, serratus anterior, rhomboid minor, trapezius and splenius cervicis. Overall, the levator scapulae muscle had both bilateral and unilateral accessory attachments to the serratus posterior superior (Figures 5.2-5.6), serratus anterior (Figures 5.7 and 5.8) and splenius cervicis (Figure 5.11), whereas only unilateral attachments were observed towards the rhomboid minor (Figure 5.9) and trapezius muscles (Figure 5.10).

Equally important, the accessory attachment to the serratus posterior superior dominantly observed in MRIs belonged to 17 male patients, while the least accessory attachments to the serratus posterior superior were observed in MRIs belonging to 14 female patients respectively.

Regarding the right levator scapulae muscle, out of 31 muscles, 80.65% had serratus posterior superior attachments, 9.68% had serratus anterior attachments, 3.23% had rhomboid minor attachments, 3.23% had trapezius attachments and 3.23% had splenius cervicis attachments. Regarding the left levator scapulae muscle, out of 34 muscles, 85.29% had serratus posterior superior attachments, 11.76% had serratus anterior attachments, and 2.94% had splenius cervicis attachments (Figure 5.1).

The MRI study is crucial in determining the exact location of the levator scapulae muscles, and its relation to other muscles, thus variations making it possible to identify variations associated with it. Equally important, accurate identification of the muscles in the MRI may prevent misinterpretation of muscle variations, which may lead to inaccurate diagnoses.

The levator scapulae muscle was identified in the MRI scans along with the variations associated with it, as done by Au et al. (2016). In comparison to other studies, the current study agreed and confirmed the accessory attachment of the levator scapulae muscles to the serratus posterior superior (Figures 5.2-5.6), Serratus anterior (Figures 5.7 and 5.8) and rhomboid minor as stated by Au et al. (2017). The accessory attachment to the trapezius muscle was also observed (Figure 5.10), confirming the reports stated by Chotai et al. (2015), Loukas et al. (2006), Naik and Lokanadham (2019), and Lima et al. (2012) amongst others.

In contrast with the study done by Au et al. (2017), the current study did not confirm the accessory attachment to the first and second ribs. The overall dominant levator scapulae muscle accessory attachments in the current study were towards the serratus posterior superior, not towards the serratus anterior. However, the current study observed accessory attachments of the levator scapulae muscles to the trapezius and the splenius cervicis. Also, the levator scapulae muscle accessory attachments to the serratus posterior superior were mostly observed bilaterally (Figures 5.2-5.5).

6.3.1 Limitations

The MRI study utilised scans that focused more on the spine, hence the levator scapulae muscles were unclear, cut, or not present in some of the digital sections, reducing the quantity of MRIs used. The MRI study only observed accessory attachment between C2 and T1. Only axial MRI scans were used, with few complemented by sagittal MRI scans. There were no volunteers with no neck and shoulder pathologies who specifically participated in this study.

6.4 Possible embryological development implications

Embryological development can be a lead cause of muscle accessory attachments. According to Durland et al. (2008), as cited in Pu et al. (2016), the serratus anterior and the rhomboid muscles are derived from somatic cells. Pu et al. (2016) also stated that it is also conceivable that somatic cells gave rise to the serratus posterior superior, however, these muscles' myogenic precursor cells first develop and integrate into the myotome, and then the somatic mesodermal cells reroute them to generate the deep shoulder girdle muscle.

Moreover, Lima et al. (2012) also described the levator scapulae muscle along with the serratus anterior, and rhomboid muscles to have the same embryonic origin. Therefore, the common origin of these muscles clarifies the accessory attachments of the levator scapulae muscle to the serratus anterior, the serratus posterior superior and the rhomboid minor, as observed in the current MRI study.

6.5 Clinical significance of the findings

The current study confirmed the existence of variations associated with the levator scapulae muscle, and it also introduced new undocumented variations. Although some variations may not be clinically significant, some are worth noting for future references in the clinical fields. The variations provide details regarding the levator scapulae muscle, thus enabling physicians to make accurate diagnoses and treat neck and shoulder-related pain and posture misalignments properly.

