An investigation into the association between breast size, muscle sensitivity and upper back pain in pre-menopausal women in Durban, KwaZulu-Natal

By

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I, Jasmine Lloyd, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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DEDICATION

The Lord is my strength and song, and He has become my salvation – Exodus 15: 2

I thank my mother and father, Francios and Marilize, and my dear sister, Eva, for their love and support on my journey.

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ABSTRACT

Background: Previous studies have examined the relationship of breast size on the upper back pain and posture however, the majority of these studies focused on postural alternations and post-menopausal women alone, leaving limited literature regarding the effect of breast size on the upper back musculature. The muscular sensitivity of the upper back region in relation to breast size has been surveyed in Australia not in South Africa it requires further investigation. The difference in cultural and ethnicity differences among Australians and South Africans negate the direct extrapolation of findings. Understanding the effect of breast size on the upper back pain and its surrounding musculature provides more insight into how healthcare practitioners consider treatment of women presenting with upper back pain to improve the treatment outcomes and patient satisfaction.

Aim: The aim of this study has been to determine if there is an association between breast size, muscle sensitivity and self-reported upper back pain in pre-menopausal women in Durban, KwaZulu-Natal.

Methodology: This was a quantitative, case-controlled, observational study design. A pressure algometer was used to measure the pain pressure threshold of 12 anatomical sites. A sample of 52 participants were recruited and divided into one of two groups: one with upper back pain and one without upper back pain. Within the groups, comparisons were made using the test. A two-sided *p*-value of <0.05 as alpha was considered as statically

two-sample t-significant.

Results: Breast size has an effect of the muscle sensitivity of the upper back anatomical sites. After self-reporting of pain, breast size A and B was most commonly found in the non- pain group where breast size D or higher was found to be most in the pain group (p= 0.054) when comparing differences between the pain and non-pain groups of five anatomical locations. Using A or B cup size as the reference group, size C has 2.2 times higher odds of being in the pain group which was not statistically significant (p=0.220) and cup sizes D or higher has almost 5 times higher odds of being in the pain group (p=0.054).

Conclusion: The results of this study show that, overall, an association exists between breast size,muscle sensitivity and self-reported upper back pain in pre-menopausal women. This was significantly noted as the cup size increased, muscle sensitivty increased,indicating a lower kPa value in T8,T10, levator scapulae, upper trapezius and middle trapezius. This stands in contrast to previous studies who noted that only the middle trapezius had the greatest variability between groups with different pain levels amongst post-menopausal women, with no control group to compare findings. As a result, the null hypothesis was rejected.

Key Words: Breast, musculoskeletal, muscle sensitivity,pain pressure threshold, upper back pain, women

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS

%: percentage

bra: brassiere

CDC: Chiropractic Day Clinic

CI: confidence Interval

cm: centimetre

DUT: Durban University of Technology

HPA: hypothalamic pituitary adrenal

IREC: Institutional Research Ethnics Committee

kPa: kilopascals

KW: Kruskal-Wallis

LS: levator scapulae

LT: lower trapezius

MT: middle trapezius

NRS: numeric rating scale

n: sample

OR: odds ratio

PM: pectoralis major

***p*:** probability

sd: standard deviation

std: standard

S: sternocleidomastoid

T2: second thoracic spinous process

T4: fourth thoracic spinous process

T6: sixth thoracic spinous process

T8: eight thoracic spinous process

T10: tenth thoracic spinous process

T12: twelfth thoracic spinous process

UT: upper trapezius

DEFINITIONS

Algometer:

A device that is most commonly used to produce a controlled pain and allows a quantitative measure of sensitivity of the muscles and skeletal tissues (Spencer 2022; Trueba-Perdomo *et al.* 2021).

Breast Hypertrophy:

Large breast size — D cup and higher. Breast size that is disproportionate to woman's biotype (Coltman *et al.* 2014; Hansson *et al.* 2021; Fonseca *et al.* 2018)

Pain Pressure Threshold:

The minimum intensity that is required for a painful stimulus due to pressure to be perceived as painful (Spencer 2022; Trueba-Perdomo *et al.* 2021).

Upper Back Pain:

Upper back pain is known to originate from the thoracic spinal region and is defined as pain located in the region of a line traversing the tip of the spinous process of T1 superiorly, a line traversing the tip of the spinous process of T12 inferiorly, and a vertical line tangent to the lateral margins of the erector spinae muscles bilaterally (Spencer *et al.* 2019; Briggs *et al.* 2009; Myburgh 2016).

CHAPTER 1: INTRODUCTION

This chapter provides background information of the study by introducing the research problem and study rationale. It also explains the importance of this study to the body of literature. The aims and objectives, as well as the flow of the dissertation, are presented.

1.1 BACKGROUND

The female breast is known as a wide base of glandular and fatty tissue located between the second and sixth intercostal that extends from the sternum to the midaxillary line and attaches directly to the pectoralis major via the Cooper's ligament (Bazira, Ellis and Mahadevan 2022; Rivard, Galarza-Paez and Peterson 2018). Before puberty there is no structural differences noted between the male and female breasts; both contain fatty tissue with the nipple located at the level of the fourth thoracic spinous process (T4) (Moore, Dalley and Agur 2017). During puberty the multiple changes occur via hormonal influences, by proliferation of glandular tissue, increasing breast size (Bazira, Ellis and Mahadevan 2022). The breast size is measured by band size and cup size (McGhee, Ramsay *et al.* 2018). The band size is measured around the underbust at the level of the inframammary fold and ranges from 63 to 112 centimetres (cm), whereas the cup size is measured around the broadest chest circumference, ranging from 77 to 140cm (McGhee, Ramsay *et al.* 2018). In the current literature, breast size A has been used to present small breast size, while D and higher is considered a large breast size, also known as breast hypertrophy (Coltman *et al.* 2014; Hansson *et al.* 2021).

Breast hypertrophy has been observed to cause changes in women which include physiological, biomechanical, and postural components (Coltman *et al.* 2018; Spencer *et al.* 2019). The breast tissue consists of adipose and fibroglandular tissue that is directly attached to the thoracic wall via the muscular fascia of the pectoralis major, rectus abdominus, and the periosteum of the fifth or sixth rib (McGhee and Steele 2020b). The adipose and glandular tissue of the breasts increase based on factors such as body mass gain, menstruation, pregnancy, and breastfeeding (McGhee and Steele 2020a). This increase in breast size results in scapulae protraction and increases the flexion torque of the thoracic spine due to a shift in the normal center of gravity (Coltman *et al.* 2018). This results in the thoracic spinal muscles and surrounding ligaments becoming strained from being overloaded, leading to postural changes such as an increase in thoracic kyphosis and cervical lordosis, leading to further muscular compensation to maintain balance, which results in an increase in muscular sensitivity and upper back pain prevalence in the female population (Papanastasiou *et al.* 2019; Spencer *et al.* 2022).

Upper back pain is known to originate from the thoracic vertebral region and is defined as pain located in the region of the line traversing the tip of the spinous process of T1 superiorly, a line traversing the tip of the spinous process of T12 inferiorly, and a vertical line tangent to the lateral margins of the erector spinae muscles bilaterally (Spencer *et al.* 2019; Briggs *et al.* 2009; Myburgh 2016).

Numerous previous studies exist regarding the effect of breast size on the upper back but the majority of these studies focused on postural alternations and post-menopausal women alone, leaving limited literature regarding the effect of breast size on the upper back musculature (Spencer *et al.* 2022; Yücel *et al.* 2024; Spencer and Briffa 2013). Spencer *et al.* (2022) was one of the first to examine the muscular sensitivity of the upper back region in relation to breast size, but this muscular sensitivity requires further investigation. This is based on the fact that the study completed by Spencer *et al.* (2022) was completed in Australia and had a sample of small breasted women. The results of Spencer *et al.* (2022) cannot be extrapolated or equated to a South African population as the cultural traditions and diverse ethnicity existing in South Africa differs significantly from other countries which leaves a lack in of research in developing countries (Khumalo and Haffejee 2022; Ndlovu 2006). Furthermore, cultural traditions, such as women carrying heavy object on their heads, using wheelbarrows for grocery transport, carrying babies on their back and traditional seating postures, play a vital role in identifying factors leading to back pain in the South African context (Khumalo and Haffejee 2022; Ndlovu 2006). Understanding the effect of breast size on the upper back and its surrounding musculature provides more insight into how healthcare practitioners consider the treatment of women presenting with upper back pain to improve treatment outcomes and patient satisfaction.

1.2 AIMS AND OBJECTIVES

1.2.1 Aim

The aim of this study has been to determine if there are associations among breast size, muscle sensitivity and self-reported upper back pain in pre-menopausal women in Durban, KwaZulu-Natal.

1.2.2 Objectives

Objective One:

To determine the breast size in pre-menopausal women aged 18–40 via objective measurement (underbust and overbust measurement using measuring tape).

Objective Two:

To determine muscle sensitivity (pain pressure threshold) in selective anatomical locations of pre-menopausal women aged 18–40 via objective measurement (pressure algometer).

Objective Three:

To determine the self-reported pain levels of pre-menopausal women aged 18–40 via subjective measurement (numerical pain rating scale).

Objective Four:

To determine if a correlations exist between breast size, muscle sensitivity (pain pressure threshold) and self-reported pain in pre-menopausal women.

1.3 HYPOTHESIS

1.3.1 Null Hypothesis

A negative correlation exists regarding bigger breast size in pre-menopausal women with upper back pain and muscle sensitivity ($p = < 0.05$).

1.3.2 Alternate Hypothesis

A positive correlation exists regarding bigger breast size in pre-menopausal women with upper back pain and muscle sensitivity ($p = > 0.05$).

1.4 STUDY RATIONALE

Breast tissue has been shown to be a common source of pain in women, varying from actual breast pain due to underlying factors such as cyclic breast pain (menstrual cycle), non-cyclic pain (not related to menstrual cycle) such as Cooper's ligament stretching, periductal mastitis, cyst, upper back pain due to postural and biomechanical changes, or breast cancer (Santen 2018; Spencer 2022; Pontes *et al.* 2020). Despite breast size having a significant impact of the upper back musculature and high pain prevalence, it remains understudied (Spencer *et al.* 2022).

The current international literature regarding breast size and upper back pain was primarily conducted in countries such as Australia and Canada, which is predominantly Caucasian in ethnicity (Coltman *et al*. 2018; Spencer *et al.* 2022). The results of these studies cannot be extrapolated or equated to a South African population, as the cultural traditions and diverse ethnicity in South Africa significantly different from other countries. This has resulted in a lack of research in developing countries (Khumalo and Haffejee 2022; Ndlovu 2006). Furthermore, cultural traditions, such as women carrying heavy objects on their heads, carrying children on their backs and, traditional seating postures, play a vital role in identifying factors leading to back pain in the South African context (Khumalo and Haffejee 2022; Motaung *et al.* 2022; Ndlovu 2006). Building on literature regarding the effect of breast size on the upper back in women in the South African population, Mthabela (2015) examined the postural changes that occurred after brassiere (bra) correction. It was found that after bra correction, the majority of participants had a decline in upper back pain as well as improved posture (Mthabela 2015). Mthabela (2015) concluded that more research needs to be done regarding back pain and breast size.

Other studies regarding the relationship between breast size and upper back pain have primarily focused on post-menopausal women (Spencer *et al.* 2022; Spencer and Briffa 2013; Yücel *et al.* 2024). It is important to note that the findings of these studies cannot be generalised or applied to pre-menopausal women because there are significant differences in estrogen levels and bone mineral density between pre-menopausal and post-menopausal women (Wang 2017; Cauley 2015). Post-menopausal women present with reduced estrogen production which is associated with decrease in bone mineral density and muscle mass,which results in a higher pain prevalence (De Castro *et al.* 2020). This study, therefore, aimed to fill the gap found in literature and observe if an increase in breast size results in higher upper back musculature sensitivity and pain levels in pre-menopausal women of the South African population.

Chiropractic care in South Africa is an alternative healthcare discipline that employs a holistic, patient-centred methodology rendering this study important for examining the healthcare system's reaction to the challenges posed by an increase in breast size and upper back pain (Chapman 2022). Better understanding of factors influencing upper back pain allows better management options for women with upper back pain and may also assist in early detection of breast cancer to reduce the mortality rate of breast cancer per year (World Health Organization 2024a). This study will also be beneficial as it aligns with the sustainable development goals of South Africa and the World Health Organization that aim to increase development in the health workforce in developing countries and promote health and well-being in programmes by 2030 (United Nations 2024; World Health Organization 2024b).

1.5 OUTLINE OF CHAPTERS

This chapter has highlighted the importance of this study, along with its aims and objectives, and the paucity in the literature related to breast size and upper back pain. Chapter Two delves into the correlation between breast size, upper back pain, and musculoskeletal sensitivity and provide a review of the current literature on this subject. Chapter Three focuses on the methodology that was used to complete this study. Chapter Four presents an analysis of the results from the study. Chapter Five discusses the results and conclusions drawn of the study, and Chapter Six highlights the study's limitations and provides future research recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides an overview of the literature pertaining to breast size, how it affects the upper back. Chapter two also includes an explanation of the relevant anatomy of the breast and thoracic spine, as well as its physiology. Furthermore, the relationship between breast size and upper back pain is discussed, which is linked to the theories discussing the effect of breast size on the upper back musculature, leading to muscular sensitivity.

2.2 OVERVIEW OF BREAST ANATOMY

2.2.1 Embryology

The development of breast tissue is an intricate process that begins during embryonic development. By the fifth week of gestation, a mammary bud starts to form in the fourth intercostal space, which then grows downward to form secondary buds and mammary lobules. During gestation, the breast stroma, which includes fat, ligaments, nerves, arteries, veins, and lymphatics, also develops. After week 12, the secondary buds continue to elongate and branch out, creating a network of breast ducts that connect the nipple with the mammary lobules (Figure 2.1) (Jesinger 2014).

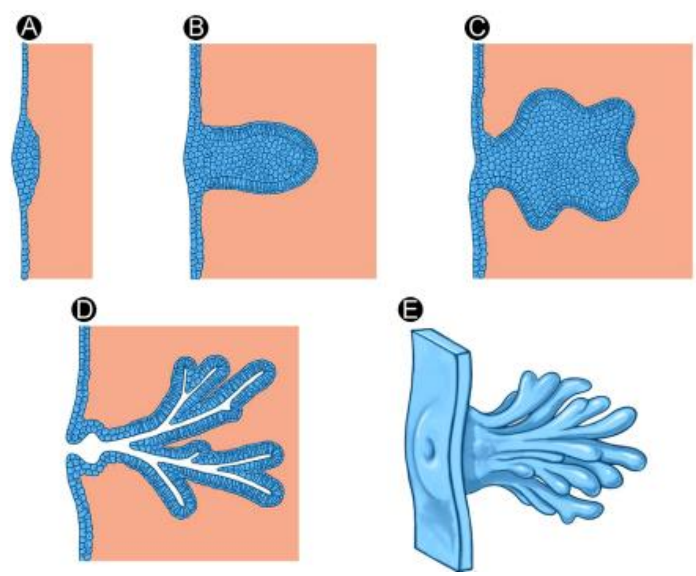

Figure 2.1 The normal embryologic development of the breast (Jesinger 2014)

Figure 2.1 shows (A) mammary bud during the fifth week of gestation, (B) growth of mammary bud downward into the chest, (C) formation of the secondary buds between the fifth and twelfth week of gestation, (D) formation of mammary lobules by the twelfth week of gestation, and (E) continued growth of mammary lobules, with lengthening of ducts.

Following birth, the nipple protrudes due to the proliferation of lubricating sebaceous glands. The breast tissue continues to develop after birth, with significant changes during puberty when estrogen and progesterone levels rise. The male breast will result in higher content of fat whereas the female breast will be made of a balance of ducts, fibro glandular stromal tissue and fat (Figure 2.2) (Jesinger 2014). After menopause the glandular tissue of the breast will start to atrophy with the connective tissue becoming less cellular with decreased amounts of collagen (Ellis and Mahadevan 2013).

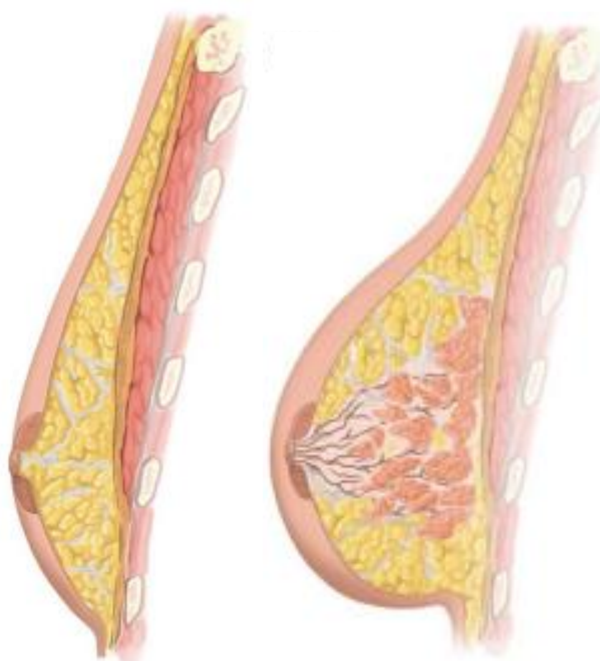

Figure 2.2 Comparison between the male (left) and female (right) breast (Jesinger 2014)

2.3 OVERVIEW OF BREAST TISSUE AND BREAST SIZE

The nipple is typically found at the level of the fourth intercostal space, but its position may vary if the breasts are pendulous. The nipple is made out of stratified squamous epithelium with dense melanocytes (Ganschow 2004) and is surrounded by the areola, which is a large sebaceous gland that can be seen with the naked eye (Ellis and Mahadevan 2013). Small elevations are also noted on the areola which is called the Montgomery’s tubercles which are known to be modified areolar glands (Ganschow 2004).

