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PECTORALIS MINOR INDEX (PMI) RANGE AND SCAPULAR DYSKINESIS IN UNIVERSITY STUDENTS PRESENTING WITH A KYPHOTIC POSTURE AND AN IDEAL POSTURE

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(MPhysT)

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DECLARATION

I Muhle Annah Komati declare that this thesis is my own work. This thesis is being submitted for the Master's Degree in Physiotherapy at the University of Pretoria, Pretoria. This thesis has not been submitted before for any other degree or examination at this or any other university.

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Editing: Pectoralis Minor Index (PMI) Range and Scapular Dyskinesis in university students presenting with a kyphotic posture and an ideal posture.

This letter serves to confirm that the above work was edited during May 2019 for submission in fulfilment of the MPhysT degree within the Department of Physiotherapy, of the Faculty of Health Sciences, at the University of Pretoria. The editing process focussed on ensuring consistent and correct use and writing of English grammar, language and punctuation.

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ABSTRACT

Introduction and Background

Pectoralis minor (PM) muscle length is commonly known to cause shoulder dysfunction when a postural deviation, like a kyphosis, is present. A kyphotic posture causes the PM muscle to pull the scapula into an anterior tilt. Subsequently, the muscle length of the scapular stabilising muscles will be affected, as these muscles assume a lengthened position, which over time causes weakness.

It is hypothesised that students studying at a higher education institution assume a prolonged sitting position, which overtime perpetuates a functional thoracic kyphotic posture. The kyphotic posture influences PM muscle length and scapular stabilising muscle length and function. Furthermore, a short PM is also known to be a contributing factor to scapular dyskinesis.

Shoulder dysfunction has a strong association with scapular dyskinesis. Consequently, shortness of the PM muscle has continually been shown to be associated with a mal-aligned static scapula and scapular dyskinesis. Therefore, this all implies that scapular dyskinesis can be an indication of PM muscle length shortness.

In the current literature, the PM muscle length is expressed as Pectoralis Minor Index (PMI) values. However, there are inconsistencies regarding PM muscle length, which may be due to the testing techniques and equipment used to measure PM muscle length.

There are gaps in existing literature in respect to PM muscle length being measured in its optimum length (the resting, actively retracted and passively lengthened positions); as well as the association between scapular dyskinesis and the PM muscle in its optimum length. This study looks to address these gaps identified.

The study aimed to assess scapular dyskinesis in association to the PMI of students between the ages of 18 and 24 years, presenting with ideal and kyphotic postures; and to measure the PM muscle length in its optimum length.

Methodology

A quantitative, analytical, observational, cross-sectional study design was used. The PM muscle length of 144 participants was measured with a Vernier® caliper; measurements were performed in the resting, actively retracted and passively lengthened positions. Scapular dyskinesis was observed via video analysis while the participant performed five controlled shoulder abduction and flexion movements while holding weights.

Results

The main finding of this study was the statistically significant differences between all three testing positions ($p<0.001$). Additionally, statistically significant differences were observed in respect to kyphotic and ideal posture groups PMI values ($p <0.001$).

There was a significant difference across the levels of scapular dyskinesis on the non-dominant side ($p=0.016$). There was no significant difference across the levels of scapular dyskinesis on the dominant side ($p=0.136$). However, within both non-dominant and dominant sides, it was found that within the results, the ideal posture group presented with a larger percentage of scapular dyskinesis than the kyphotic group.

Conclusion

The study has shown that it is not only the PM muscle length that plays a role in altered scapular alignment and kinematics, but also the stability that the scapular stabilising muscle function contributes. There were two gaps identified in the current literature, as previously mentioned. These gaps have been addressed, in the current study.

Keywords: scapular dyskinesis, scapular stabilisers, trapezius muscles, serratus anterior muscle, resting scapula, dynamic scapula, pectoralis minor length, Pectoralis Minor Index, kyphosis in students and kyphotic posture in students.

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ABBREVIATIONS

PMI	Pectoralis Minor Index
PM	Pectoralis Minor
SCI	Spinal Cord Injuries
UP	University of Pretoria
ICC	Intraclass Correlation Coefficient
ADL	Activities of Daily Living
ACJ	Acromioclavicular joint
SD	Standard Deviation
CI	Confidence Interval
EMCS	Electromagnetic Motion Capturing System

1 CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Postural disorders (kyphotic) are the result of sustained positions like studying in a sitting position (Ellapen and Van Heerden 2011:883). Pectoralis minor (PM) muscle shortening has been attributed to sustained postures involving the anterior tilting and protraction of the scapula (Borstad 2006:550; Borstad and Ludewig 2005:228). The PM muscle pulls the scapula into an anterior tilt which in turn causes upper limb dysfunction (Kibler, Ludewig, McClure, Michener, Bak and Sciascia 2013:878). Due to the anatomical origin and insertion of the scapular stabilisers, an anteriorly tilted scapula will affect the length of the scapular stabilisers, as they assume a lengthened position which overtime, causes weakness (Kim, Lee and Yoo 2018:374). Students in the Faculty of Health Sciences of the University of Pretoria attend lectures and practical sessions throughout the day and still need to study afterwards. It can therefore be hypothesised that all these activities perpetuate a functional kyphotic posture in turn resulting in possible shortening of the PM muscle.

Scapular dyskinesis plays a complex role in PM muscle length. Serratus anterior and the trapezius muscles are the two main stabilisers of the scapula. When weakness of the scapular stabilisers occurs, the scapula loses normal kinematics with shoulder movements resulting in scapular dyskinesis (Kibler et al 2013:887-88). PM muscle length will subsequently be affected by scapular dyskinesis especially with the presence of a kyphotic posture (Ludewig and Reynolds 2009:90-92). This can be a result of the close chain kinematics of the thoracic cage, which alters scapula positioning and subsequently causes upper limb dysfunction.

The anteriorly tilted position of the scapula and subsequent lengthened scapular stabilisers cause a decrease in subacromial space which may contribute to upper limb dysfunction. The effect of scapular dyskinesis in relation to PM muscle length is not well researched; these findings could be beneficial to the body of knowledge that relates to upper limb dysfunctions and the rehabilitation of shoulder related problems.

In existing literature, Borstad and Ludewig (2005:228) were the first to express PM muscle length as an index; Pectoralis Minor Index (PMI). PMI is calculated as PM muscle length (cm)/subject's height × 100, meaning the PMI is used as an expression of PM muscle length which takes into account the soft tissue and body build for each individual. According to Borstad and Ludewig (2005:228) the PM muscle was identified as short where the PMI was less than 7.65 and a lengthened PM muscle was identified where the PMI was greater than 8.61.

Further studies have since been conducted to determine the PMI value in different populations. One study conducted on 35 elite tennis players (with no shoulder pain or injury), between the ages of 12 and 15 years had a PMI value between 6.2 and 7.6 (Cools, Johansson, Cambier, Vande Velde, Palmans and Witvrouw 2010:683). Another study conducted on participants with shoulder impingement syndrome, above the age of 18 years, presented with PMI values ranging between 8.9 and 9.1 (Struyf, Nijs, Mollekens, Jeurissen, Truijen, Mottram and Meeusen 2012a:9). However, these studies cannot be compared as there are inconsistencies in the age groups; testing positions; testing techniques; and testing instruments.

Firstly, the ages of the above-mentioned studies ranged from 13 to 68 respectively. Therefore, the PMI data cannot be compared as the age groups between the studies are not homogenous. Borstad and Ludewig (2005:228) conducted a study on six healthy participants, gender and age unknown. In another study done on 35 elite tennis players, the ages were ranging between 13 and 18 years, consisting of 19 males and 16 females (Cools et al 2010:678). Struyf, et al (2012a:2) used 22 participants with shoulder pathology, over the age of 18 years, consisting of 10 males and 12 females.

Secondly, the testing positions and testing techniques mentioned in these studies are also inconsistent. In the study done by Borstad and Ludewig (2005:230), the starting position was a standing position with the arm by the side and the PM muscle in a resting position. On the other hand, for Cools, et al (2010:680) and Struyf, et al (2012a:4) the starting position for testing was a supine position with the arm by the side and the PM muscle in a resting position. In all these studies PM muscle length was evaluated but never in the most lengthened position, measurements were only performed at rest and not including the active retraction position, and the passively lengthened position.

Thirdly, the testing tool used by Borstad and Ludewig (2005:230) and Cools, et al (2010:680) was the Vernier® caliper (eliminates soft tissue influences). Struyf, et al (2012:4) made use of a tape measure (does not give true value due to soft tissue). Borstad (2006:550) further used an EMG device (too expensive) and a tape measure to measure PMI.

In summary, the PM muscle and the scapular stabilising muscles are structures affected by a kyphotic posture. When a person has a kyphotic posture (functional or structural), the PM muscle can be shortened and ultimately result in changes in scapula positioning. The kyphotic posture may have an effect on the scapular stabilising muscles which can possibly be lengthened and result in weakness (Kim et al 2018:374). This can lead to upper limb dysfunction as both these structures have the ability to decrease subacromial space when they are not functioning at their optimum level. Therefore, PM muscle length and the strength of scapular stabilisers may contribute to shoulder dysfunction as separate entities; however, the relationship between the two structures is not well researched. Therefore, the aim of this study was to assess PMI and scapular dyskinesis in healthy participants with a kyphotic posture. Noting, the gap in existing literature for PM muscle length expressed as PMI assessed in its optimum length (resting, actively retracted and passively lengthened positions) and the association with scapular dyskinesis.