The variations of levator scapulae muscle, together with muscle overuse, trauma and imbalance posture may contribute to the cervical myofascial pain (musculoskeletal disorder) (Henry & Munakomi, 2022). The cervical myofascial pain may limit the movements of the muscle for a certain period of time, as stated by Chotai et al. (2015), and Menachem (1993). The snapping scapula syndrome that affects the articulation between the scapula and the thorax may also be a result of muscle overuse, muscle imbalance, or chronic injury (Henry & Munakomi, 2022).

The variations associated with the levator scapulae muscle may also lead to the pain at the medial angle of the scapula known as the levator scapulae syndrome, which could be due to the stretching of the levator scapulae muscle (Henry & Munakomi, 2022). The unusual contraction of the levator scapulae muscle may cause muscles to contract uncontrollably, and uncoordinated twitching on the affected area, which may result in abnormal posture and repetitive movement (Dystonia - Symptoms and Causes, 2022; Lima et al., 2012). The accessory attachments and variations of the levator scapulae muscle may interfere with the management of the cervical dystonia (Au et al., 2017; Chotai et al., 2015).

Therefore, the broader levator scapulae muscle morphology may be physiologically stronger than the smaller one in terms of supporting and stabilising the axio-appendicular skeletons (Lima et al., 2012). In contrast to the levator scapulae muscles with two muscle slips which may be closely related to weak or tilted necks, and the prolonged flexion of cervical vertebrae may lead to abnormal neck posture and neck pain (Anderson et al., 2008). The shorter levator scapulae muscle may limit the flexibility of the cervical vertebrae, which might result in limited muscle movements (Damgaard et al., 2013).

Moreover, the accessory attachment of the levator scapulae to the first and second rib may strengthen the lateral flexion of the neck, may provide additional stability between the cervical vertebrae and the rib cage (Lima et al., 2012). The contractions of accessory muscle attachments to the rhomboid minor, serratus anterior, serratus posterior superior, splenius cervicis and trapezius muscles may cause myofascial discomfort and may affect how cervical dystonia is managed (Au et al., 2017).

Regarding the blood supply to the levator scapulae muscle observed in the current study, some muscles receive up to two arterial branches. The levator scapulae muscle was supplied by the dorsal scapular artery originated from the transverse cervical artery, as well as from the subclavian artery. It was also supplies by the transverse cervical artery and ascending cervical artery, both originated from the thyrocervical trunk.

Hence, noting and understanding the variations of blood supply to the levator scapulae muscle may be useful before the reconstructive surgical procedures in head and neck (Bulbul et al., 2019). Kohli et al.'s hypothesis, (as cited in Henry and Munakomi, 2022), stated that the subclavian artery's involvement in failed supraclavicular brachial plexus blocks could be related to the dorsal scapular artery passing through the brachial plexus nerve bundle.

An investigation by Verenna et al. (2016) demonstrated the passage of the dorsal scapular artery through the brachial plexus, which resulted in a compression of the lower trunk of brachial plexus. Hence, a novel approach to successful brachial plexus blocks may be required, which may include variations associated with the dorsal scapular artery (Verenna et al., 2016).

Concerning the innervation of the levator scapulae muscle, the muscle was observed innervated by up to six nerve branches (Figure 4.22), which may enable certain nerve branches to the levator scapulae muscle to be donated to the lateral pectoral nerve in cases of brachial plexus injuries, to restore motor functions to the affected upper limbs (Martins et al., 2021). In addition, with regards to the Eden-Large Procedure stated by Pinto et al. (2019), the levator muscle can be used during tendon transfer to treat trapezius paralysis, hence the dorsal scapular nerve and cervical nerves innervating it need to be noted.

6.6 Chapter summary

This chapter highlighted the findings of both the cadaveric and MRI studies. It also compared the current study results with the available literature. In the cadaveric study, the levator scapulae muscle was observed with a different number of muscle slips and multiple blood and nerve supplies to the levator scapulae muscle. However, both cadaveric and MRI studies observed accessory attachments associated with the levator scapulae muscle. The next part will focus on the conclusion.