The breast tissue is situated between the second and sixth ribs, extending from the sternum to the midaxillary line. The skin of the breasts is connected to the underlying tissue by an anterior facial layer and a fibrous extension of Cooper's ligament. The breast rests on top of the pectoralis major, and the upper abdominal oblique muscles inferiorly (Jesinger 2014).

2.3.1 Vascular Supply of the Breast

Pre-menopausal women have a higher blood volume located in their breasts, particularly the nipple, when compared to post-menopausal women (Jesinger 2014). The main arterial blood supply of the breasts originates from the internal thoracic artery branches, intercostal arteries, and the lateral thoracic artery. The internal thoracic artery is the primary artery that supplies the breast tissue and its parenchyma, whereas the lateral thoracic artery supplies the superolateral breast parenchyma. In contrast, the intercostal arteries send perforating branches through the chest wall musculature along the deep margins of the breast (Jesinger 2014). The venous system of the breast runs parallel to its arterial supply (Figure 2.3) (Jesinger 2014).

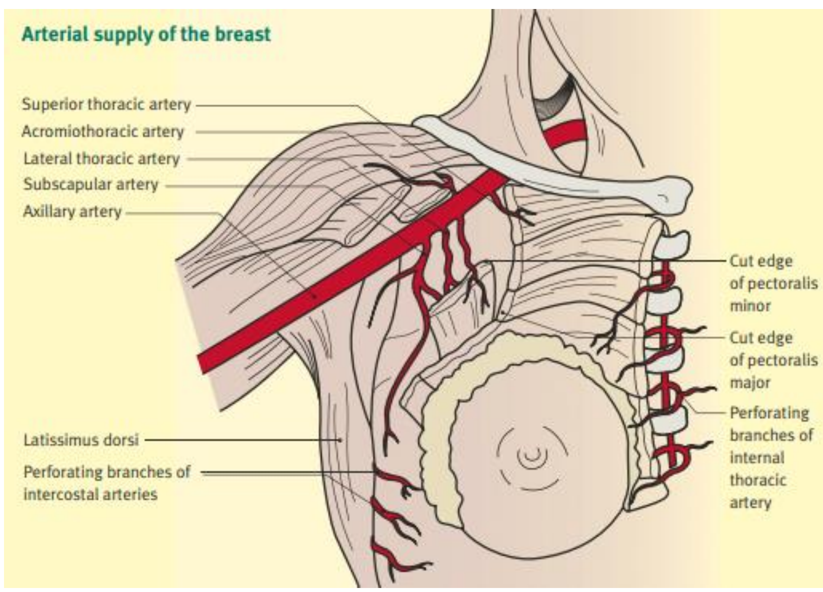

Figure 2.3 Arterial supply of the breast (Ellis and Mahadevan 2013)

2.3.2 Nerve Supply of the Breast

The nerve supply of the breast comes from the anterior and lateral cutaneous branches of the fourth to sixth intercostal nerves. These branches pierce through the pectoral fascia of the pectoralis major and travel to the breast tissue (Moore and Dalley 2018).

2.3.3 Lymphatics of the Breast

The breast's lymphatic system runs parallel to its venous system (Jesinger 2014). This system contains 20 to 30 lymph nodes that are divided into five groups: lateral, pectoral, subscapular, central and apical (Ellis and Mahadevan 2013). The lymphatic system originates from the walls of the mammary ducts and interlobular connective tissue. Most of the lymphatic drainage occurs through the axillary lymph nodes, while the rest travels towards the internal thoracic nodes (Figure 2.4) (Ellis and Mahadevan 2013).

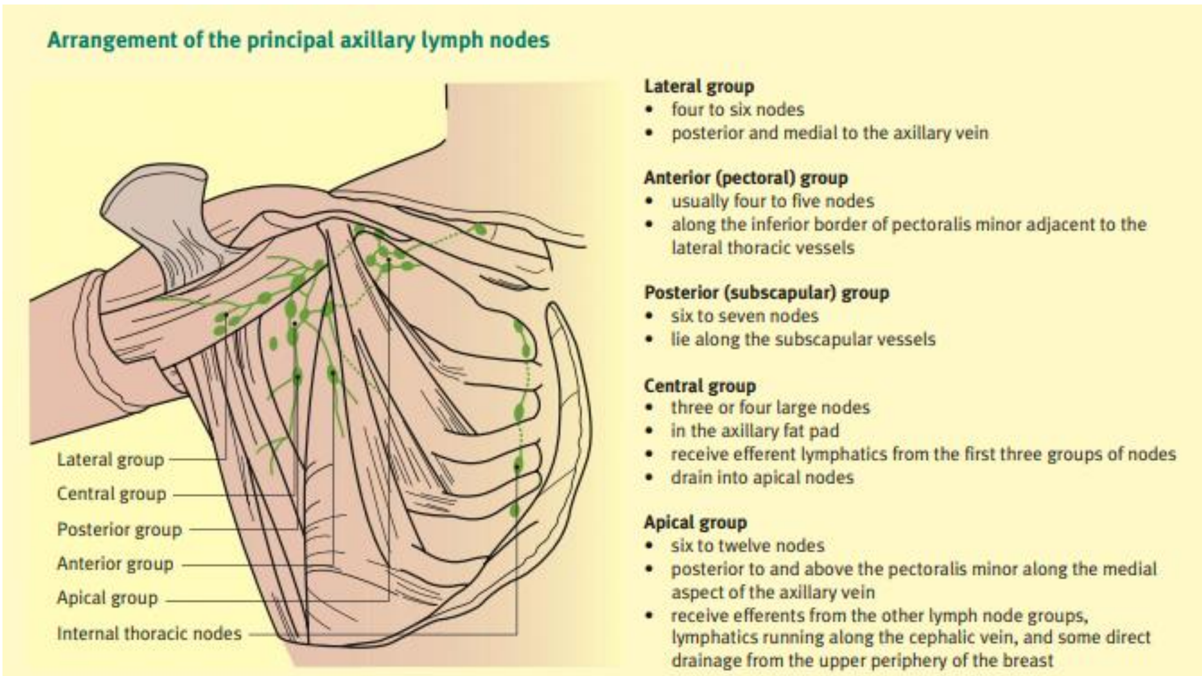

Figure 2.4 Arrangement of the principal axillary lymph nodes (Ellis and Mahadevan 2013)

2.3.4 Breast Size

Breast size is known as the measured band size and cup size. The band size is measured around a woman's underbust at the level of the inframammary fold and the cup size is measured around the broadest chest circumference (McGhee, Ramsay *et al.* 2018). In the current literature bra size A is used to represent small breast size, whereas D and higher is considered to be a large breast size (Coltman *et al.* 2014; McGhee and Steele 2010). Using a two-hand held three-dimensional scanner,large breasts are considered to be breasts that have a volume over 700 ml and hypertrophic is over 1200 ml (Table 2.1) (Coltman *et al.* 2017 ;McGhee and Steele 2020b).

Table 2.1 Breast size classification based on breast volume (Coltman *et al.* 2017)

Breast volume range	Breast size classification
<350 ml	Small
350-700 ml	Medium
701-1200 ml	Large
>1200 ml	Hypertrophic

2.4 OVERVIEW OF THORACIC SPINE (UPPER BACK)

The thoracic spine consists of 12 vertebrae. This spinal region has limited mobility due to the presence of surrounding structures such as the sternum and rib cage (Smith 2022; Middleditch and Oliver 2005). These structures provide vital protection for organs such as the heart, lungs, and major arteries and veins (Middleditch and Oliver 2005). Additionally, the thoracic spine consists of two types of vertebral bodies, namely typical and atypical vertebrae (Moore, Dalley and Agur 2017).

The typical thoracic vertebrae T5–T8, as depicted in Figure 2.5 (Moore, Dalley and Agur 2013), are recognisable by their heart-shaped vertebral bodies which increase in size towards the lumbar region. Their superior facets are closer to the root of the pedicle and more prominent than the inferior facets, which are located anterior to the inferior vertebral notch (Middleditch and Oliver 2005). The spinous processes that are found in the thoracic region are longer when compared to the other spinal regions and originate from the junction of the laminae and extend downward and backward (Middleditch and Oliver 2005; Smith 2022). Their transverse processes are broad and symmetrical, providing attachment sites for surrounding musculature and also consist of short pedicles that extend posteriorly from the postero-lateral aspect of the vertebral. The articular process consisting of two superior articular processes arising from the laminae near the pedicles and two inferior articular processes fused to the lateral margins of the laminae (Middleditch and Oliver 2005).

Additionally, each inferior articular process contains a facet on its anterior surface, known as the apophyseal joint (Middleditch and Oliver 2005). The vertebral foramen in the thoracic region is small and round, with the narrowest point found at the sixth thoracic vertebrae. This characteristic makes the spinal cord more susceptible to space-occupying lesions and nerve entrapment, further reducing the size of the vertebral foramen (Middleditch and Oliver 2005).

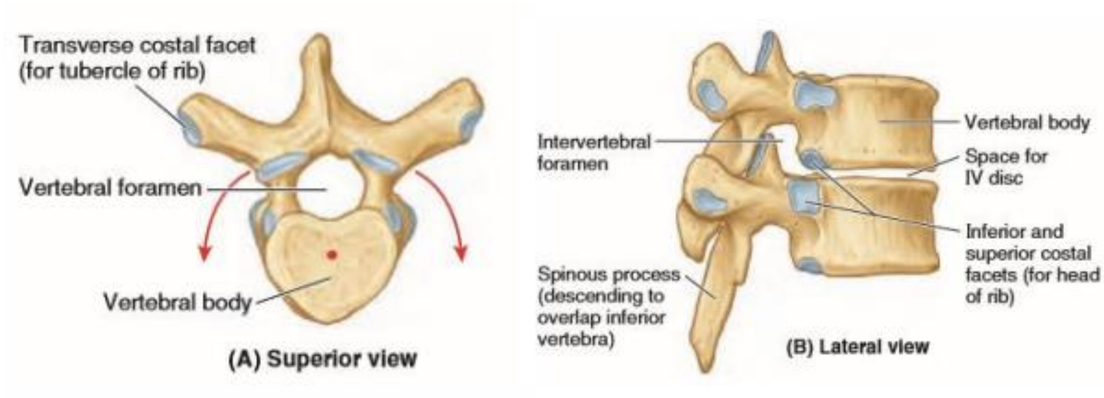

Figure 2.5 Superior and lateral views of typical thoracic vertebrae (Moore, Dalley and Agur 2013)

Atypical vertebrae in the thoracic region, including T1–T4, share several characteristics with the lower cervical vertebrae (C6/C7). The junction between cervical and thoracic regions, located at C7/T1, is the most prominent vertebrae visible on surface anatomy (Moore, Dalley and Agur 2017). T1 exhibits two cervical vertebrae characteristics that are not typically found in thoracic vertebrae. These include an uncinate process and superior vertebral notches above the pedicles. Additionally, the first thoracic vertebrae have a rectangular shape, similar to that found in the cervical vertebrae, and a broad spinous process that extends directly posterior (Cramer 2014).

T9 to T12 have features similar to those found in the lumbar vertebrae (Cramer 2014). The transverse processes of T11 and T12 do not contain any costal facets; however, they have a single pair of costal facets for rib articulation (Smith 2022). T12 is the vertebrae that shows the most significant change in features as its superior aspects contain thoracic features for rib articulation whereas its inferior aspects have lumbar spine characteristics such as the absence of costal facets (Moore, Dalley and Agur 2017).

2.4.1 The Ligaments of the Thoracic Spine

2.4.1.1 Anterior Longitudinal Ligament

The anterior longitudinal ligament is a broad fibrous band that runs along the anterior aspect of the vertebral body and its intervertebral discs, extending from the sacrum all the way superiorly to the anterior tubercle of the first cervical vertebrae (Moore, Dalley and Agur 2013). Its primary role is to prevent hyperextension of the spine as well as stability (Moore, Dalley and Agur 2017). The thoracic anterior longitudinal ligament is known to be narrower in comparison to the cervical and lumbar spine (Cramer 2014).

2.4.1.2 Posterior Longitudinal Ligament

The posterior longitudinal ligament is a thinner and weaker ligament when compared to the anterior longitudinal ligament (Moore, Dalley and Agur 2013). It travels along the posterior aspect of the vertebral bodies with its main function being to prevent disc herniation (Moore, Dalley and Agur 2013). The posterior longitudinal ligament is found to be broader in the upper thoracic region.

2.4.1.3 Ligamentum Flavum

Ligamentum flavum is a ligament that joins adjacent laminae and is known to be long and thin in the thoracic region (Moore, Dalley and Agur 2013). It is made up of 80% elastic fibres with the remaining 20% being densely packed collagen fibres. This ligament allows limited flexion in order to prevent disc injury (Cramer 2014).

2.4.1.4 Interspinous Ligament

The interspinous ligament is a ligament found between adjacent spinous process (Moore, Dalley and Agur 2013). It is known to be thinner in structure and fully developed in the thoracic region (Cramer 2014).

2.4.1.5 Supraspinous Ligament

The supraspinous ligament is responsible for connecting the spinous processes that are adjacent to each other (Moore, Dalley and Agur 2013). It is composed of two layers in the thoracic spine. The deep fibres of this ligament run between adjacent vertebrae, while the superficial fibres travel up to four vertebrae (Cramer 2014). Additionally, these deep fibres of the thoracic supraspinous ligament are continuous with the interspinous ligament (Cramer 2014).

It is also important to note that thoracic spinal ligaments are also known to be a causative factor of thoracic spinal pain (Chen *et al.* 2020). This is because certain conditions are more commonly found in the thoracic region. This includes diffuse idiopathic skeletal hyperostosis that leads to the calcification and ossification of spinal ligaments (Mader *et al.* 2020) as well as ankylosing spondylitis which is an inflammatory condition affecting many body structures, including the ligaments. Ankylosing spondylitis leads to ossification of spinal ligaments which leads to the formation of syndesmophytes, leading to spinal pain and limited range of motion (Mortezazadeh *et al.* 2020).

2.4.2 Joints

2.4.2.1 Facet Joints

Facet joints, also known as apophyseal joints (Figure 2.6), are known to be a type of plane synovial joint that allows articulation between the upper articular process with the lower articular process of the vertebral body (Moore, Dalley and Agur 2017). Each facet is protected by a thin joint capsule that contains synovial fluid (Moore, Dalley and Agur 2013). The facet joints that are located in the thoracic spine are angled at 60 degrees to the horizontal plane as well as 20 degrees to the coronal plane, which, in turn, limit the thoracic spine flexion and extension of the thoracic spine (Moore, Dalley and Agur 2013).

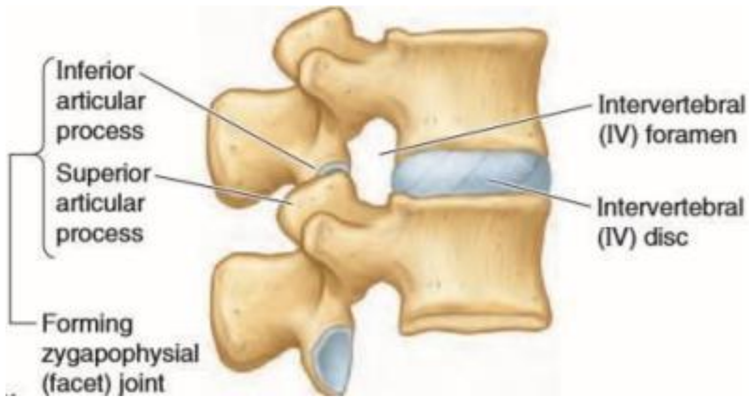

Figure 2.6 Facet joints (Moore, Dalley and Agur 2017)

2.4.2.2 Costotransverse Joints

The costotransverse joint (Figure 2.7) is a synovial joint that allows articulation between the ribs and the thoracic spine and is supplied by the lateral branch of the posterior rami (Cramer 2014; Young, Sizer and Day 2018). It contains a small synovial cavity surrounded by a weak capsule however, it is supported by a costotransverse ligament that binds the articular processes resulting in motion restriction (Young, Sizer and Day 2018). The costotransverse joints alongside the ribcage allows postural stability. However, the rib cage limits lateral flexion and rotation, resulting in limited movement that can be completed of the costotransverse joints (Cramer 2014).

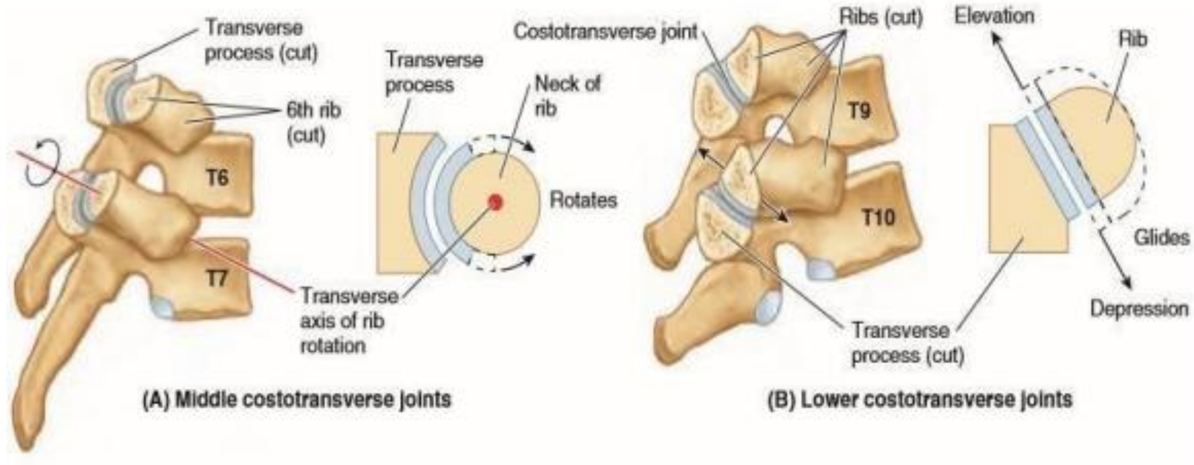

Figure 2.7 Articulations of the costotransverse joints (Moore, Dalley and Agur 2017)

2.4.2.3 Intervertebral Discs

The intervertebral discs are known as the main avascular secondary cartilaginous joints that makes up to 30% of the length of the spine where they act as shock absorbers to reduce the impact on the spine and also act as a pathway of nutrients to enter the spine and spinal cord (Moore, Dalley and Agur 2013; Frost, Camarero-Espinosa and Foster 2019). With the help of spinal movement, the nutrients and oxygen travel via diffusion from the pre-disc vessel to the outermost layer (De Geer 2018). Each intervertebral disc consists of three parts, namely a thick outer frame, known as the annulus fibrosis; a nucleus pulposus and a cartilaginous endplate (Figure 2.8) (Frost, Camarero-Espinosa and Foster 2019).