1.2 PROBLEM STATEMENT

When studying, students will most likely be in a kyphotic posture. In this adaptive posture the PM muscle is deemed short and overactive and the scapular stabilising muscles are weak and lengthened. As a result, the shoulder joint alignment can be affected and more prevalent to shoulder pain. PM muscle length has been identified to be a large contributing risk factor to shoulder pain. Conversely, a decreased PM muscle length has always been strongly associated with causing scapular dyskinesis (Kibler et al 2013:878). However, there is a limitation in literature regarding the association of scapular dyskinesis in relation to PM muscle length. In previous studies PM muscle length was only measured inconsistently in a resting position (Borstad and Ludewig 2005:229; Borstad 2006:550-551; Cools et al 2010:680; Struyf et al 2012a:4). From this information it is difficult to determine if the scapular stabilisers are affected. Therefore, PM muscle length (expressed as PMI) needs to be measured in resting, actively retracted and passively lengthened positions, taking into consideration the association of scapular dyskinesis.

1.3 RESEARCH QUESTIONS

- What is the PMI value in students aged 18-24, presenting with a kyphotic posture without shoulder pathology?
- What is the association of PM muscle length expressed as PMI and scapular dyskinesis in students aged 18-24, presenting with a kyphotic posture without shoulder pathology?

1.4 HYPOTHESIS

1. -Null hypothesis: There will be no association between PMI and scapular dyskinesis in students with an ideal posture.

   -Alternative hypothesis: There will be an association between PMI and scapular dyskinesis in students with an ideal posture.
2. -Null hypothesis: There will be no association between PMI and scapular dyskinesis in students with a kyphotic posture.

   -Alternative hypothesis: There will be an association between PMI and scapular dyskinesis in students with a kyphotic posture.
3. -Null hypothesis: There will be no difference between PM length expressed as a PMI value in students with ideal posture, compared to students with kyphotic posture.

   -Alternative hypothesis: There will be a difference between PM length expressed as a PMI value in students with ideal posture, compared to students with kyphotic posture.
4. -Null hypothesis: There will be no difference between PM length expressed as a PMI value in males, compared to females.

-Alternative hypothesis: There will be a difference between PM length expressed as a PMI value in males, compared to females.

1.5 AIMS

The aims of the study are:

- To determine the PMI value in the resting position, the actively retracted and passively lengthening positions of students aged 18-24, presenting with kyphotic and ideal postures.
- To assess scapular dyskinesis in association to the PMI value of students aged 18-24, presenting with kyphotic and ideal postures.

1.6 OBJECTIVES

The objectives of the study are:

- To determine if scapular dyskinesis is present in students aged 18-24 with ideal and kyphotic postures.
- To determine if there is a difference in PMI values between the ideal and kyphotic postures.
- To determine the PMI values in the resting position, the actively retracted and passively lengthened positions on the dominant and non-dominant side with a Vernier® caliper.
- To determine if there is a difference in PMI values between the dominant and non-dominant shoulder.
- To determine if there is a difference in the PMI values between males and females.

1.7 IMPORTANCE AND BENEFITS OF THE PROPOSED STUDY

In literature PMI has been measured inconsistently in the resting position of the scapula (Borstad 2006:550-551; Cools et al 2010:680; Struyf et al 2012a:4), where some subjects are in a relaxed supine posture (Cools et al 2010:680; Struyf et al 2012a:4) and others are standing (Borstad 2006:229). Inconsistency also exists in the age, gender and positioning of the participants. This led to inconsistencies in the PMI values obtained from these studies.

In current studies conducted at the University of Pretoria (UP) where age (18-24), gender and positioning are consistent; the PMI ranges from 8.4 to 10.3. These studies were mainly conducted on elite athletes (umbrella study Protocol #: 163/2012, 562/2015 by Korkie 2015:134).

The significance of this study is that PMI will be evaluated in the same age group category as the previous studies conducted at UP but on a healthy general population of students instead of elite athletes (these studies form part of the umbrella study Protocol #: 163/2012, 562/2015 by Korkie 2015:134). The PM muscle length will not only be measured in the resting position but also in the actively retracted and passively lengthened positions. When PM muscle length is measured in the resting position it gives an indication of the resting length of the muscle. When it is measured in an actively retracted position it gives an indication of the ability of the scapular stabilisers to contract through range. The passively lengthened measurement will give an indication of the actual PM muscle length. If a difference is observed between the three measurements it might indicate the presence of scapular stability weakness which may lead to scapular dyskinesis. This is where the gap in literature exists, as PM muscle length expressed as PMI is only measured at rest and not in its optimum length (resting, actively retracted and passively lengthened positions). Furthermore, no research exists that evaluates the association of PM muscle length and scapular stabilisers, using the dynamic scapular dyskinesis evaluation technique.

1.8 DELIMITATIONS AND ASSUMPTIONS

1.8.1 Delimitations

Only students of the Faculty of Health Sciences of the University of Pretoria are included in the study.

1.8.2 Assumptions

We assume that:

- Students at this Faculty sit for extended periods of time at a desk due to high study workload
- Most students present with poor posture during sitting (thoracic kyphosis and protracted shoulder position)
- Students at this Faculty stand for extended periods of time due to the nature of their work in clinical practice
- Most students present with poor posture during standing due to the forward posture position they assume when treating patients (thoracic flexion and protracted shoulders)
- There will be no additional proprioceptive influence from bra straps in females, when evaluating scapular dyskinesis, as all females wear bras on a daily basis

1.9 DEFINITION OF KEY TERMS

Table 1.1 below provides definitions of key terms as they are used in the current study.

Table 1. 1 ***Definition of key terms as used in this study***

Phrase	Concept
Actively retracted	The active retraction of the scapula using lower trapezius, rhomboids major and minor, resulting in active lengthening of the PM muscle, to the point of a trick movement.
Elite athlete	An elite athlete as described in this study is an individual that participates in any sporting activities at a provincial and national level.
Functional kyphosis	The excessive convex curvature on the thoracic spine due to poor posture, which can be corrected actively by the participant (Bruno, Anderson, Angostino and Bouxsein 2012:2145).
Healthy participant	A healthy participant in this particular study is an individual that does not present with shoulder pain that interferes with activities of daily living (ADL)
Non-symptomatic	In literature that is referred to in the current study, non-symptomatic participants refers to participants that do not have shoulder pain
Passively lengthened	The passive lengthening of the PM muscle to its optimum length by a second person where the origin of the muscle is stabilised and the insertion is moved away (ribs stabilised and the coracoid process moved away) to a point of restriction.
Pectoralis minor muscle length	The length of the PM muscle as measured from its anatomical origin to its insertion, from the fourth rib to the medial aspect of the coracoid process (Borstad 2008:170).
Resting position	The habitual postural position of the scapula.
Scapular dyskinesis	The alteration of normal scapular kinematics (Kibler et al2013:877).
Scapular protraction	The motion of the scapula away from the vertebral column. Outward and forward movement of the shoulder blade/ scapula. A type of movement that takes place along the transverse plane and longitudinal axis (combination of abduction and medial rotation of the scapula) (Smith, Kotajarvi, Padgett and Eischen 2002:367).
Scapular stabilisers	The muscles attached to the scapula contributing to the stability of the scapula, i.e. trapezius muscle (upper, middle and lower fibres), rhomboids major and minor; and serratus anterior (Paine and Voight 2013:618). Please note: In this current study, when we refer to scapular stabilisers we

	refer to lower trapezius and serratus anterior specifically, as these two muscles are the muscles that are affected with an anteriorly tilted scapula
Scapular stabilising muscle function	The ability of the scapular stabilising muscles (specific to this study) to hold the scapula against the thorax and to control movement during shoulder elevation.
Structural kyphosis	The abnormality affecting the bones, intervertebral discs, nerves, ligaments or muscles. Therefore, the excessive convex curve cannot be corrected actively by the participant (Miladi2012:S140).
Student	An individual registered as an undergraduate student at a higher education institution. In this study at the University of Pretoria.
Thoracic kyphosis	The biomechanical abnormality characterised by excessive convex curvature of the thoracic region of the spine. Increased flexed curving of the thoracic portion of the spine (Kendall, McCreary, Provance, Rodgers, Romani, 2005:66; Maladi 2012:5140).
Upper limb dysfunction	The disorder that may be present within the shoulder joint and structures surrounding the shoulder joint, e.g. muscles, tendons, ligaments. Shoulder dysfunction may present with or without pain and will affect optimum function (Kim and Kim 2017:npn).

Posture

- Kyphotic posture has been attributed to causing an imbalance in the shoulder girdle kinematics.
- The close kinematic chain of the thoracic cage may cause scapula protraction, in turn causing weakness of the scapular stabilisers.