CHAPTER 7: CONCLUSION

Neck and shoulder pain, associated syndromes, and discomforts are a major concern globally. The factors contributing to these medical conditions need to be addressed. Since the levator scapulae muscle is pronounced to be the leading cause of neck and shoulder pains and discomforts, its morphology, blood supplies, and nerve supplies deserve a proper study to determine the variations associated with them.

This study has confirmed the existence of the levator scapulae muscles, from its various number of muscle slips, the presence of accessory muscle slips and the accessory muscle attachments of the muscle slips. In terms of the muscle slips, three, four, five and six muscle slips were confirmed. The accessory muscle slips with distal attachments to the middle scalene and to the first two superior ribs were confirmed in the cadaveric study. The sharing of proximal attachments by two muscle slips was also confirmed, and the cervical vertebrae with no muscle slip attached to it (between muscle slips). The accessory muscle slips to the serratus anterior, rhomboid minor, trapezius, splenius cervicis and serratus posterior superior were confirmed in the MRI study.

The levator scapulae muscles observed were dominated by four muscle slips (62.50%), proximally originating from the first four transverse processes of C1-C4 and distally attached to the superomedial borders of the scapula. This category of muscle slips was however observed with accessory muscle slips with distal accessory attachments. One levator scapulae muscle had accessory muscle slips originating from C3 and C4 and distally attached to the anterolateral aspects of the first and second rib (Figure 4.12).

Similarly, two muscles had two accessory slips originating from C2 and inserted into the anterolateral aspects of the first two superior ribs (Figure 4.11).

On the other hand, an accessory muscle slip was observed in a single levator scapulae muscle extending from the fourth muscle slip (C4) to the middle scalene muscle (Figure 4.11). Moreover, this category was also observed two levator scapulae muscles with single accessory muscle slip extending between the second and third muscle slips (C2 and C3).

The second dominant muscle slip category among the levator scapulae muscle had five muscle slips (17.50 %). These muscle slips proximally originated from C1-C5, and distally attached to the superomedial borders of the scapula. Although the majority had well-defined muscle slips (six out of 27 muscles), one of the five muscle-slipped levator scapulae muscles with accessory muscle slips observed. Whereby three accessory muscle slips shared the proximal attachments the third (C3), fourth (C4) and fifth (C5) muscle slips. The accessory slips were distally attached to the anterolateral aspects of the first two ribs (Figure 4.14).

In addition to the frequently observed muscle slips categories, the levator scapulae muscles with two muscle slips, three muscle slips and six muscle slips were also observed. The two muscle-slipped categories were proximally attached to C1-C2 (Figure 4.4). The three muscle-slip categories were proximally attached to C1 and C2 (Figure 4.5), as well as to C1, C2 and C4 (Figure 4.10). The six muscle-slipped were proximally attached to C1-C5, due to some muscle slips with common proximal attachments (Figures 4.8 and

4.9). The above-mentioned categories were distally attached to the superomedial borders of the scapula.

Concerning the functions of the levator scapulae muscle, more muscle slips could hypothetically explain the stronger levator scapulae muscle, whereas fewer muscle slips could be associated with weak necks, which could result in tilted heads in children. The broadness of the levator scapulae muscle between the proximal and distal attachments could aid the axio-appendicular stability and scapula elevation functions. The broader the levator scapulae muscle, the more the number muscle slips, and the stronger the muscle. Inversely, the thinner the levator scapulae muscle, the fewer the muscle slips, and the weaker the muscle.

In the cadaveric study, the levator scapulae muscle is associated with variation, ranging from the number of muscle slips to the proximal attachments and the distal attachments. These variations could be greatly associated with neck and shoulder pain, abnormal flexion of the neck and unstable neck postures. In addition, the accessory muscle slips with accessory distal attachments could affect the normal functions of the levator scapulae muscle. Moreover, the muscle slip length could be useful during muscle transfer procedures, to improve or assist the function of other muscles.