The thoracic spine contains 12 intervertebral discs (T1/T2-T12/L1). These thoracic intervertebral discs are known to be larger in their cross-sectional area but remain thinner when compared to the cervical region but remain smaller than those found in the lumbar spine (Frost, Camarero-Espinosa and Foster 2019). This is based on the fact that the thoracic spine has minimal flexion/extension and rotation compared the other regions of the spine (Frost, Camarero-Espinosa and Foster 2019). Because of limited mobility of the thoracic spine, the intervertebral discs are less prone to torsional stress, reducing the risk of injury (Frost, Camarero-Espinosa and Foster 2019).

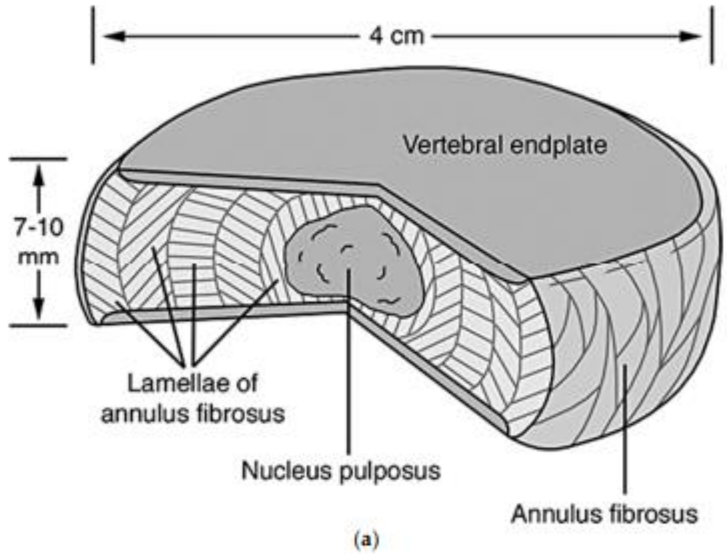

Figure 2.8 Cross section of the intervertebral disc (Frost, Camarero-Espinosa and Foster 2019)

2.4.3 Nerve Supply

The thoracic spinal nerves are less specialised per vertebrae when compared to the cervical and lumbar spine, but it is the origin of the sympathetic nervous system, making it an essential area for involuntary functions such as heart rate and breathing rate (Frost, Camarero-Espinosa and Foster 2019). The thoracic region consists of 12 spinal nerves (T1–T12), which pass through the intervertebral foramina inferiorly to the corresponding vertebrae (Moore and Dalley 2018). Once these nerves pass the IV foramina, they divide into the posterior and anterior rami to enter the thoracic wall (Moore and Dalley 2018). The anterior rami of T1–T11 then forms the intercostal nerves that supply the intercostal spaces, whereas T12 forms the subcostal nerve (Moore and Dalley 2018). The posterior rami then travel posteriorly to supply the thoracic muscles, joints, and skin (Figure 2.9) (Moore and Dalley 2018).

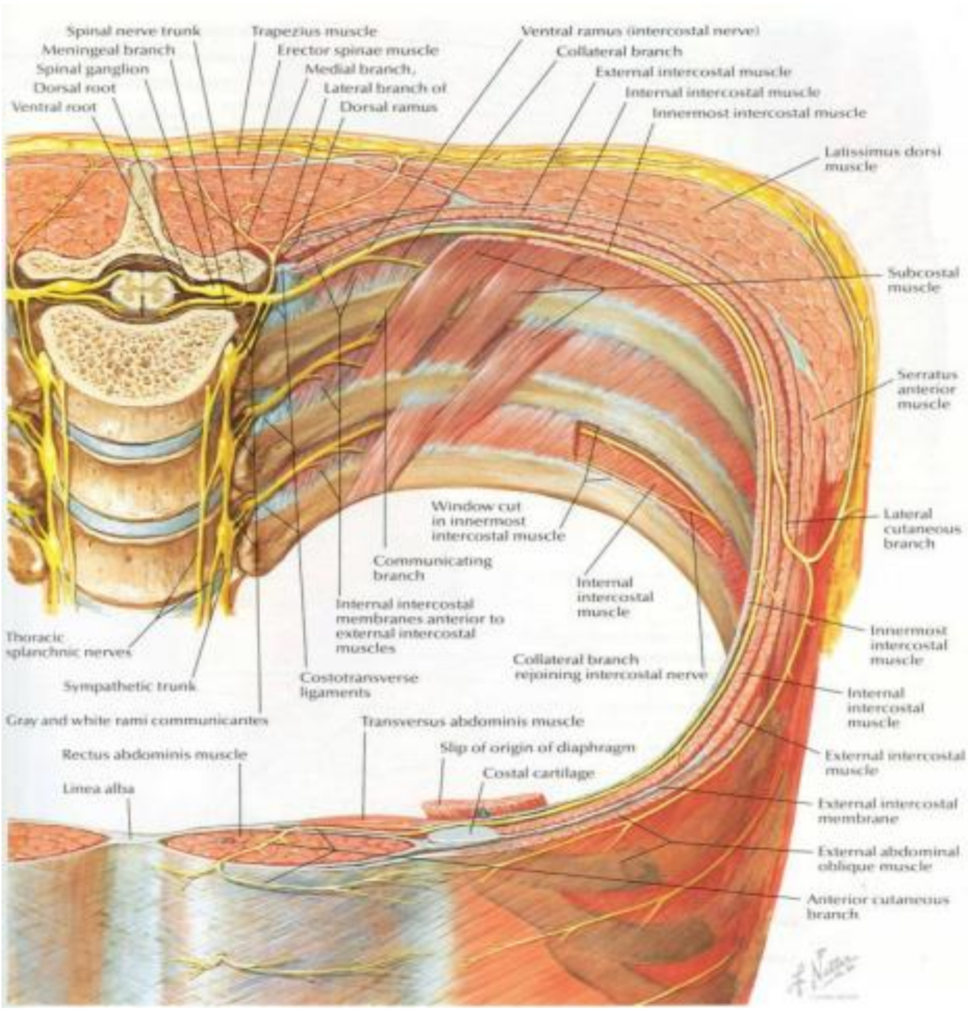

Figure 2.9 The pathway of spinal nerves of the thoracic spine region (Ndlovu 2006)

2.4.4 Muscles of the Thoracic Region

The muscles of the vertebral column (Table 2.2) are one of the most important aspects of the musculoskeletal system in order to maintaining posture and allow spinal movement and stabilization (Cramer 2014). The thoracic muscles are known to have an important role when it comes to respiration, mobilization and, stabilization (Tortora and Derrickson 2014). The trapezius, lattisimus dorsi, rhomboid major and minor, serratus posterior, splenus capitus, erector spinae and, levatores costarum provides mobility whereas the multifidus and rotatores provides stabilization (Moore, Dalley and Agur 2012).When the biomechanics are alterted it will result in saggital imbalance leading to surround muscular to compensate resulting in muscular strain (Spencer et al. 2019; Spencer and Briffa 2013; Michalik et al. 2022).

Table 2.2 The muscles of the thoracic region (Moore, Dalley and Agur 2013)

Muscle	Proximal attachment	Distal attachment	Innervation	Main action
Trapezius	Spinous processes of C7–T12	Lateral third of clavicle and spine of the scapula	Accessory nerve (XI)	Retraction of the scapula
Latissimus dorsi	Spinous process of T7–T12 Iliac crest	Intertubercle sulcus of the humerus	Thoracodorsal nerve (C6-C8)	Extension of the humerus
Rhomboid major and minor	Major: Spinous process of T2–T5 Minor: Spinous process of C7–T1	Major: Vertebral border of the scapula Minor: Vertebral end of the spine of the scapula	Dorsal scapula nerve (C4-C5)	Retracts the scapula
Serratus posterior superior	Spinous process of C7–T3	Superior aspect of 2nd–4th ribs	Intercostal nerves (2nd–5th)	Rib elevation
Serratus posterior inferior	Spinous process of T11–L2	Inferior aspect of 8th–12th ribs	Thoracic spinal nerves (T9–T12)	Rib depression
Splenius capitis	Spinous process of C7–T6	Mastoid process	Posterior rami of spinal nerves	Neck extension
Erector spinae: Thoracis longissimus Thoracis spinalis	Spinous processes of lumbar and sacral region	Longissimus: Transverse processes of the thoracic regions Spinalis: Spinous processes of upper thoracic region	Posterior rami of spinal nerves	Spinal extension
Thoracis semispinalis	Transverse processes of C4–T12	Occipital and spinous process of 4–6 segments	Posterior rami of spinal nerves	Thoracic extension
Multifidus	Posterior sacrum and transverse processes of T1–T3	Entire length of spinous processes	Posterior rami of spinal nerves	Stabilise the vertebrae during functional movement
Rotatores	Arise from transverse processes, best developed in thoracic region	Spinous process of vertebrae two segments superiorly	Posterior rami of spinal nerves	Stabilise the vertebrae
Levatores costarum	Transverse processes of C7–T11	Between the rib angle and tubercle	Spinal nerves (C8–T11)	Elevates ribs

2.5 UPPER BACK PAIN

2.5.1 Understanding Upper Back Pain

Upper back pain, also known as thoracic spine pain, is known to be a common problem among many individuals who are seen by primary healthcare practices as it is a common region for inflammatory and degenerative conditions (Briggs et al. 2009). It is defined as discomfort that is experienced in the region defined by a line traversing the tip of the spinous process of T1 superiorly, a line traversing above the costal margin at the tip of the spinous process of T12 inferiorly, and a vertical line tangent to the lateral margins of the erector spinae muscles bilaterally (Briggs *et al.* 2009; Myburgh 2016; Hasuo, Shizuma and Fukunga 2021).

Thoracic spine pain can be categorised into three types based on its duration (Myburgh 2016). Acute thoracic spine pain lasts for less than three months and is usually caused by sudden movements resulting in short periods of pain (Ndlovu 2006; Myburgh 2016). Subacute thoracic spine pain persists for six to 12 weeks or may go away and come back after some time (Ndlovu 2006; Nicholas 2022). Chronic thoracic spine pain lasts for over three months and presents in an episodic manner and known to be most commonly seen in autoimmune diseases such as systemic lupus erythematosus, as well as rheumatoid arthritis (Briggs *et al.* 2009; Myburgh 2016; Singh 2023).

2.5.2 Prevalence of Upper Back Pain

Fouquet *et al.* (2015) showed that upper back pain affects up to 9% of men and 17% of women between the ages of 20 and 59 ,who work seated daily, causing a decline in their quality in life (Spencer *et al.* 2019). With this higher prevalence among women, it was further predicted that 72% of women will experience upper back pain in their lifetime (Spencer *et al.* 2019; Fouquet *et al.* 2015; Briggs *et al.* 2009). The reason for a higher prevalence among women could be explained by certain factors such as:

- Musculoskeletal (Queme and Jankowksi 2019),
- Psychological (Nasser and Afify 2019),
- Endocrine (Pieretti *et al.* 2016), and,
- Neurophysiological (Presto *et al.* 2022; Melchior *et al.* 2016)

Each of these characteristics are discussed further in the following section.

2.5.2.1 Musculoskeletal

The musculoskeletal system allows the body to move. It is made up structures including the muscles, joints, tendons, ligaments, bones and cartilage which allows body movement and support (Ernstmeyer and Christman 2021).

The prevalence of musculoskeletal pain in the general population has been investigated, and it has been shown that pain arising from the musculoskeletal system is more frequent in women when compared to men, leading to a higher prevalence of women seeking medical care (Fillingim *et al.* 2009; Puntillo *et al.* 2021). The reason for this is based on the biological and biomechanical differences between men and women, in which the female’s muscular tissue contains a greater density of mechanical afferents than men. In turn, it results in an increased response to mechanical distortion as well as metabolites, such as lactate and ATP (Puntillo *et al.* 2021). Furthermore, women have a higher prevalence of certain musculoskeletal conditions, including osteoarthritis, fibromyalgia, and back pain (Templeton 2020).

2.5.2.2 Psychology

Psychology is the scientific study of the mind and behavior to gain more knowledge (Hayes 2023). Psychological processes have a significant emotional component that must be taken into account when examining the differences in pain responses between men and women (Pierette et al. 2016).It is shown that women are more likely than men to experience anxiety disorders and depression, which contributes to an increase in pain response.

Anxiety has been linked to higher rates of clinical and experimental pain sensitivity and is suggested to be a possible mediator of pain sensitivity differences between men and women (Meints and Edwards 2018). The same has been noted in regard to depression as women suffer more from chronic pain compared to men when they have depression (Meints and Edwards 2018). This higher prevalence of depression among women has previously been linked to a higher experience of chronic pain when compared to men (Meints and Edwards 2018). The reason for this has been linked to the function of the hypothalamic-pituitary-adrenal (HPA) axis (Sze and Brunton 2020). The HPA axis is known as the central regulating system that connects the hormonal system with the nervous system which allows individuals to adapt to the given stressor (Tsigos *et al.* 2020). It does so by releasing glucocorticoids, primarily cortisol, from the adrenal cortex into the circulatory system (Handa and Weiser 2014). Studies have demonstrated that the HPA axis exhibits a greater baseline tome in women and that during the stress response, glucocorticoid release increases rapidly, whereas the HPA axis drive decrease becomes delayed (Kokras *et al.* 2012). These elevated glucocorticoid levels have been shown to result in a higher incidence rate of depression and in turn, the impairment of the HPA axis (Kokras *et al.* 2012).

A difference also exists between men and women when it comes to childhood education of pain, which has shown to affect the perception and expression of pain during adulthood (Pieretti *et al.* 2016). Chambers, Craig and Bennet (2002) completed a study where children were exposed to a painful stimulus and the mother had to either provoke the pain or assist in reducing the pain. The results showed that women experienced a more painful expression in social situations when compared to men. This shows that early on in life, men are expected to show less pain and, in turn, do not always seek help when experiencing pain when compared to women (Pieretti *et al.* 2016; Chambers, Craig and Bennet 2022).

2.5.2.3 Estrogen

Estrogen has been shown to have both pronociceptive and antinociceptive effects on the pain pathway making its effect on the perception of pain unclear (Zhang *et al.* 2023). Estrogen is a steroid hormone secreted by the ovaries to promote growth and maintenance of the female reproductive system and affects neurotransmitters such as serotonin and endorphins (Ngoie 2018). Estrogen has been shown to lead to an increase in pain responses, especially during the different stages of the menstrual cycle (Pieretti *et al.* 2016; Templeton 2020). However, a more recent study elaborated further and examined the differences in pain response between the early to mid-follicular phase as well as the mid-luteal phase. This study found no significant differences between the two phases (Zhang *et al.* 2023).

2.5.2.4 Neuroimmunological Factors

The immune system's role in pain processing has been shown to be gender dependent. Females have a higher cytokine release during tissue damage, which in turn leads to more pain and inflammation and increases the prevalence of autoimmune conditions in women (Nasser and Afify 2019).

Furthermore, there is an increase in evidence suggesting that neuroinflammation is a causative factor of central nervous system diseases such as neuropathic pain and multiple sclerosis. Neuropathic pain is the sudden onset of pain that manifests abnormal sensory symptoms, such as hyperalgesia and allodynia, due to mechanical stimuli (Coraggio *et al.* 2018). This continuous pain transmission to the brain leads to central sensitisation which is increased excitability of the pain processing neurons and microglial cell activation, known as neuroinflammation. Males tend to present with greater levels of microglia, whereas women's neuroinflammation is mainly caused by immune cells and more exposure to neurodegenerative diseases (Coraggio *et al.* 2018). This was further explored by Coraggio *et al.* (2018) who focused on sexual dimorphism needed in microglia. They found that there is no difference within the central nervous system; however, changes were noted in the peripheral nervous system, especially in regard to immune cell proliferation. The difference between men and women regarding the microglia's number and molecular type during its development has been reported. These differences can explain the different predispositions of women and men for some brain pathologies at different brain development stages (Coraggio *et al.* 2018). However, the mechanisms that underlie the difference between sexes should still be well clarified especially regarding the hormonal causes.

Breasts have been shown to be a source of pain in women. It can vary from actual breast pain due to underlying factors such as cyclic breast pain (menstrual cycle) and non-cyclic pain (not related to menstrual cycle) such as Cooper's ligament stretching, periductal mastitis, cyst or pain felt in surrounding areas such as the upper back due to the breast tissue size or metastatic breast cancer (Santen 2018; Spencer 2022; Pontes *et al.* 2020).

2.5.3 Causes of Upper Back Pain

Despite its significant impact on the general population, thoracic spine pain is often overlooked and neglected, leaving a paucity in the literature in regard to its prevalence and incidence (Briggs *et al.* 2009). Current literature has found thoracic spine pain to be just as disabling as cervical and lumbar pain and be quite challenging to diagnose and treat (Edmonston and Singer 1997; Heneghan and Rushton 2016; Myburgh 2016). Thoracic spine pain can result from numerous sources including additional structures attaching to this region such as the rib cage and costotransverse joints but it is often labelled as non-thoracic spine pain (Myburgh 2016; Heneghan and Rushton 2016). Thoracic spine pain has been commonly linked to primary diseases such as tumours, osteoporosis, ankylosing spondylitis, and other inflammatory conditions. The differential diagnosis of thoracic spine pain is presented in Table 2.3 (Myburgh 2016).