PM length, expressed as PMI

- The PM muscle has been hypothesised to be a contributing factor of scapula malalignment.
- A short PM muscle length has been shown to reduce scapula upward rotation and scapula posterior tilting during humeral elevation, causing upper limb dysfunction.

Scapular Dyskinesis

- Upper limb dysfunction has a strong correlation with scapular dyskinesis.
- This also implies that scapular dyskinesis can be an indication of PM muscle length shortness.

Objectives

For a student population between the ages of 18 to 24 year with ideal and kyphotic postures

- To determine PMI values in the resting position, as well as actively and passively lengthened positions on the dominant and non-dominant side, with a Vernier® caliper.
- To determine if there is a difference in PMI values between the dominant and non-dominant shoulder.
- To determine if there is a difference in the PMI values between males and females.
- To determine if there is a difference in PMI values between the ideal and kyphotic postures.
- To determine if scapular dyskinesis exist in students aged 18-24 with ideal and kyphotic postures.

Study

- PMI values in resting, as well as active and passive lengthening positions of students aged 18-24, presenting with ideal and kyphotic postures, was measured.
- Scapular dyskinesis in relation to PMI of students aged 18-24, presenting with ideal and kyphotic postures, was assessed.

Figure 1. 1 Conceptual Framework

OUTLINE OF DISSERTATION

This section looks at a brief outline and description of the different chapters that are included in this research report.

Chapter 2

The literature regarding scapular dyskinesis and PMI values is reviewed. The anatomy and function of the PM muscle and scapular stabilisers are described. Discrepancies are identified in the measurements of PM length and this is further explored.

Chapter 3

The setting and methodology are explained based on the literature review and clinical reasoning.

Chapter 4

The results are presented according to each objective set.

Chapter 5

The results are discussed in order of significance. The most significant results are discussed first and the least significant last.

Chapter 6

The dissertation is concluded and important findings are summarised.

Chapter 7

Recommendations for future studies are outlined and limitations to the current study are detailed.

1.10 SUMMARY

Chapter 1 presented the current background in relation to this research study. The research question, hypothesis, aims and objectives were clarified. A gap in the existing literature has been identified for the association between scapular dyskinesis and PMI. Furthermore, inconsistencies in the measurement of PM muscle length have been identified.

In Chapter 2 the existing literature will be reviewed, analysed and explored in terms of scapular dyskinesis in association with the PMI. The scapular stabiliser muscles and the PM muscle anatomy and function will be explained. Assessment techniques for scapular dyskinesis will be reviewed. Finally, PM muscle length measurements and techniques will be reviewed.

2 CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

A kyphotic posture in recent times can be attributed to excessive use of electronic devices such as smart phones, laptops and tablets (Lv, Peng, Zhang, Ding and Chen 2016:1). In a student population heavy backpacks can also contribute to such a posture, as various models of backpacks exist in the market which do not take into consideration the muscular and physical changes they may cause (Salehzadeh and Bonab 2015:722). The daily carrying of these backpacks inflict heavy loads on the spinal cord of students and is a contributing factor to a kyphotic posture (Salehzadeh and Bonab 2015:722). The heaviness of the backpack forces the individual to lean forward, moving their centre of gravity forward to compensate for the heavy bag, this in the long term perpetuates a functional kyphosis (Grimmer, Dansie, Milanese, Pirunsan and Trott 2002:11; Bettany-Saltikov and Cole 2012:118). The prevalence of kyphosis in a student population (University of Kwa-Zulu Natal, South Africa) is 76.13% in males and 72.19% in females (Ellapen and Van Heerden 2011:883). Once a person assumes a kyphotic posture, the biomechanics of the spine and the function of the muscles are altered. Kyphotic posture has been attributed to causing an imbalance in the shoulder girdle kinematics, the PM muscle adaptively shortens and the scapular stabilising muscles are lengthened and weakened (Kendall et al 2005:92).

The current study will investigate scapular dyskinesis relates to PM muscle length, expressed as PMI in a student population with kyphotic and ideal postures. A gap in the literature which evaluates the association between scapular dyskinesis and PM muscle in its optimum length, was identified. In the current review that was done, there were a lot of inconsistencies in the literature regarding the measurement of PM muscle length, mainly in measuring techniques, measuring positions, equipment used and values. Prior to the review of these inconsistencies, a background of scapular stabilising muscles and PM muscle anatomy and function will be discussed.

Keywords used for the literature search included: scapular dyskinesis, scapular stabilisers, trapezius muscles, serratus anterior muscle, resting scapula, dynamic scapula, pectoralis minor length, Pectoralis Minor Index, kyphosis in students and kyphotic posture in students.

Literature searches included the use of journal articles and books which were found via Google scholar, CD-ROM, University of Pretoria online databases, Medline and Pubmed. The review included articles from the year 2000 to 2018 (the search did not go further back beyond the year 2000 as most of the research starting to focus scientifically sound literature on the PM muscle was after 2000), which were published in English.

This review will discuss:

- scapular dyskinesis and the influence of the PM muscle;
- evaluation of scapular dyskinesis;
- factors influencing scapular dyskinesis and the PM muscle;
- scapular stabilisers, PM muscle and posture;
- scapular dyskinesis as a result of decreased PM muscle length and scapular muscle weakness;
- the evaluation of PM muscle length; and
- the Pectoralis Minor Index (PMI).

2.1.1 SCAPULAR DYSKINESISAND THE INFLUENCE OF THE PM MUSCLE

In this section scapular dyskinesis will be defined, and an evaluation of scapular dyskinesis will be done.

Scapular dyskinesis can be described as altered scapular motion. Kibler, et al (2013:877) described scapular dyskinesis as 'dys' (alteration of) 'kinesis' (motion). This is a general term that reflects the loss of normal control of scapular motion (Kibler et al 2013:877). Scapular dyskinesis may exist in a student population due to altered scapula and humeral kinematics caused by shoulder girdle muscle fatigue (Khare and Deshmukh 2015:911). The fatigue may be due to working with the shoulders in elevated positions for prolonged periods. Scapular dyskinesis is also commonly found in athletes with shoulder injuries but can also be present in asymptomatic individuals (Pluim 2013:875), with a prevalence of 61% in overhead athletes and 33% in asymptomatic non-overhead athletes (Burn, McCulloch, Lintner, Libermananh and Harris 2016:1). It has also been found that athletes with scapular dyskinesis have a 43% higher risk of developing shoulder pain than those without scapular dyskinesis, over a nine to 24 months follow-up (Hickory, Solvig, Cavelheri, Harrold and Mckenna 2018:1). Scapular dyskinesis by itself does not mean musculoskeletal diagnosis. It has been hypothesised that scapular dyskinesis is related to changes in glenohumeral angulation, acromioclavicular joint strain, subacromial space dimension, shoulder muscle activation, humeral position and motion, which can result in subacromial impingement (Kibler et al 2013:877).

Changes in scapular kinematics can be attributed not only to altered scapular recruitment patterns (e.g. altered serratus anterior muscle activity) or muscle performance (e.g. force imbalance in the upper and lower trapezius muscle), but also inflexibility of the soft tissue surrounding the scapula may restrict normal scapular movement during daily activity and sport-specific movements (Cools, Struyf, De Mey, Maenhout, Castelein and Cagnie 2014:693). This in turn may suggest that scapular dyskinesis, as a result of scapular stabilising muscle weakness, plays a complex role in PM muscle length. Supporting this potential association is a perspective article stating that orthodox scapular stabilisation exercises alone are flawed with limited support from current evidence; therefore, the contribution of the scapula to shoulder dysfunction (in terms of muscle synergy and stiffness, and coupled movement pattern variability) should be explored (McQuade, Borstad and de Oliveira 2016:1168).

The PM muscle has been hypothesised to be a contributing factor of shoulder girdle alignment and movement (Morais and Cruz 2016). It is one of two scapulothoracic muscles and it links the shoulder girdle complex with the anterior aspect of the thorax wall (Borstad and Ludewig 2005:228). It is also the only scapulothoracic muscle with both origin and insertion anterior to the scapula (Rosa, Borstad, Pogetti, and Camargo 2017:20). This information provides a background on the influence of the PM muscle on the thorax and scapula. Now that the background information on scapular dyskinesis and the PM muscle has been acquired, the evaluation of scapular dyskinesis will be reviewed.

2.1.2 EVALUATION OF SCAPULAR DYSKINESIS

In this section, the types of evaluation techniques for scapular dyskinesis will be discussed. Dynamic scapular motion techniques have been described as the ideal method of assessing scapular dyskinesis (Kibler, Uhl, Massux, Brooks, Zeller and McMullen 2002:550-2; Uhl, Kibler, Gecewich and Tripp 2009:1242-1243; McClure, Tate, Kareha, Irwan and Zlupko 2009:161-162; Seitz, McClure, Lynch, Ketchum and Michener 2012:632; Mackenzie, Herrington, Funk, Horsley and Cools 2015b: 2; Huang, Ou, Huang and Lin 2015:1228; Rosa, et al 2017:22-3). The summary of these articles is recorded in Table 2.1 and includes a brief discussion on each.