The overall average anterior distance was 87.10 mm, posterior distance was 158.08 mm, proximal distance was 53.46 mm, and distal distance was 60.63 mm. The muscle slip length average ranged between 85.32 ± 5.78 mm and 149.87 ± 16.95 mm and muscle slip width average ranged between 7.16 ± 3.47 mm and 14.73 ±3.56 mm (Tables 4.5, 4.6, 4.7 and 4.8). The muscle parameter measurements were necessary to anatomists when performing surface tracing of muscles. In addition, it provides approximate distances, lengths and widths of the levator scapulae muscles, which could be useful during posterior neck surgeries and physical therapy.

With regards to the levator scapulae muscle blood supply, it received blood from the transverse cervical artery, a branch of the thyrocervical trunk, from the dorsal scapular artery, which either stemmed from the subclavian artery or transverse cervical artery, and also rarely received blood from the ascending cervical artery, a branch of the thyrocervical trunk. The current study only observed Type II (Figure 4.18) and Type III (Figure 4.20) blood supply to the levator scapulae muscle, both with 25.93% (Figure 4.16). This is important to be noted during surgery to avoid injuries to the less pronounced arteries to the levator scapulae muscles, like from the ascending cervical artery.

The levator scapulae muscles can be innervated by nerve branches from the cervical plexus (C2, C3/C4 nerve roots) and the dorsal scapular nerve (C5 nerve roots). The C2 nerve root gave off up to two nerve branches, the C3/C4 nerve root gave off up to three nerve branches, and the C5 nerve root gave off up to two nerve branches to the levator scapulae muscles. Overall, the levator scapulae muscle was innervated by a range of one to six nerve branches (Figure 4.22), and this may provide adequate motor functionality to the muscle. Multiple innervations can also provide chances of nerve transfer, in cases of nerve injuries. Hence, understanding the possible innervations to the levator scapulae muscle, as well as the origin of these nerve branches could also prevent nerve damage during neck and shoulder medical procedures.

In the MRI study, the frequently observed accessory attachment of the levator scapulae muscle was to the serratus posterior superior (Table 5.1). The second dominant was the accessory attachments to the serratus anterior muscles. The attachments of the levator scapulae muscles to the trapezius, rhomboid minor and to the splenius cervicis muscles were rarely observed.

The MRI study results were significant, as they provided additional knowledge related to the accessory attachment of the levator scapulae muscles. In addition, they also provided the traced image illustrating the neighbouring muscles of the levator scapulae muscle. These are important to the radiologist for accurate observations and interpretations of scans, and for the clinicians to understand the possible variations of the levator scapulae muscle. The knowledge could prevent unnecessary incisions, prevent more damage to the muscle tissues and its neurovasculature.

The study findings are clinically significant, as they provide possible levator scapulae muscle variations, which may contribute to neck and shoulder pain and discomfort, and syndromes associated with the neck and shoulders. Thus, for evolution purposes and clinical involvement of the levator scapulae muscle, it is essential to continue performing research studies on the levator scapulae muscle variations to update the available information that is crucial not only to the researchers but to the medical fields as well.

Equally important, adequate cervical MRI studies are needed to fully understand different individual cervical muscles and to point out variations or anomalies associated with the cervical muscles.

The following study findings were not encountered in the literature: the accessory muscle slips extending from the second muscle slip (C2) to the middle aspects of the third muscle slip (C3), a total of two muscle slips in adults, multiple accessory slips with the same distal insertion (lateral aspects of the first and second rib), and a total of six nerve branches to the levator scapulae muscle.

CHAPTER 8: RECOMMENDATIONS

The overall aim of the current study is to determine the morphometric variations in the levator scapulae muscle and the muscle's related neurovasculature. The levator scapulae muscle was observed with various accessory attachments. Some accessory attachments could be the lead cause of neck and shoulder pain and posture misalignments, while some might have no major functional and medical effects in individuals. Several blood supplies and nerve supplies to the levator scapulae muscle were also observed.

Therefore, the current study recommendation targets the researchers in the field of Anatomy to focus on details of neck muscles and their neurovasculature, as it was a challenge categorising the levator scapulae muscle accessory slips, as some of the slips originated from the proximal aspects of the muscle slips, whereas some muscle slips originated from the middle aspects of other muscle slips.