Table 2.3 Differential diagnosis of thoracic spine pain (Myburgh 2016)

MECHANICAL THORACIC SPINE PAIN		NON-MECHANICAL AETIOLOGIES	
	Spinal disorders	Visceral disorders	Others
Thoracic spine strain or sprain Degenerative joint disease Spinal stenosis Intervertebral disc lesions Costovertebral and costotransverse syndrome Facet joint syndrome T4 syndrome Congenital anomlies Scoliosis Kyphosis Scheuermann’s disease Fracture Trauma Osteoporosis Other Costochondritis Myofascial pain and dysfunction Fibromyalgia	Neoplasm Primary Secondary Intramedullary Extramedullary Infection Osteomyelitis Tuberculosis Inflammatory arthropathies Seropositive spondyloarthropathies Rheumatoid arthritis Seronegative spondyloarthropathies Ankylosing spondylitis Reiter’s syndrome Psoriatic arthritis Enteropathic arthritis Diffuse idiopathic skeletal hyperostosis Metabolic Osteoporosis Osteomalacia Hyperparathyroidism Cushing’s disease Eosinophilic granuloma Ochronosis	Cardiovascular disease Myocardial infarction Angina pectoris Coronary insufficiency Pericarditis Pulmonary embolism Bacterial endocarditis Heart valve disease Dissecting aneurysm Pulmonary disease Embolus, Infarction Pneumothorax Pneumonia Pleurisy Carcinoma Abdominal disease Peptic ulcer Hernia: hiatal, inguinal Pancreatitis Cholecystitis, Biliary colic Hepatitis Hepatobiliary abscess Pyelonephritis Ureteral colic	Iiatrogenic Post-thoracotomy syndrome Psychogenic Depression Anxiety Malingering Hysteria

2.5.4 Risk Factors Linked to Upper Back Pain

According to Roquelaure *et al.* (2014) the upper back pain risk factors can be divided into four groups:

1. Individual factors.
2. Organisational factors.
3. Biomechanical factors.
4. Gender.

Individual factors, such as height, were found to be an essential risk factor in individuals with upper back pain (Roquelaure *et al.* 2014). Taller individuals have a higher risk of strain on the thoracic spine region during manual handling (Roquelaure *et al.* 2014). This is supported by Monnier *et al.* (2016), who reported that marines taller than 1.86 metres reported higher levels of back pain compared to those below 1.86 metres, which was found due to increased leverages (Monnier *et al.* 2016).

Organisational factors, such as individuals in the workplace who are overworked at work and working for long periods of time without any rest, presented with higher prevalence of thoracic spine pain (Roquelaure *et al.* 2014). This is based on that the body requires high physical demand during manual handling without any rest in between tasks (Roquelaure *et al.* 2014). Standing for long periods of time with associated repetitive bending over at work is one of the main biomechanical factors that have been associated with thoracic spine pain in the working population (Roquelaure *et al.* 2014). These postural strains result in myofascial pain of the trapezius, levator scapulae, and serratus anterior (Joshi, Balthillaya and Neelapala 2019; Roquelaure *et al.* 2014). In adolescents and adults, prolonged sitting at computer or phone usage has been linked to thoracic spine pain. This is due to the downward shift of the neck, as well as inadequate elbow and wrist support, and results in a continuous flexed position of the neck and thoracic spine, leading to repeated stress on the surrounding musculature (Kanchanomai, Janwantanakul and Jiamjarasrangsi 2013; de Vitta *et al.* 2022).

2.5.5 Management of Upper Back Pain

The management of lower back pain and neck pain is well defined but research on regarding thoracic spine pain and its treatment remains limited despite the growing prevalence of thoracic spine pain (Heneghan *et al.* 2019). A study that did expound of this prevalence was completed by Tsolakis (2001), who stated that the thoracic region is a very common site for chronic myofascial pain and in turn requires direct soft tissue treatment. Tsolakis (2001) focused on comparing interferential therapy and spinal manipulation of thoracic spine pain. Tsolakis (2001) found both treatments effective and concluded that individuals may benefit from both manipulative and interferential current therapy to treat their thoracic spine pain. This is strengthened by Heneghan *et al.* (2019) and Smith (2022) who stated that thoracic spinal mobilisation and manipulation are most commonly used to manage functional impairment of the spine and has shown to have a mechanical effect globally on the thoracic region (Smith 2022; Heneghan *et al.* 2019). Other treatment methods, such as dry needling and ischemic compression, are commonly used to alleviate myofascial-related upper back pain (Myburgh 2016). This is supported by Lew, Kim and Nair (2021), who examined the effect of dry needling therapy and ischemic compression on trigger points in the upper back region. The study compared the effectiveness of dry needling therapy and ischemic compression in improving the improving the pain pressure threshold score. The findings indicated that both dry needling and ischemic compression led to a reduction in pain among participants presenting with upper back and neck pain (Lew, Kim and Nair 2021).Lew, Kim and Nair (2021) also included range of motion stretching in conjunction with dry needling and found it to improve the overall treatment outcome.

2.6 FACTORS LINKING BREAST SIZE AND UPPER BACK PAIN

The breast tissue consists of adipose and fibroglandular tissue that is attached onto the thoracic wall via the muscular fascia of the pectoralis major, rectus abdominus, and the periosteum of the fifth or sixth rib (McGhee and Steele 2020b). During body mass gain, menstruation, pregnancy and breastfeeding, the breast adipose tissue increases and glandular tissue proliferates, which may lead to breast hypertrophy (McGhee and Steele 2020b). Breast hypertrophy is known as large breasts that are disproportionate to their biotype. This imbalance caused by breast hypertrophy leads to postural chances as well as back pain, restricting everyday activities (Fonseca *et al.* 2018).

Breast hypertrophy is a primary cause of upper back pain in women (Coltman *et al*. 2018). However, despite the high prevalence of upper back pain linked to breast hypertrophy, it has not been thoroughly examined as a risk factor (Spencer *et al.* 2019). Minimal research has been conducted to demonstrate the impact breast hypertrophy has on the spine itself (Letterman and Schurter 1980). Breast hypertrophy is characterised as an increase in volume of breast tissue (Spencer 2019). It has been shown to be a common medical condition with numbers rising over the past few years that negatively impacts women at work and home (Spencer *et al.* 2019). Breast hypertrophy has been shown to cause changes in certain biomechanical components (McGhee, Coltman *et al.* 2018).

McGhee, Coltman *et al.* (2018) showed that a higher pain rate was present in women with large breasts compared to women with smaller breasts. This is supported by Coltman *et al.* (2019) who found higher pain rates in 60% of women with hypertrophic breast volume when compared to smaller (Coltman *et al.* 2019). Other factors related to the breast, such as breast ptosis and splay, also increase the prevalence of upper back pain in women with breast hypertrophy (Brown et al. 1999).

2.6.1 Breast Hypertrophy and Posture

The majority of studies regarding breast size have focused primarily on how breast hypertrophy affects spinal posture. The human body posture is supported and maintained by its musculoskeletal system (Bennett 2009). The normal centre of gravity of the human body travels from the external auditory meatus to the odontoid process, where it travels through the middle of the shoulder joint and slightly posteriorly to the hip joint centre and posterior to the patella, to end at the junction between the calcaneus and cuboid (Figure 2.11) (Bennett 2009).

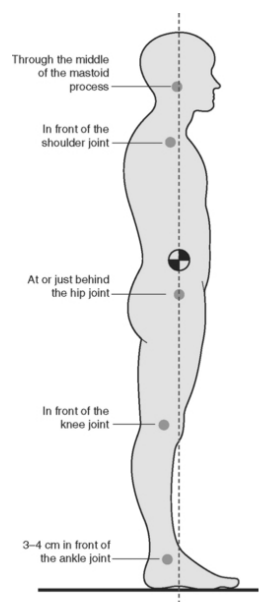

Figure 2.10 The line of gravity and its locations (Themes 2016)

However, breast hypertrophy leads to a shift in the centre of gravity (Mazzocchi *et al.* 2012). This may be because the nipple, in women with breast hypertrophy, may be positioned lower than its ideal anatomical location, resulting in the shift of centre of gravity and sagittal imbalance causing surround muscles to compensate (Spencer *et al.* 2019; Spencer and Briffa 2013; Michalik *et al.* 2022). This further results in an increase in thoracic kyphosis ,cervical lordosis and muscular sensitivity (Spencer *et al.* 2019).

Thoracic kyphosis is defined as the spinal curvature located in the sagittal plane and is known as one of the main biomechanical components that links breast size to upper back pain, with the average degree of curvature to be known as 20-40 degrees (Spencer *et al.* 2019; Letterman and Schurter 1980; Fon, Pitt and Thies 1980). Hyperkyphosis results from larger breast sizes, which is an excessive curvature of the thoracic spine over 40 degrees (Fon, Pitt and Thies 1980; McGhee, Coltman *et al.* 2018). This has been further examined by Findikcioglu *et al.* (2007) who used radiographic images to assess the difference in curvature between larger and smaller breast sizes, in which it was found that women with D-cup sizes have greater kyphosis when compared to A cup-size breasts (Figure 2.12) (Findikciolgu *et al.* 2007). These spinal alterations lead to further changes in biomechanics, such as an altered scapula position leading to a decrease in the range of motion of the upper limb (Bennett 2009).

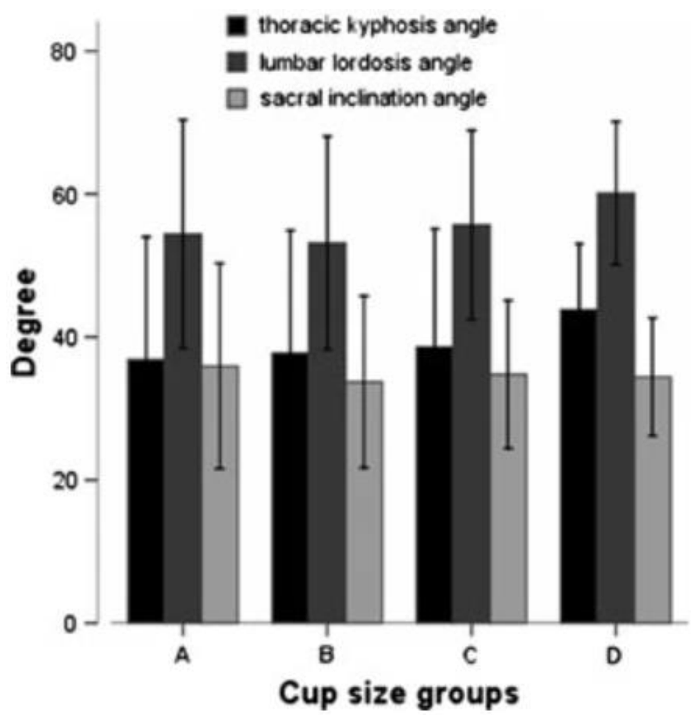

Figure 2.11 The vertebral angles of the cup size groups (Findikciolgu et al. 2007)

These posture alternations in women with breast hypertrophy are not only biomechanical components but have also been shown to be psychological (Mazzocchi *et al.* 2012). Females with breast hypertrophy are shown to attempt to hide their breasts by protracting their shoulders as they feel too embarrassed by their breast size (Mazzocchi *et al.* 2012). It is worth noting the positive effect reduction mammoplasty has on posture and self-image, where Mazzocchi *et al.* (2012) showed that just after four months (post-surgery), these women had an improvement in their posture. This included repositioning the head as well as opening up the shoulders

(Mazzocchi *et al.* 2012). This is strengthened by a study completed on women undergoing reduction mammoplasty, as Tran *et al.* (2016) showed improvements in thoracic kyphosis angles where the Cobb angle changed by 7.85 degrees (Figure 2.13). The Cobb angle is known to be obtained from radiographic images of the spine in a lateral position. This angle is calculated where the kyphotic angle starts, which usually is T4-T12 (Tran *et al.* 2016). It is the standard method of measuring scoliosis and kyphosis (Tran *et al.* 2016).

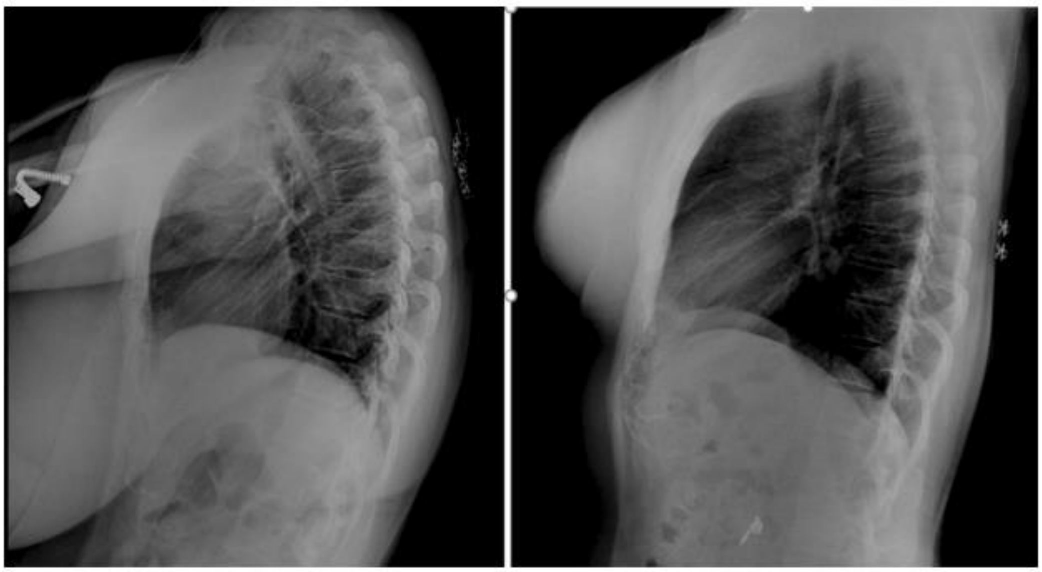

Figure 2.12 Correction of thoracic kyphosis on lateral spinal radiography (Yücel et al. 2024)

2.6.2 Ptosis and Breast Splay

Both breast ptosis and breast splay have been shown to be highly prevalent in women with breast hypertrophy, due to the lateral breast margin that moves laterally and carries most of the weight when compared to the stationary medial border (Brown et al. 1999). Females with breast hypertrophy have been shown to have great ptosis as well as breast splay (Spencer *at al.* 2019). Ptosis of the breasts is defined as the inferior position of the nipple in regard to its inframammary fold (Spencer *et al.* 2019). It most commonly occurs due to the supporting structures such as the Cooper's ligament, and pectoralis muscle start to lose firmness (Shunnmugam *et al.* 2023). It has been shown to be a common characteristic that is seen in women with breast hypertrophy that results in physical symptoms, such as neck and back pain, only relieved by breast reduction with correction of ptosis (Uebel *et al.* 2019; Shunnmugam *et al.* 2023). Schneider-Affeld (2009) classified breast ptosis according to the Regnault classification that assesses breasts according to the nipple position to the inframammary fold (Table 2.4).

Table 2.4 Regnault classification (Schineider-Affeld 2009)

<table>
<tr><td rowspan="3">Complete or true ptosis</td><td>Grade I</td><td>Areola at the height of the inframammary fold and above the breast</td></tr>
<tr><td>Grade II</td><td>Areola below the inframammary fold and above the breast contour</td></tr>
<tr><td>Grade III</td><td>Areola below the inframammary fold and the contour of the breast</td></tr>
<tr><td>Partial Ptosis</td><td colspan="2">Areola above mammary fold and gland ptosis</td></tr>
<tr><td>Pseudoptosis</td><td colspan="2">Areola above mammary fold; loose hypoplastic skin (marked weight loss after pregnancy)</td></tr>
</table>

Breast splay is defined as the distance found between the right and left nipple where tape measurements are used while the individual is seated (Westreich 1997). It has been noted to be more common in women with a higher body mass index which results in these women having breast hypertrophy and a higher breast splay, which in turn has shown to affect the force that the breast has on the upper back (Spencer *et al.* 2019; Coltman *et al.* 2018).

2.6.3 Incorrect Bra Size Wear

It was estimated that 70% of women wear the incorrect bra size which is most commonly noted in women with breast hypertrophy (Greenbaum *et al.* 2003; Wood, Cameron and Fitzgerald 2008). This, in turn, results in poor posture and upper back pain that have led many women to shy away from having a physical active lifestyle (Greenbaum *et al.* 2003; Coltman *et al.* 2014). Many factors have been found to be the reason why women wear incorrect bra sizes, including a lack of standardisation guidelines for bra fitting, women not getting their bras professionally fitted, a lack of education about bra fit (Coltman *et al.* 2017; Haworth *et al.* 2022; Greenbaum *et al.* 2003; McGhee and Steele 2010).

Bra straps are designed to provide additional support for the breasts and keep the bra aligned to the body. However, when the bra straps are too tight, it may result in a downward drag of the breast weight (Haworth *et al.* 2022; Ryan 2000). Furthermore, when the bra cup is too large, the shoulder strap bears most of the weight of the breast volume, leading to the shoulders pulling down, leading to ischemia of the trapezius muscle and upper back pain (Haworth *et al.* 2022)

It is challenging to find the correct and supportive bra size for women with larger breasts; however, it is theorised that correction of bra size is the primary non-surgical protocol to manage upper back pain related to breast hypertrophy (Spencer and Briffa 2013; Kerrigan, Collins *et al.* 2002). Mthabela (2015) investigated this by looking at the effect of wearing the correct bra size on women's posture and found that a supportive bra relieved up to 85% of female participants with upper back pain. This is further supported by Kerrigan *et al.* (2002) who showed that 3% of women with hypertrophic breasts had minimal back pain after they wore a supportive bra.