Table 2. 1: Summary of studies evaluating the dynamic scapular motion

Kibler, et al (2002:560-556)	Qualitative clinical evaluation of scapular dysfunction: a reliability study	A reliability study Objective: to determine the intra-rater and inter-rater reliability of a clinical evaluation system for scapular dysfunction.	n=26 subjects (age, 29.5± 9 years)	Clinical observation of scapular motion with shoulder elevation. All subjects performed three repetitions of bilateral arm elevations in scaption and abduction in a counterbalanced order to prevent fatigue. Arm elevation and lowering were performed at a rate of 45°/s. This was controlled by having the subject practice moving through the range of motion several times while the investigator, using a stopwatch, counted each second off aloud.	A moderate level of agreement and reliability was present with this system. With an Intratester reliability of 1 physician (ƙ= 0.59, *P* <.001) and 1 physical therapist (ƙ= 0.49, *P* <.001).	This method only identifies scapular motion in a single plane, which is not a good assessment as scapular dyskinesis occurs in multiple planes. Therefore, this test has a low reliability.
Uhl, et al (2009:1240-1248)	Evaluation of clinical assessment methods for scapular dyskinesis	Inter-rater reliability and validity Objectives: to assess the inter-rater reliability and validity of 2 clinical assessment methods of categorising scapular dyskinesis and quantify the frequency of asymmetry of bilateral scapular motion in injured and	n=56 subjects, 35 with shoulder injury and 21 with no symptoms. Ages for asymptomatic group were 24±3 years and symptomatic group 32±11 years.	Each assessment included observing the medial and superior scapula borders during 3 to 5 trials of arm elevation in the sagittal and scapular planes. The clinicians categorised the scapular motion into 1 of the 4 categories (4-type method) according to Kibler, et al (2002). A 3D electromagnetic tracking device recorded the 3D position and orientation of each subject's thorax and bilateral scapulae at 100 Hz. Subjects completed 8 repetitions of arm elevation and lowering with elbows in full extension in a sagittal plane in concert with a metronome at a rate of 75°/s. As well as the scapular plane, defined as 45° to the frontal plane. The final 5 of the 8repetitions were used for data analysis.	The inter-rater reliability of the 4-type clinical assessment method yielded a 61% agreement between the 2 investigators, resulting in a ƙ correlation of 0.44(*P* < .01). The yes/no assessment method yielded a79% agreement, with a ƙ correlation of 0.41 (*P* <.01). The 2 assessment methods compared with the criterion of the 3D kinematic analysis resulted in an overall accuracy of the 2 evaluation methods ranging between 45%	Good simplification of 4-type classification. Good repetition of shoulder elevations, enough to observe control of scapula. However, the equipment is expensive and not easily accessible and the kappa values were poor.

		uninjured shoulders by use of 3-dimensional (3D) kinematic analysis.			and 66%. The sensitivity of the 4-type method varied across the types of scapular patterns, ranging from 10% to 54%, and the specificity ranged from 62% to 94%.	
McClure, et al (2009:160-164)	A clinical method for identifying scapular dyskinesis Part 1: reliability	Correlation design using ratings from multiple pairs of testers. Objective: to determine the inter-rater reliability of a new test designed to detect abnormal scapular motion.	n=142 athletes	Each participant performed 5 repetitions of bilateral, active, weighted shoulder flexion and bilateral, active, weighted shoulder abduction (frontal plane) while they were videotaped from the posterior and superior views. Participants performed simultaneous elevation of their arms in flexion and abduction, overhead as far as possible to a 3-second count using the ‘‘thumbs up’’ position and then lower to a 3-second count, with weights measured according to participants body weight.	Percentage of agreement was between 75% and 82%, and kw ranged from 0.48 to 0.61.	Well described technique and easy to replicate in the clinical setting as 5 repetitions are enough to observe control of scapula and show a true reflection of scapular dyskinesis. This test also shows good inter-rater reliability.
Seitz, et al (2012:631-640)	Effects of scapular dyskinesis and scapular assistance test on subacromial space during static arm elevation	Intra-rater reliability Objectives: to determine the influence that scapular dyskinesis and passive manual correction	n=40 healthy participants (20 with dyskinesis; 20 with normal motion), between the ages of 18 and 70 years, free	McClure et al 2009 testing procedure followed: - The scapular dyskinesis test consists of 5 repetitions of bilateral, active, should flexion and abduction, holding either 1.4 kg (3 lb) or 2.3 kg (5 lb) weights based on body mass. -The Polhemus 3Space Fastrak electromagnetic-based motion capture system, to collect 3D kinematic data of the scapula, humerus, and trunk. -Participants were seated in an armless chair with the lumbar spine firmly against the seat. With the thumb	Obvious dyskinesis was present in the dominant shoulder in 55%. Examining the effects of dyskinesis on 3D scapular kinematics: there were no statistically significant interactions with	Equipment for testing scapular dyskinesis is expensive and the testing procedure with EMG is not suitable for clinical purposes.

		with the SAT have on subacromial space and 3-dimensional (3D) scapular kinematics.	from shoulder or upper arm pain for at least 6 months	facing forward, the arm was positioned at rest, 45°, or 90 ° of active shoulder scapular plane elevation verified with an inclinometer. The Scapular Assistance Test (SAT) manoeuvre was applied to the scapula while the participant actively maintained a static arm position. Two consecutive trials were performed at each arm angle (rest, 45° and 90°), under each condition (with and without SAT), in random order by drawing.	upward rotation, posterior tilt, external rotation or main effects of dyskinesis in either upward rotation, posterior tilt or external rotation.	
Huang, et al (2015:1227-1234)	Specific kinematics and associated muscle activation in individuals with scapular dyskinesis	Cross-sectional investigation	n=82 volunteers (65men, 17 women) who were a mean age of 22.9 ± 3.3 years, with unilateral shoulder pain	-Surface electromyogram (sEMG) was used. -The electrodes were placed over the upper, middle and lower parts of the trapezius and serratus anterior muscles using previously established methods. -Modified by Kibler, et al (2002) method. -The starting position was arms at the side of the body, elbow straight and shoulder in a neutral position. -Participants were asked to elevate the arms, using the thumb-up position, to the end range over a 3-second count and then to lower them over a 3-second count. With weights measured according to participant's body weight. -Participants also performed 6 trials of bilateral, active, weighted arm elevation in the scapular plane.	Specific alterations of scapular muscular activation and kinematics were found in different patterns of scapular dyskinesis. The findings also validated the use of a comprehensive classification test to assess scapular dyskinesis, especially in the lowering phase of arm elevation.	Equipment used is expensive and not easily accessible. Only one plane of movement assessed (scapular plane) and this is not an accurate presentation for scapular dyskinesis as it is best assessed in multiple planes.

Rosa, et al (2017:20-29)	Effects of a stretching protocol for the pectoralis minor on muscle length, function, and scapular kinematics in individuals with and without shoulder pain	Parallel-group intervention with repeated measures. Objectives: to evaluate the effects of a stretching protocol on function, muscle length, and scapular kinematics in subjects with and without shoulder pain.	n=50 subjects (25patients with shoulder pain and 25 healthy subjects)	For 3D scapular kinematics, Flock of Birds (miniBird) hardware was used for data capture and analysis. Subjects elevated their arm from a dependent position through their full range of motion at a 3 seconds count to elevate their arm and 3 seconds to lower it. 3 repetitions of elevation were completed.	Results showed that PM stretching decreased pain and improved function in subjects with shoulder pain but was not effective at changing the PM length or scapular kinematics.	This would be an acceptable test for scapular dyskinesis as there are three repetitive movements that allow for scapular control to be assessed. However, the equipment used for scapular kinematics is expensive and not readily available.

Tests to evaluate scapular dyskinesis

At the second International Consensus Conference on the scapula which was held in Lexington Kentucky in 2013, it was concluded that dynamic scapular dyskinesis testing are the most recommended compared to resting scapula positions (Kibler et al 2013:878). Be that as it may, most of these methods use expensive equipment and are impractical for the use in a clinical setting (Struyf, Nijs, Mottram, Roussel, Cools and Meeusen 2012b:1). From a clinical point of view, a test is deemed appropriate and accurate, if it is reliable, valid and easy to implement in a clinical setting (Nijs, Roussel, Struyf, Mottram and Meeusen 2007:69).

In earlier research, a 4-type classification for scapular dyskinesis was devised (Kibler et al 2002:551-553). The classification breaks down scapular dyskinesis into four categories. The dynamic scapular motion is only performed in the scapular plane and therefore only accounts for one plane of movement. This had a Kappa-value for the inter-rater reliability of 0.4 and a Kappa value of 0.5 for the intra-rater reliability. The inter-rater reliability was fair and the intra-rater reliability was moderate. This technique is easy to replicate and is inexpensive. However, this 4-type classification was evaluated, regarding its validity against 3D kinematic analysis (Uhl et al 2009:1240). It had a low accuracy for inter-rater agreement of 61% with a Kappa-value of 0.44. Therefore, the clinical value for this test has been proven to be weak. The 4-type classification was further simplified to 'yes/no' criteria of dyskinesis (Uhl et al 2009:1242-1243). This 2-type method removed the constraint of the clinician to decide on a single most prominent pattern when multiple planes of asymmetry may have been observed (Uhl et al 2009:1243). The 2-type method yielded a 79% agreement, with a Kappa-value of 0.41, implying that the inter-rater agreement increased but the reliability did not improve. Therefore, the clinical use for the 2-type method is weak. A cross-sectional investigation study, to assess scapular kinematics and associated muscular activation during arm movements, was conducted on individuals with scapular dyskinesis (Huang et al 2015:1228-1229), using the Kibler, et al (2002:551-553) 4-type classification. Electromagnetic motion-capturing and surface electromyography were used for this assessment; this equipment is expensive and not easily accessible. The findings affirm the use of an inclusive classification test to assess scapular dyskinesis, especially in the lowering phase of arm elevation. However, as previously mentioned the 4-type classification has a low reliability and is not the most inclusive testing technique for scapular dyskinesis as it only tests in a single plane.