Another challenge was tracing further the accessory attachments of the levator scapulae muscle towards the first two ribs. Thus, tracing and dissecting the entire levator scapulae muscle must be put into consideration to determine the exact points of proximal and distal attachment as well as other variations associated with it as performed by Fakoya et al. (2020), Lashley and Granite (2021), and Louk et al. (2006). Besides, the levator scapulae muscle must be completely cut off to determine the precise distances of the muscle as well as the lengths and widths of the muscle slips.

The embryological and developmental anatomy of the neck muscles needs adequate attention, as it will make it easier for future researchers to identify and understand the variations associated with the neck muscles. When presenting the levator scapulae muscle variations, a thorough literature study is required to compare and find suitable nomenclatures for variations related to the levator scapulae muscle (Loukas et al., 2006).

However, it was also a challenge to categorise and find the appropriate nomenclature for the transverse cervical artery and dorsal cervical artery collateral branches to the levator scapulae muscle. Thus, naming the collateral branches after the branch they bifurcated from, would be helpful for future researchers. Moreover, it would be great to rename the dorsal scapular artery arising from the transverse cervical artery as dorsal scapular artery-tra (tra: transverse), whereas the dorsal scapular artery from subclavian artery would be named dorsal scapular artery -sub (sub: subclavian).

Similarly, the transverse cervical artery stemming from the thyrocervical trunk could be named transverse cervical artery-thy (thy: thyrocervical), while the one branching from the subclavian artery could be named transverse cervical artery-sub (sub: subclavian). In addition, the arterial branch from the ascending cervical artery may be referred to as the ascending levator scapular artery. The nerve supply must also be traced to confirm the exact origin, especially the cervical nerve branch from the C2 nerve root which was rarely stated in previous studies. However, these suggestions could be more practically effective if the dissection is done before students' practical sessions.

In the cadaveric study, due to a close relationship between the anterolateral aspects of the first two ribs and the serratus anterior muscles, there is a possibility that the levator scapulae muscle slips that have extended towards the first and second ribs might as well be associated with the serratus anterior muscles. Hence, a thorough investigation is needed to trace the levator scapulae muscle, and that will include getting rid of all the anatomical structures to expose the extensions of the muscle.

Similar to the cadaveric study, the accessory attachments of the levator scapulae muscle towards the serratus anterior muscle observed in the MRI study might as well be extending towards the first two ribs, as the upper serratus anterior muscle is attached on lateral aspects of the first two ribs (Smith et al., 2003). Moreover, various literature cited by Au et al. (2016), stated that the literature has not described the appearance of cervical spine muscles on the MRI clearly, the recently published MRI related to cervical muscles is incomplete, with some muscles not labelled and some muscles were presented as groups instead of individuals, and also not all cervical vertebral levels were portrayed.

The MRI study should use scans of volunteers with no health problems related to the neck and upper back, to compare the findings with the MRI scans of patients with minor neck and dorsum pathologies. Equally important, frontal/ coronal plane scans would help trace and study variation associated with the levator scapulae muscle from an anterior aspect, in addition to the sagittal and transverse scans. Thus, the MRI results provided insight and knowledge on the location of the levator scapulae muscle in the scans and the neighbouring muscles. Furthermore, 3D reconstruction of the muscles was not done, this would have clearly defined accessory attachments of the levator scapulae muscle.

It is recommended that both cadaveric and MRI study results be noted, as they provide important knowledge about the possible variations associated with the levator scapulae muscle. This study provided the average number of muscle slips in the levator scapulae muscle, which is four muscle slips, followed by five muscle slips. The conclusion drawn from the results is that people with tilted necks or weak necks could have few muscle slips, while those with strong and stable necks have more muscle slips.

Equally important, the accessory muscle slips can be mistaken with the clotted veins, they could also interfere with the normal functions of the levator scapulae muscle or could functionally assist or affect the distally attached muscles. However, not all the muscle slips are clinically significant, especially the tiny one between muscle slips. The measurements can provide approximate distances of the levator scapulae muscle and the length and width of muscle slips. This makes it easier for clinicians and therapists to adequately trace the levator scapulae during medical procedures.