2.7 RELATIONSHIP BETWEEN MUSCLE SENSITIVITY, BREAST SIZE AND UPPER BACK PAIN

As the literature suggests, there are various factors linking breast size to upper back pain, due to the shift in centre of gravity, leading to musculature changes from the downward traction of breast hypertrophy, placing stress and strain on surrounding muscles of the upper back region leading to muscular sensitivity (Coltman *et al.* 2013; Spencer *et al.* 2019) .

Spencer *et al.* (2022) examined the relationship between breast size and musculoskeletal sensitivity using the pain pressure threshold to measure the sensitivity of the upper back musculature by means of a pressure algometer. The pain pressure threshold is defined as the minimum intensity that is required for a painful stimulus due to pressure to be perceived as painful. Spencer *et al.* 2022 found that women with larger breasts experience greater sensitivity in their sternocleidomastoid muscle. Tomer and Verma et al. (2020).

2.8 GAP IN THE LITERATURE

The limitations of previous studies were small sample sizes and limited sample size of larger breasted women because it was found that women with larger breasts feel embarrassed about their breasts and did not want to participate in such studies (Lyidobi *et al.* 2021) . A study conducted in 2008 by Wood, Cameron and Fitzgerald found no correlation between breast size and pain but a more recent study, conducted by Coltman *et al.* (2018), found that having a larger breast size significantly increases the likelihood of experiencing back discomfort (Coltman *et al.* 2018).

It is also worth noting that the majority of the studies regarding the relationship between breast size and upper back pain have mainly focused on post-menopausal women (Spencer *et al.* 2022; Spencer and Briffa 2013). Lower estrogen levels decrease bone mineral density leading to narrower intervertebral disc spaces which results in facet joint arthritis and osteoporosis which results in a higher incidence of back pain in post-menopausal women (Wang 2017). It is important to note that the findings of these studies cannot be generalized or applied to pre-menopausal women as post menopausal women, who are 40 years old and above, have an increased chance of presenting with post-menopausal factors,(Wang, 2017; Cauley, 2015).

In addition, studies regarding breast size and upper back pain have primarily been done in countries such as Australia and Canada, which is predominantly Caucasian in ethnicity (Coltman *et al*. 2018). The results of these studies cannot be extrapolated or equated to a South African population as the cultural traditions and diverse ethnicity existing in south Africa differs significantly from other countries (Khumalo and Haffejee 2022; Ndlovu 2006), leaving a lack of research in developing countries. Furthermore, cultural traditions such as women carrying heavy object on their heads and traditional seating postures, play a vital role in identifying factors leading to back pain in the South African context (Khumalo and Haffejee 2022; Ndlovu 2006).

2.9 SUMMARY OF THE LITERATURE

Upper back pain is a common complaint amongst the general population and has been shown to be just as disabling as lumbar and cervical spine pain, but it remains understudied especially in the South African context. Upper back pain has many causes ranging from non-thoracic spine pain and most commonly diagnosed as primary diseases. Many factors, such as musculoskeletal, psychological, endocrine and neurophysiological characteristics contribute to the higher prevalence of upper back pain in women but breast hypertrophy with breast-associated characteristics is shown to be the main causative agent.

Breast hypertrophy is a frequent complaint amongst many women experiencing upper back pain but literature on this matter remains limited. Breast hypertrophy results in changes in spinal posture, which in turn result in muscular compensation. Other factors related to the breast, such as breast ptosis and splay, also increase the prevalence of upper back pain in women with breast hypertrophy.

Ill-fitting bra with bra straps that are too loose of too tight must also be kept in mind when women present with upper back pain. Reduction mammoplasty and bra correction has been shown to be the most effective method in relieving upper back in women with breast hypertrophy (Papanastasiou *et al.* 2019).

Furthermore, limited literature exists in regard to the musculoskeletal sensitivity linked to upper back pain in women specifically. Understanding the muscular effects may contribute to the current literature about breast hypertrophy and its link to muscular sensitive and upper back pain. This would allow future research to be done in this field, leading to an improvement in the management of patients with breast hypertrophy who experience upper back pain.

Therefore, the suggestion from Spencer *et al.* (2022) was taken into consideration to re-examine the effect of breast size on the upper back musculoskeletal sensitivity using the digital algometer. The study focused on pre-menopausal women in Durban, KwaZulu-Natal, who had a pain pressure threshold of 12 anatomical sites assessed. The participants were divided into two cohorts based on their experience with upper back pain, and their underbust and overbust measurements were recorded to determine their cup size. The study aimed to re-examine the association between breast size,upper back musculature and musculoskeletal sensitivity.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This chapter highlights the methods used to carry out the study. It includes the study's design, the methodology used, and the inclusion and exclusion criteria for the potential participants. Furthermore, this chapter also explains the sampling procedure utilised in the study.

3.2 STUDY DESIGN

The research study followed a quantitative, case-control observational study design. Quantitative research emphasises quantification in collecting and analysing the relevant data of the participants to measure the variables that exist in the social world (Rahman 2016). This design was chosen as it provides clarity whether breast size is associated with upper back muscular sensitivity and pain (Taur 2022)

3.3 STUDY LOCATION

The study took place at the Chiropractic Day Clinic (CDC) at the Durban University of Technology (DUT) in Durban KwaZulu-Natal, South Africa. The CDC is known as a chiropractic teaching clinic that provides chiropractic treatment to all individuals by students currently completing their Master's Degree in Health Science of Chiropractic.

3.4 STUDY POPULATION

The study recruited pre-menopausal women between the ages of 18 and 40 years, of all ethnicities, who resided in Durban, KwaZulu-Natal using the following inclusion and exclusion criteria:

3.4.1 Inclusion Criteria

- Participants had to be biological women who resided in Durban, KwaZulu-Natal, South Africa. Biological women have a higher prevalence of upper back pain when compared to men (Fouquet *et al.* 2015).
- Women between the ages of 18-40 were chosen due to:
    - The age of 18 excluded puberty still being in progress if participants were under the age of 18 (Hebert *et al.* 2019). Previous literature states that linear

growth occurring during puberty is associated with higher back pain prevalence in individuals undergoing puberty (Hebert *et al.* 2019).

  - Women who are 40 years old and above have an increased chance of presenting with post-menopausal factors, which includes a decline in estrogen, which results in a decrease in bone density and other hormones, such as serotonin and endorphins (Becker and McGregor 2017; Pieretti *et al.* 2016; Wang *et al.* 2016). This estrogen and bone density decline increases the likelihood of osteoarhritis and osteoporosis, which may result in the pain to rise from non-muscular sources (Coltman *et al.* 2018; Myburgh 2016).

- Bra size A–E to standardise the variables.

3.4.2 Exclusion Criteria

- Women currently menstruating at the time of data collection due to the decline in estrogen, which results in changes in the endogenous pain modulation and analgesia, as well as interacting with the nociceptive process within the peripheral and central nervous system, which in turn results in an increase in pain perception (Zhang *et al.* 2023; Wáng, Wáng and Káplár 2016).
- Menopausal women due to post-menopausal-related factors, such as a decrease in bone density, may have given false results (Coltman *et al.* 2018). Menopause results in a decline in estrogen which, in turn, leads to a decrease in serotonin and endorphins levels, causing an increase in back pain prevalence (Becker and Mcgregor 2017; Pieretti *et al.* 2016; Wang *et al.* 2016). Furthermore, a decline in estrogen affects bone mineral density and can result in osteoporosis (Coltman *et al.* 2018).
- Back trauma and back surgery may give false results as pain may come from other sources such as osteophytes, fractures, scoliosis, and ankylosing spondylitis (Myburgh 2016).
- Back conditions such as arthritis as it may have given false results as the pain may be from non-musculature sources (Myburgh 2016).
- Participants who were currently being administered pain medication within six months of participating in the study e.g., Cataflam, which influences pain perception (Spencer *et al.* 2022).
- Those who did not want to sign the consent form for study participation.

3.5 RECRUITMENT OF PARTICIPANTS

The study recruited participants primarily by distribution of an advertisement on Facebook, Instagram and Whatsapp (Appendix E) and by means of word of mouth. After participants responded to the advertisement, they were subjected to a pre-screening telephonically to ensure eligibility to participate in the study (Table 3.1).

Table 3.1 Telephonic screening questions

<table>
<tr><th>Telephonic questions</th><th>Rationale behind question</th><th>Answer that provides eligibility</th></tr>
<tr><td>Are you between the ages of 18-40?</td><td>Puberty still in progress if under 18 (Hebert et al. 2019)
Over 40, post-menopausal factors such as a decrease in bone density may affect results (Coltman et al. 2018)</td><td>Yes</td></tr>
<tr><td>Are you currently on your menstrual cycle?</td><td>Menstruation causes a decline in estrogen causing an increase in pain perception pain (Wáng, Wáng and Káplár 2016)
Ensure women are not menopausal</td><td>No</td></tr>
<tr><td>Do you wear a bra between the sizes of A-E?</td><td>To standardise variables</td><td>Yes</td></tr>
<tr><td>Have you had any trauma to your back?</td><td rowspan="3">May give false results as pain may come from other sources such as osteophytes, fractures, scoliosis, Ankylosing spondylitis (Myburgh 2016)</td><td>No</td></tr>
<tr><td>Do you have a history of arthritis or any other conditions that effects your back?</td><td>No</td></tr>
<tr><td>Have you ever had back surgery?</td><td>No</td></tr>
<tr><td>Are you on any sort of pain medication?</td><td>Influences pain perception (Spencer et al. 2022)</td><td>No</td></tr>
</table>

Once it was determined that the participants were eligible to participate in the study, an appointment was made at the DUT CDC.

3.6 SAMPLING

3.6.1 Sample Size

This study had a sample size of 52 participants. This was established by test for two proportions using a large effect size of 0.8 between two groups, with a binary variable outcome. With alpha at 0.05 and the power of 80% (Esterhuizen 2023). The 52 participants were separated into two groups of 25 participants each. Group A was the case group and Group B the control group. The control group included women without presenting with upper back pain and the case group consisted of women who presented with back pain (Esterhuizen 2023).

3.6.2 Sampling Strategy

The sampling strategy chosen for this study was probability sampling method using simple random sampling. This sampling method was used to provide all pre-menopausal women of all ethnicities, from Durban, KwaZulu-Natal, an equal opportunity of being selected to participate (Sharma 2017)

3.7 MEASUREMENT TOOLS

3.7.1 The Numeric Rating Scale (Subjective)

The numeric rating scale is a well documented 11-point scale used to assess pain presented by an individual (Karcioglu *et al.* 2018). This scale has been used previously over other rating scales based on its simplicity as it can be given verbally as well as in writing (Karcioglu *et al.* 2018). Furthermore, it is the known as most commonly implemented instrument to measure pain severity (Karcioglu *et al.* 2018). The numerical rating scale was followed to determine participants level of upper back pain with 0 presenting without pain and 10 being severe pain (Figure 3.1). This was completed in order to divide participants into one of two groups: one with upper back pain and other without upper back pain.

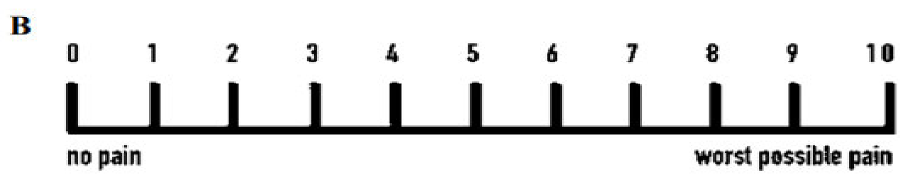

Figure 3.1 Numeric rating scale (Karcioglu et al. 2018)

3.7.2 Underbust/Overbust Measurement

A cloth tape measure (in centimetres) was used to measure the underbust and overbust size in order to determine each participant's actual cup size (Figure 3.2).

Table 3.2 International underbust and overbust sizing (McGhee, Ramsay *et al.* 2018)

Underbust (cm)					Overbust				
	A Cup	B Cup	C Cup	D Cup	DD Cup	E Cup	F Cup	G Cup	H Cup
63-67	77–79	79–81	81–83	83–85	85–87	87–89	89–91	91–93	93–95
68–72	82–84	84–86	86–88	88–90	90–92	92–94	94–96	96–98	98–100
73–77	87–89	89–91	91–93	93–95	95–97	97–99	99–101	101–103	103–105
78–82	92–94	94–96	96–98	98–100	100–102	102–104	104–106	106–108	108–110
83–87	97–99	99–101	101–103	103–105	105–107	107–109	109–111	111–113	113–115
88–92	102–104	104–106	106–108	108–110	110–112	112–114	114–116	116–118	118–120
93–97	107–109	109–111	111–113	113–115	115–117	117–119	119–121	121–123	123–125
98–102	112–114	114–116	116–118	118–120	120–122	122–124	124–126	126–128	128–130
103–107	117–119	119–121	121–123	123–125	125–127	127–129	129–131	131–133	133–135
108–112	122–124	124–126	126–128	128–130	130–132	132–134	134–136	136–138	138–140

After the participant was adequetly dressed in a gown without a brassier,the band size was measured around the woman's underbust at the level of the inframammary fold and the overbust around the broadest chest circumference, both measurements taken once with participant standing over the gown given to participant (McGhee, Ramsay *et al.* 2018). The international underbust and overbust sizing chart (Table 3.2) from McGhee, Ramsay et al. (2018) was followed to determine each participant's actual cup size.

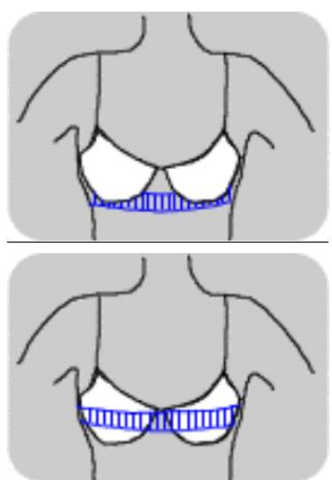

Figure 3.2 Underbust and overbust measurements (Wood, Cameron and Fitzgerald 2008)

3.7.3 Pressure Algometer

A pressure algometer is a reliable measuring tool to examine tissue sensitivity and has been used before to differentiate between health and diseased to provide a quantitative measure of musculoskeletal sensitivity (Spencer *et al.* 2022). It has been used previously by authors to determine the pain pressure threshold in order to assess musculoskeletal sensitivity (Trueba-Perdomo *et al.* 2021). Kinser, Sands and Stone (2009) concluded that the use of digital algometer can be useful in quantifying pain. This is further supported by Tabatabaiee *et al.* (2020) who used assessed the pressure threshold of the piriformis muscle and found an increase in tenderness with an associated decrease in pain pressure threshold of non-healthy group when compared to the healthy group.

In this study the pain pressure threshold of the 12 anatomical sites using a pressure algometer was then recorded, as shown in Figure 3.3. These sites were selected as sites that were potentially under strain form increased breast size (Spencer *et al.* 2022). This was done by locating and marking the 12 anatomical sites using a non-permanent marker. The anatomical sites included the following:

- Skeletal sites: C7 spinous vertebrae is known to be the most prominent spinous process when looking at the surface anatomy (Neumann 2010). C7 was used as a guide to locate T2, T4, T6, T8, T10, and T12 by counting down from C7. The 12th rib also aided in the identification of the T12 spinous process.
- Musculoskeletal sites: The following muscles at their relevant sites were used to identify their pain pressure thresholds:
    - Pectorals major: Middle third of the clavicle, 2 cm inferiorly.
    - Levator scapulae: Superior scapular border, 2 cm supero-medially.
    - Sternocleidomastoid: Mastoid process, 3 cm inferiorly.
    - Upper trapezius: Superior scapular angle, 5 cm superolateral.
    - Middle trapezius: T3 Spinous process, 2 cm laterally.
    - Lower trapezius: T8 Spinous process, 2 cm laterally.

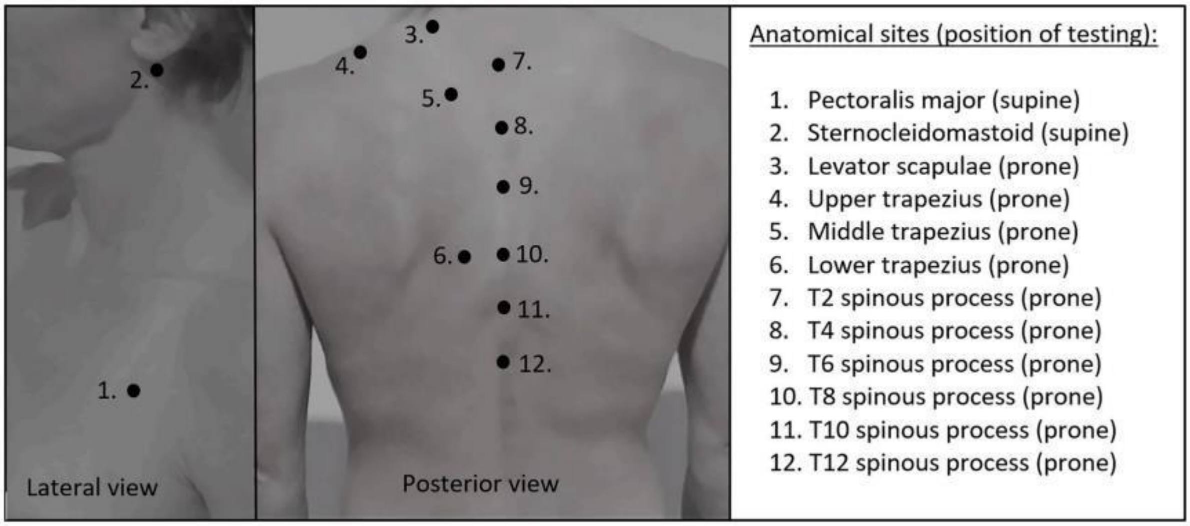

Figure 3.3 Anatomical sites for pain pressure threshold testing (Spencer et al. 2022)

Before starting with the pressure algometer, the participants had the opportunity to familiarise themselves with the pressure algometer (Spencer *et al.* 2022). To prevent pain and injury the upper cup limit cut off was 1000kPa. The pain pressure threshold was then to be measured on the non-dominant side, at each location three times where the average pain pressure threshold of each site was used (Spencer *et al.* 2022).