A technique that has moderate reliability and clinical value, with satisfactory inter-rater reliability of a Kappa-value ranging from 0.48 to 0.61, is described by McClure, et al (2009:162). The standard technique used in practice, as proposed by McClure, et al (2009:161) is five repetitions of weighted shoulder flexion and abduction respectively. Participants were instructed to grasp dumbbells according to body weight, 1.4 kg (3 lb) for those weighing less than 68.1 kg (150 lb) and 2.3 kg (5 lb) for those weighing 68.1 kg or more (McClure et al 2009:161). Dyskinesis was categorised into normal, subtle and obvious. The types of dyskinesis to be observed were winging of the scapula medial and inferior borders, as well as dysrhythmia. Each shoulder was assessed individually for active flexion and abduction independently, and thereafter the two movements (flexion and abduction) were assessed in combination for that specific shoulder. This is a simple, reliable and affordable method of assessing scapular dyskinesis. This technique has since been used in clinical settings as a practical application, which is supported by Pluim (2013:875-6).

Further studies have utilised the technique described by McClure, et al (2009:161) but went on to use an electromagnetic-based motion capturing system to monitor 3D scapular kinematics (Seitz et al 2012:632-633). Even though there was presence of apparent obvious scapular dyskinesis in participants in this study, the 3D orientation of the scapula was not altered in static positions of arm elevation compared to participants without dyskinesis. This may be due to the fact that scapular kinematic alterations are more apparent during dynamic testing settings than during static settings (Seitz et al 2012:634). This supports the clinical use of dynamic scapula testing techniques without the use of expensive equipment.

Although the assessment of the resting position of the scapulais not included in the current study, scapula markers will be used to simplify the analysis of scapular dyskinesis in the methodology of the current study. Therefore, an overview of the resting positions of the scapula is included in the paragraphs to follow.

The position of the scapula at rest is used to assist in the assessment of scapular dyskinesis, as the landmarks provide visual input during scapular motion. Therefore, palpation of scapula landmarks is a useful tool in clinical practice to determine dynamic scapular dyskinesis. Literature supports that surface palpations are useful and valid in determining the bony location of the scapula and thoracic spine and the position of the scapula in relation to the thoracic spine (Lewis, Green, Reichard and Wright 2002:30). Landmarks of the resting scapula are described as the upper edge of the scapula which should be located at the second or third thoracic vertebra, the inferior angle at the seventh to ninth thoracic vertebrae, and the medial border of the scapula positioned parallel to the spine (Nijs, Roussel, Struyf, Mottram and Meusen 2007:70). These landmarks assist in making the assessment of dynamic scapular motion much easier. Assessment techniques of the resting scapula are briefly reviewed in the next paragraph.

Studies have been conducted that performed measurements from the acromion to table, in order to determine the resting scapula position (Nijs, Roussel, Vermeulen and Souvereyns 2005:1350-1351; Lee, Cynn, Yoon, Choi, Choi, Choi and Ko 2015:257; Ko, Cynn, Lee, Yoon and Choi2016:274). This technique has a good inter-observer reliability with an Intraclass Correlation Coefficient (ICC), ranging from 0.88 to 0.94, making it easy to replicate (Nijs et al 2005:1353). Irrespective of, the technique does not evaluate scapular dyskinesis, as it is a static test that does not consider scapular muscle function. Other studies were conducted where measurements were done from various parts of the scapula borders and spinous processes (Nijs et al 2005:1350-1; Mackenzie, Herrington, Funk, Horsley and Cools 2015b:1-2). Nijs, et al (2005:1350-1) performed measurement from the medial scapula border to the fourth thoracic spinous process. Mackenzie, et al (2015b:1-2) performed measurements from the inferior angle of the scapula to the closest horizontal spinous process of the thoracic spine; the root of spine of the scapula to the closest horizontal spinous process of the thoracic spine and the distance from the inferior angle of the scapula to the root of the spine of the scapula. These distances were used to calculate the scapula rotation angle. These studies did not account for scapular muscle function either.

It can be concluded that the resting scapula positioning measurement is not the best suited method in observing scapular dyskinesis, as scapular dyskinesis is dependent on the activity of the muscles in dynamic motion (Kibler et al 2013:878). However, the resting scapula landmarks are viewed as a useful tool in observing scapular dyskinesis. The best suited method of observing scapular dyskinesis is through the use of dynamic tests, of which the majority are unfortunately expensive and not appropriate for clinical practice. To date, the most appropriate way of observing scapular dyskinesis in clinical practice and most reliable is described by McClure, et al (2009:161), as previously mentioned.

In the next section, the factors that influence scapular dyskinesis will be reviewed.

2.1.3 FACTORS INFLUENCING SCAPULAR DYSKINESIS AND THE PM MUSCLE

In this section the factors that influence scapular dyskinesis will be reviewed. These include changes in scapular kinematics when muscles are weak and the effects of changes in muscle length and function.

The first factor to be discussed is the effects of muscle weakness on scapular kinematics. Serratus anterior and the trapezius muscles are the two main stabilisers of the scapula when glenohumeral movement takes place. Soft tissue mechanisms of scapular dyskinesis involve tautness or intrinsic muscle problems for muscles like PM and the short head of biceps brachii (due to their attachment on the coracoid process); as shortening of these muscles causes an anterior tilt of the scapula (Kibler et al 2013:877-878). Serratus anterior activation and strength is decreased in patients with a kyphotic posture, due to the scapula position because the scapula is placed in an anterior tilt which puts the serratus anterior muscle at a constant stretch. This results in the loss of posterior tilt and upward rotation of the scapula, which in turn causes scapular dyskinesis (Cools, Dewitte, Lanszweert, Notebaert, Roets, Soetens, Cagnie and Witvrouw 2007:1744-5). Furthermore, the upper and lower trapezius force couple may be altered causing delayed onset of lower trapezius activation, which alters scapula upward rotation and posterior tilt. If the scapular stabilising muscles remain weakened and PM muscle remains shortened, it may eventually result in subacromial impingement (Kibler et al 2013:878). Muscle length and strength play a vital role in scapular kinematics. To understand the role of the muscles affecting scapular kinematics, an overview of the anatomy will be given.

Serratus anterior originates from the first eight or nine ribs and inserts on the medial border of the scapula. The trapezius muscle has three fibres that have different functions, namely the upper, middle and lower fibres of trapezius. The trapezius muscle originates from the external occipital protuberance, medial third of the superior nuchal line, ligamentum nuchae, the spinous processes of C7 to T12 and inserts on the lateral third of the clavicle, acromion process of the scapula, medial margin of the acromion and superior lip of the spine of the scapula and the medial third of the spine of the scapula. The PM muscle originates on the anterior surface of the third to fifth ribs on the cartilaginous junction and inserts on the coracoid process (Borstad and Ludewig 2005:228; Kendall et al 2005: 320; Ludewig and Reynolds 2009:96).

The overall function of the muscles affecting scapular kinematics is: serratus anterior does protraction and stabilisation of the scapula and assists in upwards rotation of the scapula (Kendall et al 2005:332). The upper fibres of the trapezius muscle performs cervical extension, cervical lateral flexion and scapula elevation. The middle fibres of the trapezius muscle performs scapula elevation, adduction and upward rotation. The lower fibres of the trapezius muscle performs scapula depression, adduction, stabilisation of the scapula and it assists in scapula upwards rotation (Kendall et al 2005:326). The PM muscle has two main functions, firstly (with the origin fixed) it pulls the scapula anterior and inferiorly towards the ribs, and secondly (with the insertion fixed) it raises the ribs during inspiration. Synergistically it assists with scapula protraction (Kendall et al 2005:320).

When weakness of these muscles occurs, the scapula loses normal kinematics with shoulder movements (Kibler et al 2013:887-88). The scapula either goes into an anterior tilt, which means the lower fibres of the trapezius muscle can be weakened. Or the medial border of the scapula may protrude from the thorax (wing) implying weakness of serratus anterior. PM muscle length will subsequently be affected by scapular dyskinesis especially with the presence of a kyphotic posture because the muscle kinematics are compromised (Ludewig and Reynolds 2009:90-92). PM muscle extensibility is essential to allow normal scapular kinematics. The role of PM muscle length on scapular kinematics will be reviewed in the section to follow.