Overall, there is more to the human anatomy than the available information. Generally, there are great variations associated with the muscle attachments (proximal and distal attachments), their blood supply, as well as their nerve supply. Thus, research is the best way to update the available information for anatomists, clinicians and the nation at large. Equally important, the levator scapulae muscle is useful for everyday activities, hence living a healthy lifestyle, doing regular exercises, avoiding overuse of the muscle (lifting and carrying heavy loads on the head), and avoiding a prolonged flexion of the neck is significant.

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APPENDICES

Appendix A: Ethical clearance certificate

UNAM
UNIVERSITY OF NAMIBIA

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOM0001 **Date: 1 April 2022**

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project: A cadaveric and MRI study of the anatomical variations of levator scapulae

Principal researchers: Ester Ndagwedha Iita (MSc student), Quenton Wessels (Main supervisor), Janine Correia (co-supervisor)

Staff Number/ Student number: Student number 201203124

Remarks: This is an interesting study looking at the morphometric differences of the levator scapulae (LS) muscle and the variations associated with its neurovasculature, to bridge the gap of knowledge that currently exists about the LS muscle and its accessories.

Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:

i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,

ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

____

(Chairperson Decentralized Ethics Committee)

____

Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)

Appendix B: Research permission letter

CENTRE FOR RESEARCH SERVICES
Office of the Pro-Vice Chancellor: Research, Innovation & Development
University of Namibia, Private Bag 13301, Windhoek, Namibia
340 Mandume Ndemufayo Avenue, Pioneers Park, Office F223 - Fblock, Second Floor
☎ +264 61 206 4673; E-mail:kmbulu@unam.na; URL: http://www.unam.edu.na

UNAM
UNIVERSITY OF NAMIBIA

RESEARCH PERMISSION LETTER

Date: 21/04/2022

Student Name: ESTER NDAGWEDHA IITA

Student Number: 201203124

Programme: MASTER OF SCIENCE (ANATOMY)

Approved Research Title: A cadaveric and MRI study of the anatomical variations of levator scapulae.

TO WHOM IT MAY CONCERN

I hereby confirm that the above-mentioned student is registered at the University of Namibia for the programme indicated. The proposed study met all the requirements as stipulated in the University guidelines and has been approved by the relevant committees.

The proposal adheres to ethical principles as per attached Ethical Clearance Certificate. Permission is hereby granted to carry out the research as described in the approved proposal.

Best Regards

Dr. AEE Shikongo
Head: Postgraduate Support Services
Tel: +264 61 206 3129
E-mail: aeshikongo@unam.na

CENTRE FOR RESEARCH SERVICES
Office of the Director
2022 -04- 21
University of Namibia
UNAM

Appendix C: Permission letter from Roman Catholic Hospital

ROMAN CATHOLIC HOSPITAL WINDHOEK
NURSING SERVICE MANAGEMENT
P.O. BOX 157, TEL.: 270-2015, FAX: 270-2039
E-MAIL: bshipanga@rchna.org

January 31, 2022

Dear Mr. Quenton Wessels,

Re: Request – A cadaveric and MRI study of the anatomical variations of levator scapulae

Reference is made to the above request for *a cadaveric and MRI study of the anatomical variations of levator scapulae.*

We hereby grant Ms. Ester Iita to conduct her second phase study, which relates to a document review of MRI scans of patients of Dr. van der Horst (carbon copied) on the following conditions.

- The patients' confidentiality is to be maintained;
- No patients' files are to be taken out of the hospital; and
- No information contained in the patients' file are to be shared with any third party;

Trust this is in order.

Yours faithfully,

[signature]

Sr. Bernadette Shipanga
Nursing Service Manager

Roman Catholic Hospital
P.O. Box 157, Windhoek
31 JAN 2022
Tel: 061-2702015
bshipanga@rchna.org

cc. Dr. Alex van der Horst, Orthopaedic Surgeon.