3.8 VALIDITY AND RELIABILITY

Validity is known as the accuracy of how a concept is measured within a quantitative study, whereas reliability is the amount of times a research instrument provides consistent results when used at different times (Heale and Twycross 2015). Both are required to ensure the utmost quality during the study procedure (George and Mallery 2018). Prior to beginning the study procedure, all measurement tools were calibrated. To maintain consistency across all participants, each participant received identical instructions and followed the same sequence of procedures.

3.8.1 Numeric Rating Scale

The numeric rating scale is a well documented 11-point scale used to assess pain presented by an individual (Karcioglu *et al.* 2018). It is done by asking the individual to rate their pain out of 10 with 0 indicating no pain and 10 being the worst pain ever (Karcioglu *et al.* 2018).

This pain rating scale is scored as:

- 0 = no pain
- 1–3 = mild pain
- 4–6 = moderate pain
- 7–10 = severe pain (Karcioglu *et al.* 2018).

This scale has been used previously over other rating scales based on its simplicity as it can be given verbally as well as in writing (Karcioglu *et al.* 2018). Furthermore, it is the known as most commonly implemented instrument to measure pain severity (Karcioglu *et al.* 2018).

3.8.2 Measuring Tape

The underbust and overbust measurement is the method of choice amongst professional bra fitters to determine breast size (McGhee *et al.* 2018). These two measurements are taken by the use a measuring tape (in centimetres) where the underbust measurement was taken and the inframammary fold, whereas the overbust measurement is taken at the broadest aspect of the breast tissue (Schinkel-Ivy and Drake 2016). According to Schinkel-Ivy and Drake (2016), obtaining accurate underbust and overbust measurements is of paramount importance when determining breast cup size, as larger cup sizes may result in upper back pain among female patients.

3.8.3 Pressure Algometer

A pressure algometer is a reliable measuring tool to assist tissue sensitivity and has been used before to differentiate between healthy and diseased tissue (Spencer *et al.* 2022). Kinser, Sands and Stone (2009) tested the validity and reliability of the pressure algometer by placing pressure onto a force plate using the pressure algometer. The results showed that the application rate of the pressure algometer force was constant with an average of 6.8 ± 0.932 $N.s^{-1}$, showing that the pressure algometer can lead to an accurate force application.Kinser, Sands and Stone (2009) concluded that using a pressure algometer can be helpful in quantifying pain. This is further supported by Tabatabaiee et al. (2020), who used the pressure algometer to assess the pain pressure threshold of the piriformis muscle. The results showed an increase in tenderness with an associated decrease in pain pressure threshold of the non-healthy group compared to the healthy group.

Spencer *et al.* (2022) shifted the focus of using the pressure algometer to examine 12 anatomical sites that are potentially under strain from larger breast sizes. According to Spencer *et al.* (2022), the pain pressure threshold was measured on the non-dominant side, at each location three times where the average pain pressure threshold of each site was used (Spencer *et al.* 2022) . The results of Spencer *et al.* (2022) showed that the sternocleidomastoid muscle was the most sensitive in both groups. In contrast, the middle trapezius showed high sensitivity only in the moderate to severe pain group when using the digital algometer and concluded that the pressure algometer must be re-examined to assess the relationship between upper back pain and breast size. The same measurement scale was used for all participants.

According to previous research, upper back pain is caused by larger breast size. Previous studies have consistently established a relationship between breast size and a low pain pressure threshold. In 2022, Spencer *et al.* conducted a study using a pressure algometer to measure the pain pressure threshold of 12 anatomical sites. Their findings indicated that women with larger breasts experience greater sensitivity in their sternocleidomastoid muscle. Tomer and Verma *et al.* (2020) also supported this relationship, as they found that an increase in breast size is associated with greater myofascial pain in the trapezius muscle. Based on the consistency of results across previous studies, it can be concluded that breast size is a causative agent of upper back pain.

3.9 RESEARCH PROCEDURE

Data collection commenced once full ethical approval (072/24) was granted from the DUT Research Committee (IREC) (Appendix C) and permission to access the CDC was obtained (Appendix B). Data collection took place at the CDC at DUT (07/24).

If the participants met the eligibility criteria through telephonic interview, an appointment was made to attend the CDC. On arrival, the participants were requested to report to the researcher on the numeric rating scale if they experienced upper back pain or not in order to allocate participants to the respective group, with 0 being no pain and 10 being severe pain. Afterwards the participants were given a letter of information (Appendix F) and then asked to fill in an informed consent form (Appendix G) . The researcher gave the participants an adequate verbal explanation of the study in order for all the participants' questions to be answered. In private, with the door and curtains closed of one of the CDC rooms, participants were asked to remove their shirt and bra and then change into a gown. Once the participant was appropriately dressed, the researcher, with a female chaperone, measured the underbust and overbust over the gown to determine the participant's cup size. Thereafter, the pain pressure threshold was measured at the 12 anatomical sites. Each anatomical location was measured on the participants' non-dominant side, to provide standardised values, as the dominant side contains an increase in muscular volume when compared to the non-dominant side (Spencer *et al.* 2022;

Bhise and Patil 2016). Each anatomical location was measured three times to calculate the average (Spencer *et al.* 2022). These 12 anatomical sites were located and marked on the participant by using a non-permanent marker.

The appointment was concluded by allowing the participant to get dressed in private and then thanked for attending.

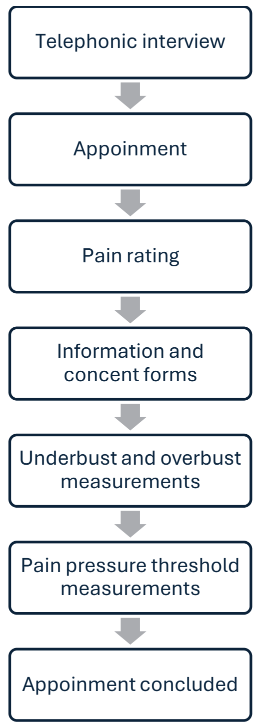

Figure 3.4 Research procedure flow diagram

3.10 DATA ANALYSIS

The IBM statistical software version 29 was used to analyse the date. Multiple logistic regression analysis was conducted to assess odds ratios of association between breasts size and back pain whilst controlling for confounding variables; 95% confidence intervals were reported around adjusted odds ratios (Esterhuizen 2023). A two-sided *p*-value of <0.05 as alpha was considered as statically significant. Associations between categorical risk factors and pain were assessed using the chi squared test and continuous variables were compared between the controlled and case groups using the two sample T-test to compare certain values of the two groups (Esterhuizen 2023; Manfei *et al.* 2017).

Three algometer readings at each site were averaged. Average algometer readings in kg/cm² were converted to kPa using the following formula: kPa value = kg/cm² value x 98.0665.Summary statistics such as mean and standard deviation were used to summerize continuous data which were normally distributed and median and interquartile ranges were used to summarise data which were not normally distributed or ordinal. Categorical variables were summarised using counts and percentages by group. For statistical associations, cup size was categorised into 3 groups, A or B which was the reference group, C, and D or higher. Logistics regression analysis was used to assess the association between cup size and pain after adjusting for confounding effects of age and ethnic group. Nonparametric Kruskal-Wallis tests were used to compare algometer readings between the three breast cup size groups and between the pain groups. A *p*-value of <0.05 was considered as statistically significant.

3.11 DATA MANAGEMENT AND STORAGE

In this study, the participants' names were replaced by codes when placed onto data collection sheets and Excel spreadsheet (Appendix H and I). The research data will be in safe keeping at the CDC under supervision of the clinic director, clinic and university for a period of five years where after it will be shredded. The researcher will delete this data at the end of five years. Electronic data will be kept in a password locked external hard drive for which only the researcher knows the password. The researcher will delete this data at the end of five years.

3.12 ETHICAL CONSIDERATIONS

3.12.1 Autonomy

Autonomy is defined as every individual having the right to make rational decisions and choices about their life (Varkey 2021). In order to respect the autonomy of each participant, they were provided with a letter of information about the study (Appendix F) and informed consent form (Appendix G). Autonomy was obtained by gaining the participants' signatures for the letter of information (Appendix F) and on the informed consent form (Appendix G). The participants were informed that participation in the study was voluntary and that they were allowed to withdraw from the study at any point in time if they wished to do so, without any compromise to them.

3.12.2 Justice

Justice is defined as fairness and ensures that the benefits and risks of a study are distributed equally (Ketefian 2015). All potential participants who met the inclusion and exclusion criteria were invited to participate in the research. No participant was coerced or pressured into participating, and all decisions to participate were made voluntarily. Furthermore, to promote impartiality and fairness, no discrimination on the basis of race or religion was permitted in the selection of participants. This ensured that all eligible individuals had an equal opportunity to participate in the study.

3.12.3 Confidentiality

Confidentiality means not disclosing personal information given by participants to another party without the participants' authorisation (Varkey 2021). In this study, confidentiality was maintained at all times, from data collection to publishing results. The participants' names were replaced by codes when placed onto data collection sheets and Excel spreadsheet. The research data will remain in safe keeping at the CDC for a period of five years, where after it will be shredded. The participants' rights and welfare were also kept safe.

3.12.4 Beneficence

Beneficence is about promoting welfare to all individuals (Varkey 2021). As there is limited research on this related topic, it will benefit women in Durban, KwaZulu-Natal, and the chiropractic profession in South Africa, as it improves clarity around the relationship between breast size and back pain.

3.12.5 Non-Maleficence

Non-maleficence is a concept that emphasises the importance of avoiding harm to any individual (Varkey, 2021). In this study, all participants were treated fairly and equally, with no harm in any way. The study was conducted under supervision in the CDC, and the participants' health was protected as reliable measurement tools were used.

3.13 CONCLUSION

This chapter showed the research process that was used for this study. It also showed how data were gathered and examined in order to draw the results of the findings of the study which are discussed in the next chapter.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

This chapter presents the study results in the form of graphs and tables. Data gathered from participants were analysed as described in Chapter Three and summarised as follows:

The analysis included:

- Demographic data analysis consisting of ethnicity and age.
- Underbust and overbust measurement to determine breast size of participants.
- Muscle sensitivity amongst the pain and non-pain groups of selective anatomical locations.
- Self-reported pain levels of the pain group.
- Multiple logistics analysis and nonparametric Kruskal-Wallis tests were used to compare algometer readings between the three breast cup size groups and between the pain groups.

This research study was based on the following hypotheses:

- Null Hypothesis: Bigger breast size in pre-menopausal women does not increase upper back pain and muscle sensitivity.
- Alternate Hypothesis**:** Bigger breast size in pre-menopausal women increases upper back pain and muscle sensitivity.

4.2 CONSORT FLOW DIAGRAM

The consort flow diagram shows the distribution of the participants during the research process. After self-reporting of upper back pain, 52 participants were allocated into one of two groups; 26 participants were allocated to the case group (pain) and 26 participants were allocated to the control group (no pain).

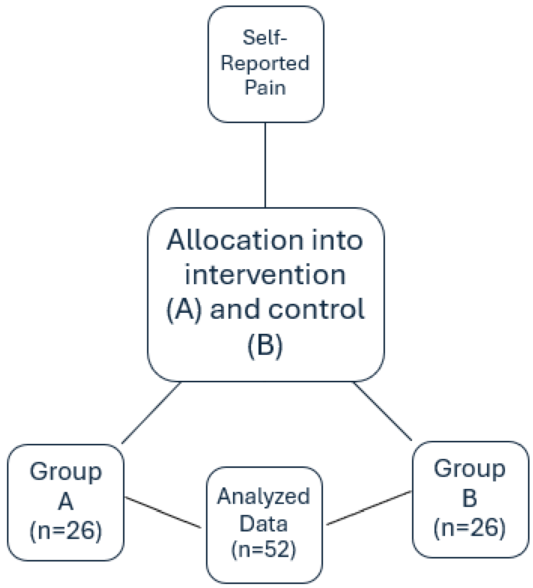

Figure 4.1 Consort flow diagram

4.3 DEMOGRAPHICS

4.3.1 Ethnicity and Age

The sample size consisted of 52 participants who were between the ages of 18 and 40 years. All participants met the inclusion criteria and were allocated into either the case or control groups based on if they reported with pain (case group) or without pain (control group) with ethnicities that varied throughout the sample. Table 4.1 presents the mean age and ethnicities of the sample within the two groups.

Table 4.1 Demographics of study participants by group

		Group					
		Pain		**No pain**		**Total**	
		Count	%	Count	%	Count	%
Ethnicity	Black	14	53.8%	17	65.3%	31	59.6%
	White	8	30.8%	8	30.8%	16	30.8%
	Coloured	2	7.7%	1	3.8%	3	5.8%
	Indian	2	7.7%	0	0.0%	2	3.8%
	Total	26	100.0%	26	100.0%	52	100.0%
Age	Median (IQR)	23	21–24	22	21–25	23	21–25

The average age of the case group was 23 years (sd=4.5) compared to control group that consisted of an average age of 22 years (sd=4.2). Table 4.1 also demonstrates that the ethnic groups were similar, with black females found mostly in both groups (59.6 %).

4.4 ANALYSIS OF DATA

4.4.1 Objective One

Objective one was to determine the breast size in pre-menopausal women aged 18–40 via objective measurement (underbust and overbust measurement using measuring tape).

4.4.1.1 Breast Size

Table 4.2 Underbust and overbust measurements by group

		Group	
		No pain	**Pain**
Underbust (cm)	Valid N	26	26
	Mean	84	90
	Standard Deviation	10	12
	Minimum	74	72
	Maximum	108	112
Overbust (cm)	Valid N	26	26
	Mean	98	106
	Standard Deviation	12	14
	Minimum	83	82
	Maximum	126	133

This study included breast size A to E. The breast size of participants of both groups was taken. Table 4.2 summarises the mean underbust and overbust measurements between the two groups. The control group consisted of a mean average of 84cm (sd=10) underbust and 98cm (sd= 12) underbust, whereas the case group had a mean value of 90cm (sd=12) underbust and 106cm (sd=14) overbust. These measurements were then used to determine the cup size of each participant as shown in Table 4.3. When comparing the different cup sizes amongst the control and case group, it shows that participants of the control group had a higher frequency of smaller cup sizes, size A and B cups, when compared to the case group that contained a higher frequency of larger cup sizes, C to E cups.

Table 4.3 Cup size by group

		Group			
		No pain		Pain	
		Count	%	Count	%
Cup size	A	9	34.6%	4	15.4%
	A/B	1	3.8%	2	7.7%
	B	5	19.2%	2	7.7%
	B/C	4	15.4%	1	3.8%
	C	4	15.4%	8	30.8%
	C/D	0	0.0%	1	3.8%
	D	1	3.8%	3	11.5%
	DD	2	7.7%	4	15.4%
	E	0	0.0%	1	3.8%

4.4.2 Objective Two

Objective two was to determine muscle sensitivity (pain pressure threshold) in selective anatomical locations of pre-menopausal women aged 18–40 via objective measurement (pressure kPa).

4.4.2.1 Muscle Sensitivity (Pain Pressure Threshold)

Table 4.4 Algometer readings by group

Anatomical site	Group							
	No pain				Pain			
	Mean	sd	Minimum	Maximum	Mean	sd	Minimum	Maximum
T2	487.1	224.3	241.9	980.7	382.3	154.6	166.7	653.8
T4	542.4	221.2	271.3	980.7	421.7	160.8	209.2	706.1
T6	566.5	202.7	304.0	980.7	408.4	146.3	160.2	751.8
T8	578.4	216.0	255.0	980.7	424.3	146.0	176.5	748.6
T10	564.0	227.1	183.1	980.7	439.5	170.0	196.1	823.8
T12	547.4	234.7	156.9	980.7	464.3	153.4	241.9	872.8
PM	395.3	156.8	127.5	725.7	307.5	139.9	120.9	611.3
LS	454.8	222.3	160.2	980.7	334.4	143.3	134.0	585.1
S	192.6	71.3	114.4	431.5	157.0	43.1	101.3	264.8
UT	373.3	165.6	147.1	980.7	266.8	85.2	117.7	467.5
MT	523.6	226.1	255.0	980.7	400.6	159.5	173.3	738.8
LT	565.9	253.8	202.7	980.7	459.3	149.6	235.4	791.1

Table 4.4 illustrates the pressure readings in kPa of each of the 12 anatomical sites between the control and case group. There was a significant difference in kPa values amongst the control and case group where it is noted that there is lower kPa values at each of the 12 anatomical sites found amongst participants who presented with pain; this is further illustrated in Figure 4.2.