The scapular stabilising muscles work together as a force couple. A force couple can be defined as two or more muscles, acting in different directions causing the rotation of a joint in a specific direction (Levangie and Norkin 2001:213). For the purposes of this study, the force couple that takes place on the scapula when the shoulder is elevated is best described by Magarey and Jones (2003: 197). Figure 2.1 illustrates this force couple [The image was also adapted from Magarey and Jones (2003: 197); permission for use of image in Annexure A]

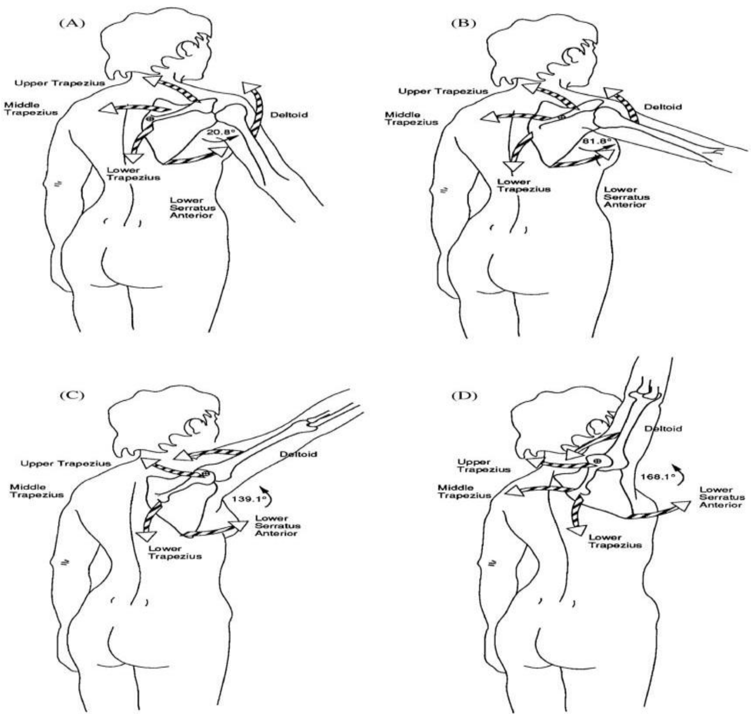


Figure 2. 1: Force couple around the scapula when shoulder elevation takes place

In the first 60° of shoulder elevation, the primary muscles involved in upward rotation of the scapula are the lower fibres of serratus anterior and upper trapezius, with lower and middle trapezius functioning eccentrically to control the movement. In the next 60° of elevation, muscle function changes more towards the lower fibres of the trapezius which are actively involved in upward rotation of the scapula, along with lower serratus anterior and upper trapezius. Once the shoulder reached 120°, upper trapezius is no longer positioned to be able to upwardly rotate the scapula, whereas lower trapezius is now ideally situated to perform this function, in conjunction with lower serratus anterior. In the final stages of elevation, lower trapezius and lower serratus anterior are the primary rotators of the scapula. Therefore, a short PM muscle length may have an influence on the force couple, as it alters scapula alignment (pulled into an anterior tilted position), which affects normal scapular kinematics.

The second factor to be discussed is the effect of the changes in muscle length and function on the scapula. When the PM muscle is overactive it may change the position of the scapula (Lewis and Valentine 2007:2) causing changes in normal upper limb function. Along with tightness of the biceps brachii (short head), the two muscles can create an anterior tilt and protraction of the scapula due to the downward pull on the coracoid (Borstad and Ludewig 2005:228; Kibler et al 2013:878). Furthermore, a shortened PM length has been shown to reduce scapula upward rotation and posterior tilting during humeral elevation (Finley, Goodstadt, Soler, Somerville, Friedman and Ebaugh 2017:213). In turn, the scapular stabilisers become lengthened and weakened because the scapula is in a prolonged protracted and anterior tilted position, causing lengthening of the serratus anterior and the trapezius muscles. In this lengthened position, serratus anterior and lower trapezius eventually weaken (Kim et al 2018:374).

The weakening of the stabilising muscles is because the scapular stabilisers are in a sustained outer range of the muscles, which is least strong and the actin and myosin fibres are further apart. This is all in relation to range of muscle work, meaning the range in which a muscle contracts from a position of full stretch to maximal contraction (shortening). This range can be divided into outer, middle and inner range of a muscle contraction. Outer range is from the position where the muscle is fully stretched to halfway of full range of motion. Middle range is from midpoint of the outer range to midpoint of the inner range. Inner range is described as halfway through the full range of motion to the position where the muscle is fully shortened. A muscle is usually at its strongest in the middle range as this is the position where the fibres can maximally contract. This is due to the actin and myosin fibres overlapping (glide theory). The weakest contraction force is in the inner and outer ranges. (Clarkson 2000:16)

Subsequently, this means that scapula mal-alignment has a strong association with scapular dyskinesis (Ludewig and Reynolds 2009:100; Seitz et al 2012:632). This also implies that scapular dyskinesis might be an indication of PM muscle length shortness. However, scapular dyskinesis often has multiple factors, having both intrinsic and extrinsic risk factors and can thus seldom be attributed to an isolated cause (Kibler et al 2013:877). The intrinsic risk factors can be described as personal related factors, which include muscle and joint structure within the body. Extrinsic risk factors are environmental related factors external to the body, e.g. a poor desk setup (Olivier, Taljaard, Burger, Brukner, Orchard, Gray, Botha, Stewart and Mckinon 2016:80). One of the intrinsic risk factors, being posture, will be explored in the next section.

2.1.4 SCAPULAR STABILISERS, PM MUSCLE AND POSTURE

In this section the influence of posture on scapular stabilisers and PM muscle length will be discussed. Structures contributing to scapular dyskinesis include scapular stabilising muscle strength and PM muscle length. As much as the stabilising muscles play a role in scapular stability, the length of the PM muscle contributes to ideal posture.

Ideal posture can be defined as a state of muscular and skeletal balance (Kendall et al 2005:51), meaning the spine and peripheral joints are aligned. If an abnormal posture is sustained for a prolonged period, an imbalance in muscle kinematics takes place. In current society, musculoskeletal abnormality and pain are increasing due to repetitive work and bad work posture (Kim, et al 2018:373). A common postural dysfunction is a thoracic kyphosis. A thoracic kyphosis increases tension in the shoulder muscles, in turn causing changes in scapula alignment (Yoo 2018:411). The scapula adapts a position of protraction and downward rotation; and in this prolonged position PM may shorten.

Ultimately, if a thoracic kyphosis is left uncorrected it may cause upper crossed syndrome, resulting in weakening and lengthening of the rhomboids, serratus anterior and lower trapezius muscles (Kim et al 2018:374). Additionally, the PM muscle, pectoralis major and upper trapezius muscles may shorten; due to muscular shortening and weakening (Page 2011:256; Kim et al 2018:374). The treatment of a protracted scapula often includes the strengthening of the rotator cuff and scapular stabilisers, as well as the stretching of the PM muscle (Ruivo, Pezarat-Correia and Carita 2017:2; Kim et al 2018:374). This all suggests that PM muscle length, especially in individuals with a kyphotic posture, may be directly implicated by scapular stabiliser strength. This is another gap in existing literature that has been identified. A correlation between PM muscle length and a kyphotic posture was found in a study conducted by Borstad (2006:553), however, the influence of scapular stabilising muscles on PM muscle length was not explored. Another study has shown that posterior tilting strength exercises (which strengthen the scapular stabilisers) and PM muscle stretches, improves PM muscle length at rest (Lee et al 2015:258); this study suggests that scapular stabilising muscle strength has a direct implication on PM muscle length. A more recent study conducted by Finley, et al 2017:216 suggests that changes between the active retraction and passive lengthening of the PM muscle may be due to weakness of scapular stabilising muscles. The study by Finley, et al (2017:216) has indicated a gap in literature for assessing the relationship between scapular stabilisers muscle function and PM muscle length in its ultimate length, not only at rest. It is therefore important to evaluate the association of scapular dyskinesis and PM muscle length in its optimum length.

2.1.5 SCAPULAR DYSKINESIS AS A RESULT OF DECREASED PM MUSCLE LENGTH AND SCAPULAR STABILISER MUSCLE WEAKNESS

In this section, the link between the PM muscle length and scapular stabilisers (dyskinesis) will be reviewed.

As early as 2005, a study reported changes in scapular kinematics with arm elevation (Borstad and Ludewig 2005:230-236), where there was significant interaction for scapula internal rotation at lower arm elevation in the coronal plane.