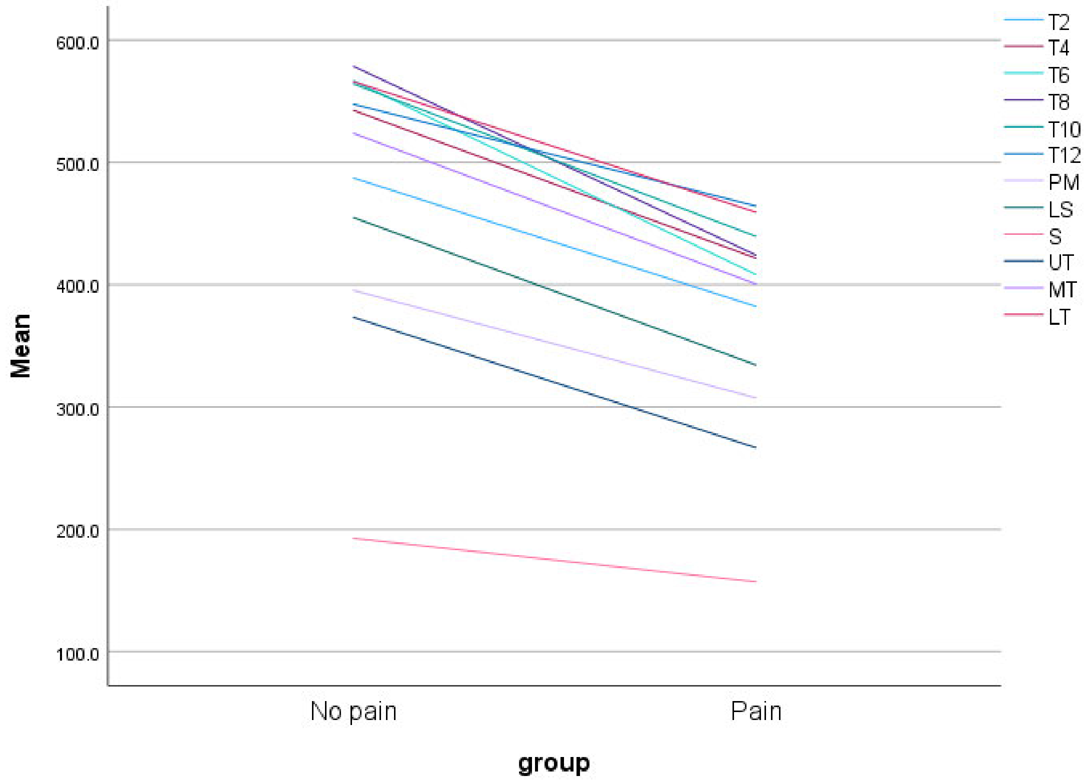

Figure 4.2 Mean pressure algometer measurements in the pain and no pain groups by anatomical site

4.4.3 Objective Three

Objective three was to determine the self-reported pain levels of pre-menopausal women aged 18–40 via subjective measurement (numerical pain rating scale).

4.4.3.1 Self-Reported Pain

Table 4.5 summarises the self-reporting pain readings of the case group. It was found that the mean pain was reported as 6.6 with a range from 3 to 10.

Table 4.5 Self-reported pain scores in the pain group

Statistics	
Pain rating	
n	26
Mean	6.60
Std. Deviation	1.949
Minimum	3
Maximum	10

4.4.4 Objective Four

Objective four was to determine if a correlation exists between breast size, muscle sensitivity (pain pressure threshold) and self-reported pain (NRS) in pre-menopausal women.

4.4.4.1 Breast Size vs Muscle Sensitivity

Table 4.6 Muscle sensitivity for three cup size groups

Anatomical location	**Cup size**						**KW *p*-value**
	A or B		C		D or higher		
	Mean	sd	Mean	sd	Mean	sd	
T2	474.8	210.5	425.2	185.1	366.1	187.3	0.215
T4	512.5	197.1	501.4	193.4	386.6	210.1	0.097
T6	541.5	202.1	479.6	143.6	387.2	214.4	0.081
T8	553.2	171.7	501.2	194.8	393.2	228.9	0.024
T10	546.8	188.0	519.8	219.2	378.3	199.6	0.036
T12	532.7	189.2	515.9	220.8	433.3	190.2	0.251
PM	362.6	157.4	371.7	140.9	294.8	165.9	0.295
LS	446.0	185.1	397.4	206.7	282.6	160.8	0.026
S	189.3	73.5	168.7	43.8	154.5	53.4	0.202
UT	366.7	167.5	306.7	100.5	244.3	104.6	0.025
MT	515.3	213.8	469.6	180.8	338.5	177.7	0.012
LT	561.0	230.0	513.2	205.1	410.4	164.3	0.203

Table 4.6 shows the significant difference in kPa values of five of the 12 anatomical locations amongst different breast sizes. For statistical associations breast size was categorized into three groups A or B, C, and D or higher. Between the three cup size groups, according to the

non-parametric Kruskal-Wallis test, as the cup size increased the muscle sensitivity, indicating a lower kPa value in T8, T10, LS, UT and MT in the case group when compared to the control group . This is further illustrated in Figure 4.2.

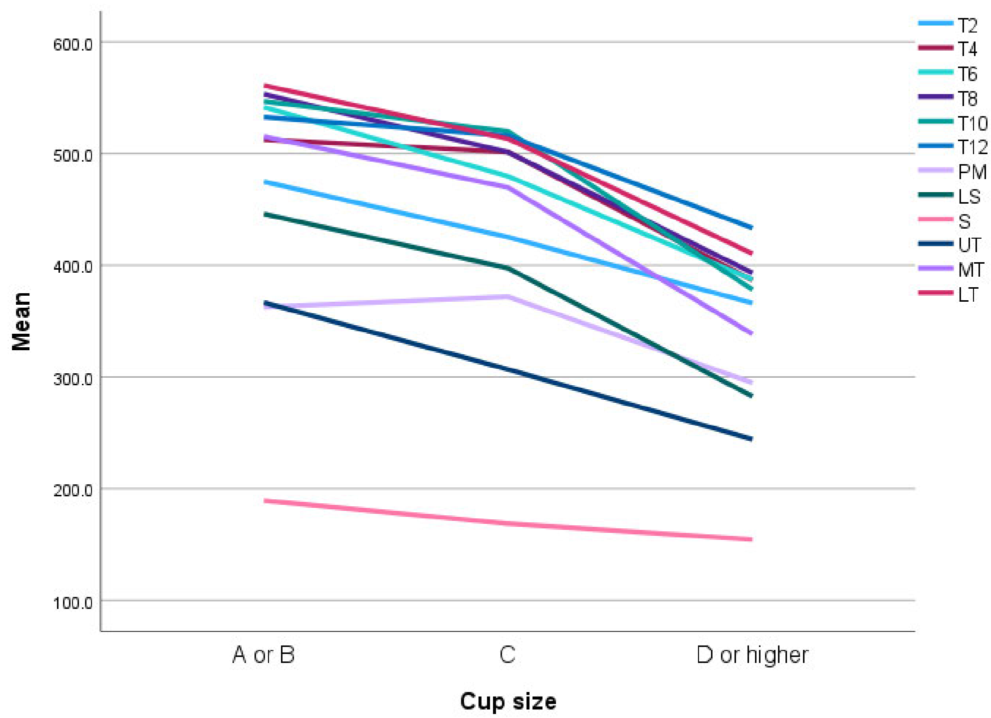

Figure 4.3 Pressure algometer measurements by cup size

4.4.4.2 Breast Size vs Pain Group

Table 4.7 shows that the effect of breast size on the rating of pain reported by the participants. There was a trend of increasing likelihood of being in the pain group relative to the non-pain group with increase cup size. Using A or B cup size as the reference group, size C has 2.2 times higher odds of being in the pain group which was not statistically significant (p=0.220) and cup sizes D or higher has almost 5 times higher odds of being in the pain group (p=0.054) after adjusting for confounding effects of age and ethnic group. The odds ratios and confidence intervals are presented in Table 4.7.

Table 4.7 Adjusted logistic regression analysis from cup size relative to pain group

	p-value	Odds Ratio	95% CI for OR	
			Lower	Upper
Cup size (C) vs (A or B)	0.220	2.243	0.617	8.152
Cup size (D or higher) vs (A or B)	0.054	4.958	0.975	25.211
Age	0.909	0.991	0.853	1.152
Ethnic group (black vs other)	0.499	1.531	0.445	5.267
Constant	0.745	0.561		

4.4.4.3 Breast Size vs Self-Reported Pain in Pain Group

Table 4.8 shows the self-reported median pain score of three groups. There was no significant difference in pain between the three breast size groups (*p*=0.508), according to the Kruskal-Wallis test. However, D or higher cup sizes showed a lot of overlap in pain scores when compared to the other two groups.

Table 4.8 Pain scores by cup size in pain group (*n*=26)

		Cup Size			*p*-value
		A or B	C	D or higher	
Pain rating	Median	6	6	8	0.508
	Percentile 25	5	5	5	
	Percentile 75	8	7	10	

This is further highlighted in Figure 4.4 which shows the distribution of pain scores across the three cup size groups.

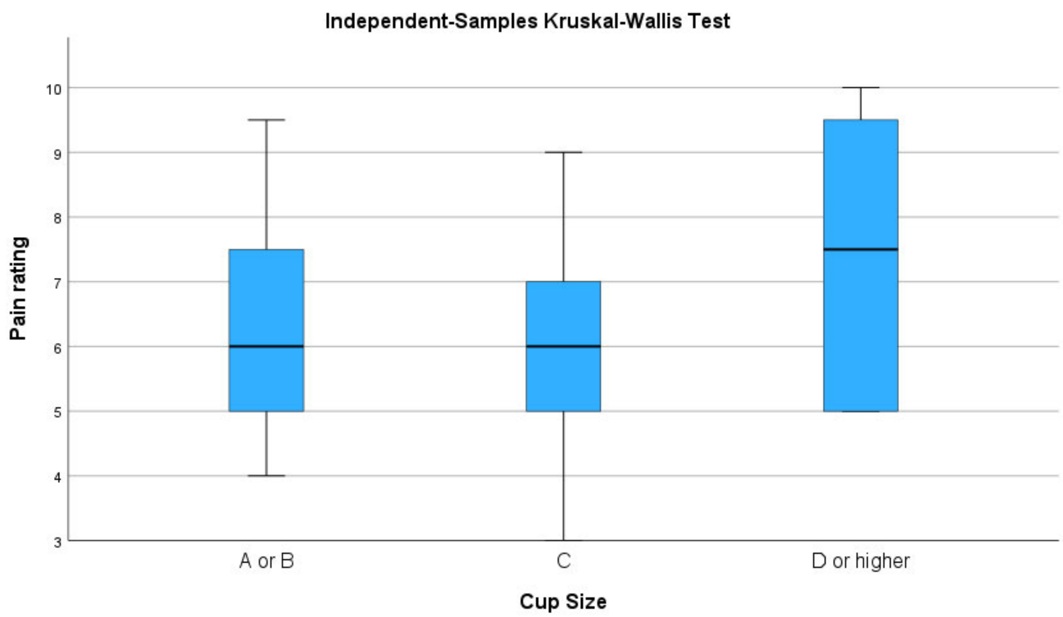

Figure 4.4 Pain scores by cup size in the pain group

4.5 CONCLUSION

This chapter summarises that breast size has an effect of the muscle sensitivity of the upper back anatomical sites. More so, there were statistically significant differences between the two groups of five anatomical locations and, therefore, the null hypothesis was rejected. The interpretation and meaning of these results are further discussed in the next chapter.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

This chapter consists of the discussion of the results presented in Chapter Four in context of current literature. The statistical and clinical significance of the presented data is discussed regarding possible theories. References are made to relevant sections in Chapter Four as well as Chapter Two.

5.2 DEMOGRAPHICS AND BACKGROUND VARIABLES

5.2.1 Age

Age was an inclusion criterion in this study and was limited to biological women between the ages of 18 and 40 years. Participants in this age range were chosen in order to prevent post-menopausal effects. Additionally, due to the decline in estrogen, post-menopausal is marked by a decrease in bone mineral density and body mass gain (Wang 2017). Thus, post-menopausal women present with a higher incidence of back pain (Wang 2017).

Table 4.1 indicates that the mean age was 23 in the pain group and 22 in the non-pain group. This indicates that the pain and non-pain groups were comparable due to their almost identical age. This, however, cannot be compared to other studies conducted as the participants had a mean age of 61 and 69 years and without a control group (Spencer et al. 2022; Spencer and Briffa 2013; Wood, Cameron and Fitzgerald 2008).

5.2.2 Ethnicity

Participants of all ethnicities were included in the study as it was an important factor in building on previous literature. The inclusion of all ethnicities is at variance with previous literature regarding breast size and upper back pain which has primarily been conducted in countries such as Australia and Canada, which are predominantly Caucasian in ethnicity (Coltman *et al*. 2018). The current study was completed in KwaZulu-Natal, South Africa, where there is a diverse ethnic population, though the African demographic represents a larger proportion.

There were significantly more black participants than other ethnicities in both the case and control groups making these groups comparable. The total number of black participants was 59.6%; white was 30.8 %; coloured was 5.8 % and Indian was 3.8%.

5.3 BREAST SIZE

The mean underbust measurement of participants was 84cm for the non-pain group and 90cm for the pain group. In relation to this, the mean overbust measurement for the non-pain group was 98cm and 106cm for the pain group. Underbust and overbust measurements is known as the most accurate measurement to obtain breast size and is commonly used among professional bra fitters (Schinkel-Ivy and Drake 2016; McGhee, Ramsay *et al.* 2018). The underbust and overbust measurement of breast size was chosen instead of women self-reporting of breast size; this is based on the majority of women wearing the incorrect bra sizes because they do not know their actual breast size (Mthabela 2015). The international underbust and overbust sizing chart was a more accurate way to measure the breast size of each participant (McGhee, Ramsay *et al.* 2018).

Table 4.3 depicts a higher frequency of size A and B cups in the non-pain group and a higher frequency of C to E cups within the pain group. A breast size over E was an exclusion criterion in order to standardise the variables. This is also in accordance with previous studies which included women with various breast sizes and found that women with a larger breast size had higher incidence rates of upper musculoskeletal pain due to the saggital imbalance leading to muscular strain (Iyidobi *et al.* 2021; Spencer *et al.* 2019; Spencer *et al.* 2022).

5.4 MUSCLE SENSITIVITY

Table 4.4 shows the statistically significant difference in the kPa values at all anatomical sites, showing lower kPa values within the pain group when compared to the non-pain group, indicating more muscular sensitivity, as shown in Figure 4.1. The lower kPa values were most commonly seen in the pain group and as the breast size increased.

There was a higher muscular sensitivity found in five of the 12 anatomical locations.The muscular sensitivity was higher in five of the 12 anatomical locations in women with a large breast size compared to women with smaller breast sizes. The control group showed a higher pain pressure threshold in smaller breast sizes indicating that smaller breast sizes lead to lower muscular sensitivity.

5.4.1 Case Group

Postural changes occur as breast size increases leading to higher prevalence of pain in women with larger breast sizes (Mazzocchi *et al.* 2012; McGhee, Coltman *et al*. 2018). This is due to a shift in the normal centre of gravity, leading to sagittal imbalance and an increase in the upper back pain prevalence in women (Fonseca *et al.* 2018; Michalik *et al.* 2022).

Previous studies have observed that there would be an increase thoracic kyphosis and cervical lordosis as well as protraction of the scapulae in women with larger breast sizes which would lead to surrounding musculature to work harder to maintain balance resulting in chronic strain of the middle trapezius,lower trapezius, rhomboid major and, rhomboid minor (Spencer *et al.* 2019; Spencer *et al.* 2022). These results were most commonly noted by Findikciolgu *et al.* (2007) where D breast size presented with higher prevalence when compared to participants with A breast size. In relation to this, Spencer *et al.* (2022) also found that larger cup sizes were noted in women who reported with upper back pain but Spencer *et al.* (2022) did not include a control group to compare its findings.

Figure 4.2 shows that there was a significant increase in muscular sensitivity in the case group in larger breast sizes. However, this was only statistically significant at five of the 12 anatomical locations: T8. T10, LS, UT and MT after the breast sizes were divided into three groups (A or B, C and D or higher). Some results of the current study are similar to what was found by Spencer *et al.* (2022), who found a significant increase in muscular sensitivity in participants with larger breast sizes but only statistically significant in the middle trapezius.

Numerical pain rating scale was completed on participants who reported with pain, with the mean pain being reported as 6.6, ranging from 3 to 10 as shown in Table 4.5. In previous studies, it was observed that the mean pain range was 8.3; however, this was completed on post-menopausal women alone (Spencer and Briffa 2013). It was noted that participants with a larger breast size were more likely to fall under the case group size found to have 2.2 higher odds of falling under the case group, making it not statistically significant (p=0.220), whereas sizes D or higher had five times higher odds of being a part of the pain group (p=0,054).

Comparing the three groups of breast size in Table 4.8, there was no significant difference in pain rating amongst the three groups (p=0.508). D or higher cup sizes did present with higher pain scores; however, there was a lot of overlap amongst the three groups as shown in Figure 4.3. This stands in contrast to Spencer *et al.* (2022) who found no significant difference regarding pain rating amongst difference breast sizes in groups with mild upper back pain and another with moderate to severe upper back pain.

5.4.2 Control Group

A control group was included in the current study to build onto the study completed by Spencer *et al.* (2022). That study did not include a control group and divided participants according to their severity of pain (mild or moderate to severe pain). In the control group of the current study there was a higher pain pressure threshold (lower muscular sensitivity) with the majority of participants presenting with A and B breast sizes when compared to the case group. This indicates that smaller breast size resulted in a lower muscular sensitivity. Due to the control group presenting without upper back pain, it did not necessarily imply that the breast size would be smaller and have a higher pain threshold. Although asymptomatic, 15.4% C, 3.8% D and 7.7% DD were found amongst the control group and did not experience any pain.

5.4.3 Comparison between Case and Control Groups

Pre-menopausal participants presenting with or without upper back pain were selected and divided into one of two groups based on whether they experienced upper back pain or not. Pre-menopausal women were chosen due to previous literature regarding breast size and upper back pain focused primarily on post-menopausal women alone (Spencer *et al.*2022; Spencer and Briffa 2013). It is important to note that estrogen plays an important role in the pain pathway where it leads to higher pain prevalence especially during different phases of a woman's menstrual cycle (Zhang *et al.* 2023; Templeton 2020). Menopause results in a decline in estrogen leading to a decline in bone mineral density leading to intervertebral disc space narrowing resulting in which risk factors for upper back pain prevalence in post-menopausal women such as facet joint arthrtitis (Wang 2017).

In the current study, pre-menopausal women between the ages of 18 and 40 participated with the intention to further research and contribute building on current literature by examining if breast size leads to muscular sensitivity in the pre-menopausal population presenting with or without pain.

Figure 4.2 shows a positive trend showing an increase in muscle sensitivity with an increase in cup size, where the pressure algometer values decreased as the cup size increased. In the case group, five of the 12 anatomical locations had statistically significant lower kPa value, namely the T8, T10, LS, UT and the MT when compared to the control group, indicating a . These five anatomical locations showed a decrease in the pain pressure threshold, with an increase in muscular sensitivity compared to the control group. It is also important to note that Spencer *et al.* (2022) found that the MT as a site of interest showed the greatest variability amongst the post-menopausal participants in the study. This study results shows similarity because the MT was part of the five anatomical locations on pre-menopausal women that was statistically significant amongst participants.

It is also worth noting that there was a trend of increasing the likelihood of being in the pain group relative to the non-pain group as the cup size increased. Breast size A and B was found to be most commonly found in the non-pain group when compared to breast size D or higher being most common in the pain group (*p*=0,054). Breast size C was noted to be present in both the case and control group but it had 2.2 times higher odds of being in the pain group, which was not statistically significant (*p*=0.220). This finding shows that larger breast size does, in fact, lead to a higher upper back pain prevalence and lower pain pressure threshold in pre-menopausal women which favours the alternate hypothesis. The findings of this study concur with studies by Coltman *et al.* (2018), Coltman *et al.* (2019) and *Spencer et al.* (2019).

5.5 CONCLUSION

This study showed that breast size does affect the muscular sensitivity of the upper back musculature leading to upper back pain of the pre-menopausal population. The results of the case group confirm this and, thereby, favour the alternate hypothesis. This was primarily noted in five of the 12 anatomical locations and, therefore, builds on previous literature regarding muscular sensitivity related to breast size. Additionally, it provides more insight as to how breast size impacts the women of the South African population and specifically add to the body of knowledge.

CHAPTER 6: CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 CONCLUSION

The results of this study show that, overall, there was a statistical difference in breast size, upper back pain prevalence and muscular sensitivity between the two groups, as determined by breast size measurements and pain pressure threshold readings, suggesting that breast size has an effect on upper back pain prevalence and muscular sensitivity in premenopausal women. This was significantly noted at five upper back anatomical sites when comparing the control and case group. This stands in contrast to Spencer *et al. (*2022) who noted that only the middle trapezius had the greatest variability between groups with different pain levels amongst post-menopausal women, with no control group to compare findings, and, as a result, the null hypothesis was rejected.

6.2 LIMITATIONS

The following limitations were identified throughout the study:

1. The current sample size (*n*=52) was small. Although the findings were favourable with the similarities being identified, these findings should be confirmed with a greater number of subjects.
2. The placement of the pressure algometer. Despite considerable effort to ensure reproducibility, it was not possible to standardise or verify the exact placement of the pressure algometer on each of the 12 anatomical locations among participants.
3. The effect of HIV and ARVS on the prevalence of upper back pain was not accounted for. South-Africa is known to have one of the largest HIV epidemics globally (Kim *et al.* 2021). HIV and ARVS are known as common risk factors for chronic pain due to the altercations in pain transmission of the peripheral neurons (Liu and Tang 2023).
4. External risk factors, such as occupation and body mass index, were not accounted for.

6.3 RECOMMENDATIONS

The following recommendations are made to assist future studies to improve the data gained from the current study and allow more statistically significant results:

- Sample size: A larger sample size should be implemented to achieve more statistically significant results across pre-menopausal women.
- A research assistant should be considered to aid in the pressure algometer placing to standardise and verify electrode placement.
- Future studies should consider comparing participants' muscular sensitivity before and after breast reduction surgery in order to provide more depth to the current study.
- Additional measurements such as breast ptosis and splay should be considered in future studies to add depth to the current data obtained. This would examine if breast ptosis or breast splay increases the likelihood of women experiencing more upper back pain
- Future studies should consider comparing muscular sensitivity of women who wear bras and a group of women who do not to examine if women who do not wear bras have higher muscular sensitivity regardless of breast size when compared to women who wear a bra.

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APPENDICES

Appendix A: Permission to Conduct Research at DUT

DUT
DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

DIRECTORATE FOR RESEARCH & POSTGRADUATE SUPPORT

Directorate for Research and Postgraduate Support
3rd Floor, Open House, Steve Biko Campus
Durban University of Technology
P O Box 1334, Durban, 4000

T +27 373 2577
E Gatekeeper@dut.ac.za
W https://www.dut.ac.za/research-ps/

27 June 2024

Ms J Lloyd
c/o Department of Chiropractic
Faculty of Health Sciences
Durban University of Technology

Dear Ms Lloyd

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research and Innovation Committee (IRIC) has granted **Gatekeeper Permission** for you to conduct your research "An investigation into the association between breast size, muscle sensitivity and upper back pain in pre-menopausal women in Durban, KwaZulu-Natal" at the Durban University of Technology. **Kindly note that this letter must be issued to the IREC for approval before you commence data collection.**

The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

Upon completion of your research project, you are requested to share the summary of your key research findings.

Yours sincerely

Dr F Akpa-Inyang
(for) Dr V Govender
Director (acting)
Research and Postgraduate Support

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Appendix B: Permission to Conduct Research at DUT Chiropractic Day Clinic

MEMORANDUM

To : Prof Adam
Chair: IREC

From : Dr Desiree Varatharajullu
Head of Department: Chiropractic; Clinic Director: Chiropractic Day Clinic

Date : 27.06.2024

Re : Request for permission to data collect on Chiropractic students and to use the Chiropractic Day Clinic for research purposes

Permission is hereby granted to:

Ms Jasmine Lloyd (Student Number: 21910598)

Research title: "An investigation into the association between breast size, muscle sensitivity and upper back pain in pre-menopausal women in Durban, KwaZulu-Natal."

Ms. Lloyd is hereby granted permission to conduct data collection on registered Chiropractic students. Ms. Lloyd, is requested to submit a copy of her FRC/IREC approved proposal along with proof of her MHSc: Chiropractic registration to the Clinic Administrator/s before she starts with her research in order that any special procedures with regards to her research can be implemented prior to the commencement of her seeing participants for the purposes of data collection in the clinic.

Head of Department: Chiropractic; Clinic Director: Chiropractic Day Clinic: Chiropractic

Cc: Mrs Linda Twiggs: Chiropractic Day Clinic
Dr A Abdul-Rasheed: Supervisor
Dr C Prince: Co-Supervisor

Appendix C: IREC Approval

DUT
DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

INSTITUTIONAL RESEARCH ETHICS COMMITTEE

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

5 July 2024

Ms J Lloyd
190 Botanic Gardens Road
Berea
Durban

Dear Ms Lloyd

An investigation into breast size associated with upper back pain and musculoskeletal sensitivity in Durban, KwaZulu-Natal
Ethical Clearance number IREC 072/24

The DUT-Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

It is compulsory for a student or researcher to apply for recertification on an annual basis. The failure to do so will result in withdrawal of ethics clearance. It is the responsibility of the researcher and the supervisor to apply for recertification.

Please note that you are required to submit a Notification of Completion of Study form together with an abstract to the DUT-IREC office on completion of your study.

Yours Sincerely

Prof J K Adam
Deputy Chairperson: DUT-IREC

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Appendix D: Email Correspondence to Adapt Study

7 November 2023
Linda Spencer
linda.spencer@curtin.edu.au

Request for Permission to use and modify study

Dear Linda Spencer

My name is Jasmine Lloyd, a 5th year Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's Dissertation is: An investigation into breast size associated with upper back pain and musculoskeletal sensitivity in Durban, KwaZulu-Natal.

I am hereby seeking your consent to re-evaluate/adapt your study (Taking a strain: An examination of upper back musculoskeletal tissue sensitivity in relation to upper back pain and breast size. A cross sectional study)

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the DUT-Institutional Research Ethics Committee (DUT-IREC).

If you require any further information, please do not hesitate to contact me +27 60 529 7035. Thank you for your time and consideration in this matter.

Yours sincerely,

Jasmine
Durban University of Technology

Appendix E: Advertisement

Appendix F: Letter of Information

LETTER OF INFORMATION

Title of the study: An investigation into the association between breast size, muscle sensitivity and upper back pain in pre-menopausal women in Durban, KwaZulu-Natal

Principal investigator/ researcher: Jasmine Lloyd BHCs Chiropractic (DUT)
Co-Investigators/supervisors: Dr Ashura Abdul-Rasheed M. Tech Chiropractic and Dr Cleo Prince M. Tech Chiropractic (DUT)

Dear Participant,

I would like to take this opportunity to welcome you to my study. I am a 5th year chiropractic student at the Durban University of Technology doing research for my Master of Health Science in Chiropractic. This letter serves to provide some background of my study.

Brief Introduction and Purpose of the Study:

Upper back pain is a common complaint among women with large breast sizes which has shown to result in poor muscle activation and tissue sensitivity often lead to reduction mammoplasty. A study by Spencer et al. (2022) explored this relationship further however, the study only included post- menopausal women. As a result, there's a lack of research on the relationship between breast size and upper back pain in pre-menopausal women. This study aims to investigate the possible connection between upper back pain and pain pressure threshold caused by breast size.

What is research:

Research is a systematic search or enquiry for generalized new knowledge. It includes the collection of data and documenting important information related to the study and its findings. With your participation in this research, you are allowed to discuss it with your family and friends and given a copy of the letter of information which you can take home with you.

Objective of the main study:

The aim of this study is to investigate breast size associated with upper back pain and musculoskeletal sensitivity in a sample of pre-menopausal women in Durban, KwaZulu-Natal.
The aim will be accomplished through the following objectives:

1. To determine the prevalence of upper back pain amongst pre-menopausal women in Durban, KwaZulu-Natal
2. To determine the participants breast cup size by overbust and underbust measurements
3. To determine the pain pressure threshold of 12 anatomical sites in participants using the pressure algometer
4. To determine if an association exists between upper back pain and low pain pressure threshold that is caused by large breast sizes.

Procedure of Main study:

After you have responded to the advertisments, you will be requested to call the researcher for a telephonic interview in order to see if you meet the following inclusion and exclusion criteria:

Inclusion Criteria

- Biological women.

- Between ages 18 and 40.
- Bra size A-E
- English speaking

Exclusion Criteria

- Currently Menstruating
- Back trauma.
- Back surgery.
- Breast reduction surgery.
- Back conditions such as arthritis.
- Are you on any sort of pain medication such as cateflam

If you meet the criteria through telephonic interview you will then be asked if you experience any upper back pain or not in order to be place you into one of two groups; one with upper back pain and one without. Afterwards an appointment will be scheduled at the Chiropractic Day Clinic which will take 15 minutes for each participant.Upon arrival, you will be given a letter of information and will then be asked to fill in an informed consent form letter. An adequate verbal explanation of the study by the researcher will be given to you in order for all your questions to be answered. You will then be asked to remove their shirt and bra and then change into a gown in private with the door,windows and curtains closed.

Only a female chaperone will be allowed to be present during the duration of your visit.The researcher will then measure your underbust and overbust over the gown in order to determine the breast cup size.

Thereafter, the pain pressure threshold will be measured of the 12 anatomical sites including:

Skeletal sites: T2, T4, T6, T8, T10, T12.
Muscular sites: Pectoralis major, levator scapulae, sternocleidomastoid, upper trapezius, middle trapezius and lower trapezius.

After completion of appointment you will also receive education on correct bra sizing.

Responsibilities of participant:

Meeting the inclusion and exclusion criteria with honesty. Remove top and undergarments and then change into a gown in order to get underbust and overbust measurement taken. Thereafter participant will have to sit in order to get the pain pressure threshold of 12 anatomical sites taken using the pressure algometer.

Risks of main study: No risk associated with your participation to the main study.

Reason/s why the Participant May Be Withdrawn from the Study: Please note that you are able to withdraw from the study if you wish to do so. To prevent any pain caused by the pressure algometer used it will be given a cut off of 1000kpa. To provide comfort you will given a private room to change into a gown and keep the gown on during the entire duration of their participation in the study.The door,windows and blinds will remain closed during the session and only a female chaperone will be allowed to be in the room

Benefits of the main study: This purpose of this study is to improve the clarity around the breast size being a causative agent for upper back pain and musculoskeletal sensitivity which will in return help practitioners identify signs and symptoms early on, which can lead to early diagnoses and thus improve the management of these conditions and improve the quality of life of these patients. It will also allow women to be educated on if they are wearing the correct bra size.

Remuneration: No remuneration will be awarded to your for participiating in this study

Costs of the Study: You as a participant shall not cover any costs towards the study

Confidentiality: Confidentially throughout the study will be ensured by keeping your information anonymous. Your information will not be included in the published study and will remain confidential. The data collected during the study will only be accessible by the researcher, supervisor and co- supervisor.

Results of the study:
The final results of this study will be available as a dissertation at the DUT library and can be shared with your digitally, if you wish

Research related injury: No research related injury with the main study.

Storage of all electronic and hard copies including tape recordings:
Confidentiality will be maintained at all times, from the data collection to the publishing of results. The names of the participants will be allocated by codes to keep the identity of the participants anonymous and consent forms will be collected first and placed in a sealed envelope before the questionnaires are handed out. In accordance with Durban University of Technology's guidelines, the signed consent forms will be locked in one of the Chiropractic Day Clinic rooms with only the researcher and supervisors having access to this room for a period of five years. After the five-year period, the best practices will be followed to destroy the data, such as burning or shredding of the papers by the researcher. Electronic data will be kept in a password locked external hard drive with only the researcher knowing the password. The researcher will delete this data at the end of five years.

Persons to Contact in the Event of Any Problems or Queries: Please contact the researcher, Jasmine Lloyd, (060 529 7035), my supervisor Dr Ashura Abdul-Rasheed (031 492 3483), my co-supervisor Dr Cleo Prince (073 425 7871) or the DUT-Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Acting Director: Research and Postgraduate Support on researchdirector@dut.ac.za

Your assistance is greatly appreciated
Jasmine Lloyd

Appendix G: Informed Consent

INFORMED CONSENT

Title of the study: An investigation into the association between breast size, muscle sensitivity and upper back pain in pre-menopausal women in Durban, KwaZulu-Natal

Principal investigator/ researcher: Jasmine Lloyd BHCs Chiropractic (DUT)
Co-Investigators/supervisors: Dr Ashura Abdul-Rasheed M. Tech Chiropractic and Dr Cleo Prince M. Tech Chiropractic (DUT)

Statement of Agreement to Participate in the Research Study

I hereby confirm that Jasmine Lloyd, the researcher, informed me about the nature, conduct and benefits of the study- Research Ethics Clearance number: 072/24
I confirm that I have received a participant letter of information regarding the main study, which I have read and understood.
I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
I may, at any stage, without prejudice, withdraw my consent and participation in the study.
I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
I understand that significant new findings developed during the course of this research which may related to my participation will be made available to me.

Full Name of Participant	**Date**	**Time**	**Signature/Thumbprint**

I Jasmine Lloyd herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Full Name of Researcher	**Date**	**Signature**
Full Name of Witness	**Date**	**Signature (If applicable)**
Full Name of Legal Guardian (If applicable)	**Date**	**Signature Guardian (If applicable)**

Appendix H: Data Collection Sheet (Group A)

1	Participant Numb	Age	Ethnicity	Underbust (cm)	Overbust (	Cup size	T2	T4	T6	T8	T1O	T12	Pectoralis	Levator sc	Sternoclei	Upper trap	Middle trapzeius	Lower Trapzeius	Pain rating
2	A1																		
3	A2																		
4	A3																		
5	A4																		
6	A5																		
7	A6																		
8	A7																		
9	A8																		
10	A9																		
11	A10																		
12	A11																		
13	A12																		
14	A13																		
15	A14																		
16	A15																		
17	A16																		
18	A17																		
19	A18																		
20	A19																		
21	A20																		
22	A21																		
23	A22																		
24	A23																		
25	A24																		
26	A25																		
27	A26																		

Appendix I: Data Collection Sheet (Group B)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Participan	Age	Ethnicity	Underbus	Overbust (	Cup size	T2	T4	T6	T8	T1O	T12	Pectoralis	Levator sca	Sternoclei	Upper trapz	Middle trap	Lower Trapzeius
2	B1																	
3	B2																	
4	B3																	
5	B4																	
6	B5																	
7	B6																	
8	B7																	
9	B8																	
10	B9																	
11	B10																	
12	B11																	
13	B12																	
14	B13																	
15	B14																	
16	B15																	
17	B16																	
18	B17																	
19	B18																	
20	B19																	
21	B20																	
22	B21																	
23	B22																	
24	B23																	
25	B24																	
26	B25																	
27	B26																	

Appendix J: Ethics Online Training TRREE Certificates

TRREE

Zertifikat

Certificat

Certificado

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

jasmine lloyd

a complété avec succès - has successfully completed

Archived - Module 1 - Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/04/10
CID : DkbKgwtulG

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

APPROVED BY SIWF FMH ISFM
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Continuing Education Programs (2 credits)

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FPH Programmes de formation postgraduée et continue
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[REV : 20220217]

TRREE

Zertifikat Certificado Certificat Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
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du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/04/10

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

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TRREE

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Appendix K: Turnitin Report

Appendix I: Editor's Certificates

Helen Bond
IMPELA EDITING SERVICES
impelaediting@gmail.com
079 395 5873

29 October 2024

CERTIFICATE

Jasmine Lloyd

Dear Jasmine

Thank you for using Impela Editing Services to edit your Master's dissertation entitled "*An investigation into the association between breast size, muscle sensitivity and upper back pain in pre-menopausal women in Durban, KwaZulu-Natal*".

I have proofread for errors of grammar, punctuation, spelling, syntax and typing mistakes. I have formatted your work and checked the references (this means checking the formatting) according to the DUT Harvard referencing style.

I wish you all the best in your submission and your future career.

Kind regards

Helen Bond (Bachelor of Arts, HDE)