This finding suggested that scapular stabilisers may be affected. However, the scapular muscle stabilisers were not tested for weakness in this specific study. Affirming this finding was a study that proved that scapula posterior tilting exercises improved the length of the PM muscle (Lee et al 2015:258). The PM muscle length and scapula upward rotation angle, as well as the activity of the upper trapezius, lower trapezius and serratus anterior muscles were significantly greater for posterior tilting exercises after PM muscle stretch. The scapula anterior tilting index was significantly lower post scapula posterior tilting exercises after PM muscle stretching. Furthermore, a study showed that the figure-8 strap improved PM muscle length, which facilitated a passive stretch of the PM muscle (Ko et al 2016:276-277). The scapula anterior tilt decreased in the figure-8 strap group as compared to the control group without the figure-8 strap. There were no significant muscle activity differences within the upper trapezius, lower trapezius and serratus anterior. The figure-8 strap provided external stability of the scapula, which is the ideal position of the scapula if the scapular stabilising muscles are functioning at optimum strength, this study showed a relationship between scapular stabilising muscle function and the PM muscle length. Affirming these conclusions was Finley, et al (2017:214-216) whose results showed significant differences in muscle length between the three positions of rest, active lengthening/retraction and passive stretching. All of these findings indicate that there is possible weakness of the scapular stabilisers in turn causing the PM muscle not to be at its optimal length. However, the relationship of PM muscle length and scapular kinematics, which is assessed through scapular dyskinesis testing, is not well researched. The evaluation of PM muscle length will be reviewed in the following section, as it is an important contributing factor to scapular dyskinesis.

2.1.6 EVALUATION OF PM MUSCLE LENGTH

In this section the different tests to evaluate PM muscle length will be reviewed. PM muscle is commonly known as a contributor to abnormal scapula positioning (Morais and Cruz 2016:1; Rosa, Borstad, Pires, Camargo 2016:176-177). One other study sharing this view expressed that participants with a short PM muscle length had increased scapula internal rotation at rest compared to the group of participants with a long PM muscle length (Borstad 2006:553).

In order for a test to be clinically valuable, the test needs to be reliable and diagnostically accurate (Lewis and Valentine 2007:2). This means that the test needs to be easily replicable both within the same tester (intra-rater reliability) as well as between testers (inter-rater reliability). Additionally, to determine the diagnostic accuracy of a test, the measurement taken needs to be compared to a reference test, or what Lewis refers to as a "gold-standard" (Lewis and Valentine 2007:2). A test also needs to demonstrate specificity (meaning that the test will be able to measure what it intends to measure). The method for measuring PM muscle length, therefore, needs to account for all possible factors that might affect the length of the PM muscle.

Inconsistencies exist in literature regarding PM muscle length values. The inconsistencies exist due to the different techniques used to determine the length of PM muscle; the testing technique; the participant positioning during measurement; and the equipment used to measure PM muscle length. The PMI values range from 7.42 to 9.78 (Borstad and Ludewig 2005:230; Struyf et al 2012a:9; Ko et al 2016:276). These inconsistencies explain the range in PM length values.

Firstly, the techniques used to evaluate PM muscle length will be reviewed. This will be followed by the differences in participant positioning during the evaluation, and finally the variety of equipment used for measurements will be explored.

There are different techniques and tests that have been described to evaluate PM muscle length. These techniques can be categorised into direct and indirect techniques. Indirect techniques refer to techniques where PM muscle length is not measured from its anatomical landmarks. Direct techniques refer to measurement of PM muscle length from its anatomical landmarks. These two categories will be explored and the inconsistencies will be reviewed.

Techniques to evaluate PM length

In this section PM muscle values will be reviewed as a result of indirect and direct measurement techniques.

Indirect techniques refer to techniques where the PM muscle length was measured as the distance between the posterior aspect of the acromion and table or wall (Nijs et al 2005:1350-51; Lewis and Valentine 2007:3-5; Struyf, Nijs, De Coninck, Giunta, Mottram and Meeusen 2009:523-24).

In a prospective repeated-measures design study conducted on 29 participants with shoulder pain (Nijs et al 2005:1350-51), the objectives were to examine the inter-observer reliability, internal consistency, and clinical importance of three clinical tests for the assessment of scapula positioning in patients with shoulder pain. The mean range for the symptomatic side while relaxed was 71.9mm [±15.2 Standard Deviation (SD)] and with retracted scapulae was 46.0mm (±20.5SD). For the non-symptomatic side, the mean range while relaxed was 72.3mm (±12.5SD) and 47.9mm (±20.1SD) for the actively retracted scapulae. These results show that there are no significant differences in PM muscle length when comparing the symptomatic and asymptomatic sides in both relaxed and actively retracted positions.

In a case control study conducted on 90 participants (45 with shoulder symptoms and 45 without shoulder symptoms) (Lewis and Valentine 2007:3-5), the participants were positioned in supine, with arms by their sides and elbows flexed and resting on the abdomen. This study had a mean measurement range from 5.9 cm (non-dominant side) to 6.3 cm (dominant side) in the asymptomatic group and from 6.0 cm (non-dominant) to 6.3 cm (dominant) in the symptomatic group. These results suggest that there is no difference in PM muscle length with respect to symptomatic and asymptomatic individuals; as well as with dominance. This method showed good intra-rater reliability of non-symptomatic subjects 0.92 to 0.93 and that of symptomatic subjects 0.90 to 0.93.

In an inter-tester reliability study conducted on 30 healthy student musicians (Struyf et al 2009:523-24), the findings in the relaxed position provided a mean measurement of 7cm (±1.7 SD) to 7.9cm (±1.7 SD) and 4.0cm (±1.4 SD) to 4.3cm (±1.6 SD).

In this indirect testing procedure, there are clear discrepancies in PM muscle length values. Although there are inconsistencies regarding values, it should be noted that there were similarities within the findings relating to dominance and pathological sides. Thus, these inconsistencies may be attributed to the differences in testing positions (supine and standing) and techniques (arms by side with elbows in extension; and arms by side with elbows flexed and resting on abdomen). Irrespective of all this, the testing position from the acromion to the bed or wall is not the most ideal in determining PM muscle length, as it does not adjust for soft tissue changes and postural influences on the PM muscle. It is clear that this technique does not have a diagnostic value and therefore a more direct technique would be advisable.

The more direct technique is where the bony landmarks of the PM muscle are measured from origin to insertion. These landmarks were confirmed in a cadaver analysis of 11 fresh cadavers by Borstad and Ludewig (2005:229), where there was excellent validity demonstrated with an ICC of 0.96. In this technique PM muscle length is expressed as the PMI. The PMI will be discussed in the section below.

2.1.7 PECTORALIS MINOR INDEX (PMI)

In a Two-group comparison study, PM muscle length was expressed as an index; PMI (Borstad and Ludewig 2005:228). PMI is calculated as PM muscle length (cm)/subject's height × 100, and takes into account soft tissue, body build and height for each individual. Even though the calculation of PMI accounts for body build, there are still discrepancies in the PMI values.

In a study consisting of 50 participants without shoulder pain, the PMI values were ranging between 7.42 and 9.13 (Borstad and Ludewig 2005:230). In another study consisting of 50 participants without shoulder pathology, the PMI values were ranging between 7.42 and 9.13 (Borstad 2006:554). Additionally, a pilot study consisting of 6 participants concluded that a short PMI value was anything less than 7.65. A long PMI value was any value more than 8.61 in an elite group where the Confidence Interval (CI) was set for 68% of the population (Borstad and Ludewig 2005:228). This consequently suggests that this value may not be accurate as a small population was tested. Moreover, a study done on 82 subjects, with a SD of 0.80 (mean PMI – 1 SD), with a 68% CI stated that PM muscle will be shortened when the PMI value is less than 7.44 (Borstad 2008:173). In a descriptive study with a cross-sectional design on 35 tennis players, the PMI value of the dominant side for males was 7.1 (±0.4 SD) and the non-dominant side was 7.9 (±0.4 SD). Contrary to these values, the PMI value for females on the dominant side was 6.9 (±0.7 SD) and the non-dominant side was 7.5 (±0.7 SD) (Cools et al 2010:683).

These values show that across gender, the PMI on the dominant side is shorter than the non-dominant side. Additionally, females have a lower PMI value compared to males. In a randomised clinical trial conducted on 22 participants with shoulder impingement, the PMI was 8.9 (±1.2SD) in the control group and 9.1 (±2.3 SD) in the experimental group *(*Struyf et al 2012a:9). In a 15 participant study, all with a short PMI, it was noted that participants who performed scapula posterior tilting exercise alone had a PMI of 8.18 (± 0.70 SD) and those who performed scapula posterior tilting exercise after PM stretching presented with a PMI of 8.69 (± 0.95 SD) (Lee et al 2015:260). In an inter-rater and intra-rater reliability study consisting of 50 participants (25 presenting with shoulder pain and 25 presenting without shoulder pain), the PMI of the dominant side of participants without shoulder pain ranged between 8.86 (±0.65 SD) and 9.17 (±0.54 SD) and the PMI for the non-dominant side ranged between 9.21 (±0.62 SD) and 9.22 (±0.59 SD). The PMI for participants who presented with shoulder impingement symptoms on the symptomatic side ranged between 9.27 (±0.69 SD) and 9.66 (±0.68 SD); the PMI for the asymptomatic side ranged between 9.52 (±1.07 SD) and 9.64 (±0.72 SD) (Struyf, Meeus, Fransen, Roussel, Jansen, Truijen and Nijs 2014:296). These findings indicate that there are no significant differences in PMI values in the symptomatic and asymptomatic sides.

In a one-group pre-test-post-test design, 15 male participants with a forward head posture had their PM muscle length measured. PMI without figure-8 strap was 9.22 (±0.68 SD) and 9.78 (± 0.90 SD) with a figure-8 strap (Ko et al 2016:276). In a study conducted on 46 professional golfers and 36 control volunteers (Mackenzie, Herrington, Funk, Horsley and Cools 2015a:3), the mean PM muscle length on the dominant side of the golfers was 16.67cm (1.13 SD) and on the non-dominant side 15.80cm (1.25 SD). The mean PM muscle length on the dominant side for the control group was 16.30 (1.30 SD) and 16.84 (1.31 SD) on the non-dominant side. In a reliability study consisting of 100 participants (50 symptomatic and 50 asymptomatic participants) (Rosa et al 2016:178), PM muscle length was expressed in centimetres. PM muscle length values on the asymptomatic side between two raters were ranging between 16.30cm (±1.43 SD) and 16.42cm (±1.43 SD). The PM muscle length for the symptomatic side between two raters was 16.66cm (±1.64SD) and 16.97cm (±1.80 SD). In a parallel-group intervention with repeated measures study, conducted on a sample of 25 patients with shoulder pain and 25 healthy subjects with PM muscle tightness (Rosa, et al 2017:25-6), the healthy group presented with a PM muscle length of 15.99cm (1.35 SD) at rest and 17.33cm (1.47 SD) in active retraction. The group with pain presented with a PM length of 16.36cm (1.57 SD) at rest and 17.65cm (2.03 SD) in active retraction.

When comparing the PM muscle length values (PMI values and PM muscle length in centimetres) of these studies (Borstad and Ludewig 2005:230; Borstad 2008:173; Cools et al 2010:683; Struyf et al 2012a:9; Struyf et al 2014:296; Lee et al 2015:260; Mackenzie et al 2015a:3; Ko et al 2016:276; Rosa et al 2016:178; Rosa et al 2017:25-6), a lack of consistency in the valuesare shown throughout all the studies. Although the PM muscle length values differ, a common factor is that the dominant and non-dominant sides are similar, as well as the symptomatic and asymptomatic sides. Implying that these discrepancies in PM muscle length values may be attributed to inconsistencies in the age of participants, testing positions, testing techniques; and testing instruments. The lack of consensus indicates that there is a need for a value for PMI to be established so that future researchers and clinicians may accurately measure and interpret the length of the PM muscle.

Currently there are discrepancies in the literature regarding the measurement of the PM muscle length. These discrepancies include the participants' age, testing techniques, testing positions and equipment used; and are discussed below.

Participants' age

The ages of participants in the studies mentioned in the previous paragraph ranged from 13 to 68 years respectively. Therefore, the PMI data cannot be compared as the age groups between the studies are not homogenous. There were studies conducted where the age of the participants was not disclosed (Borstad and Ludewig 2005:228-pilot study; Borstad 2008:171). Studies have been performed with the participants' ages ranging between 13 and 18 years (Cools et al 2010:678), while other studies participants ages ranged between 18 years to 50 years (Borstad and Ludewig 2005:228; Borstad 2006:551; Struyf et al 2012a:4; Struyf et al 2014:295; Lee et al 2015:256; Mackenzie et al 2015a:2; Ko et al 2016:274; Rosa et al 2016:177; Finley et al 2017:213; Rosa et al 2017:24).

Age could be a considered a factor as it may play a role in the length of the PM muscle and in turn PMI values. It can be argued that the PMI may be different across the young and the elderly due to physical changes that take place in the body, including postural changes such as kyphosis. Therefore, mean PMI values for the young and the elderly needs to be established.

Participant testing techniques and positioning

In this section, testing technique and positioning utilised in the various studies will be reviewed. Table 2.2 reflects the summary and unique qualities of each research study available from existing literature.

Table 2. 2- ***Summary of studies evaluating the length of the PM with description of the testing techniques and positions***

Author(s)	Study design and Objectives	Sample/population	Methods	Results	Comments
Borstad and Ludewig (2005:227-238)	2-group comparison Objective: to compare scapular kinematics during arm elevation between groups distinguished by PM resting length	n=50 participants without shoulder pain were divided into groups with long or short PM according to normalised pectoralis minor resting length Participants were between the ages of 20 and 40 years.	-Participants were split into 2 groups of 25 each. -The pectoralis minor resting length was determined on each subject, based on 1 second of data collected after the subjects were asked to stand with their arms at their sides and look straight ahead. -Measurements from coracoid process to fourth sternocostal junction.	PM was considered short if PMI was less than 7.42 and long if more than 9.13 (this was confirmed with the pilot study that indicated that a short PMI= <7.65 and a long PMI = >8.61)	Standing procedure is not an ideal testing position as it does not eliminate any postural influences presented by the thoracic spine. Arm by side and elbow extended position: this position is not ideal as it does not eliminate the passive insufficiency influence of biceps brachii on the scapula position. Measurements were done at rest. This position only caters for PM at rest and not throughout its available range. Resting position is described as the habitual postural position of the scapula.
Borstad (2006:549-557)	Comprehensive cross-sectional study Objective: to explore the relationships among posture, PM muscle length, and movement alterations at the shoulder.	n=50 without shoulder pain Participants were between the ages of 18 and 40 years.	-Measurements from the coracoid process to fourth rib junction. -Measurements at rest. -Subjects standing, arms by side.	Short PMI= 7.42 Long PMI= 9.13	
Borstad (2008:169-174)	Cadaver study: pilot study Human study:	-11 cadavers for validation of the study. -Human Subject Analysis: the dominant side PM length of 26	-Measured in relaxed standing position, arm by side.	Mean PMI 8.24(0.80). Short PMI <7.44 (mean PMI – 1 SD)	

	Clinical measurement validity study Objective: to validate the measurement of the PM muscle length using palpable landmarks and to explore the accuracy of the measurement using a clinical instrument.	subjects (11 male, 15 female) without a history of shoulder pathology was measured.	-All measurements from coracoid process to fourth rib junction	
Lee, et al (2015:255-261)	Comparison study Objective: to compare scapula posterior tilting exercise alone and scapula posterior tilting exercise after PM stretching on the PMI, scapula anterior tilting index, scapula upward rotation angle, and scapula upward rotators' activity in subjects with a short PM.	n=15 subjects with a short PM participated in this study (age ¼ 22.07 ± 1.95 years)	PMI used at PM landmarks described by Borstad 2008	PMI: Scapula Posterior Tilting (SPT) ex alone= 8.18 (± 0.70) SPT and PM stretch =8.69 (± 0.95)

Ko, et al (2016:273-279)	Cross-sectional study Objectives: to investigate the immediate effect of a figure-8 strap on PM length, scapula alignment, and scapula upward-rotator-muscle activity.	n=15 male participants (age 22.1 ±1.9 y) with forward shoulder posture.	-This was measured in two conditions: with and without application of a figure-8 strap. -Participants stood against a wall without a figure-8 strap and the investigator measured the PM length, arm by side. - These two points were the medioinferior angle of the coracoid process and just lateral to the sternocostal junction of the inferior aspect of the fourth rib.	-Short PM Group was defined as having a PMA equal to or below 10.18. -With figure-8 strap PMI = 9.22 ±0.68 - Without figure-8 strap PMI =9.78± 0.90	Ko, et al (2016) additionally performed measurements at rest and passive stretch by utilising the figure -8 strap. This in turn provides PM values throughout its full range of muscle length.
Rosa, et al (2016:176-183)	Reliability study Objectives: to evaluate intra-rater, inter-rater, and between-day reliability of PM muscle length measurement in subjects with and without signs of shoulder impingement.	100 individuals (50 asymptomatic and 50 symptomatic) participated in this study.	-Measurements on coracoid process and the fourth rib landmarks. -Participants were asked to remain in a standing and relaxed posture with their arms at their sides in a neutral position and to avoid postural correction. -Measurements done at rest.	Asymptomatic Rater 1:16.30 cm (±1.43) Rater 2: 16.42 cm (±1.43) Symptomatic Rater 1: 16.66 cm (±1.64) Rater 2:16.97 cm (±1.80)	

Rosa, et al (2017:20-29)	Parallel-group intervention with repeated measures. Objectives: to evaluate the effects of a stretching protocol on function, muscle length, and scapular kinematics in subjects with and without shoulder pain.	50 subjects (25 patients with shoulder pain and 25 healthy subjects).	-PM length was measured in both the resting and retracted scapula position. -Participants were asked to remain in a relaxed posture (standing) with the arms at the side in a neutral position.	Healthy group: Rested PM: 15.99 cm (1.35) Retracted PM: 17.33 cm (1.47) Pain Group: Rested PM: 16.36 cm (1.57) Retracted PM: 17.65 cm (2.03)	Rosa, et al (2017) additionally performed measurements with the arm at rest and active retraction of the scapula (active lengthening of PM). The active position allows for elongation of the PM in some of its available range (according to the subjects strength). However, it is not full available range as there is no passive stretch measurement.
Finley, et al (2017:212-218)	Cross-sectional repeated measures. Objectives: to establish the reliability and construct validity of a novel technique to measure PM muscle length under actively and passively lengthened conditions.	34 healthy adults (between the ages of18 and 35 years; 18 females, 16 males)	-PM muscle length was measured on the dominant arm in three length conditions: resting, actively lengthened, and passively lengthened. From coracoid process to fourth rib adjacent to the sternocostal	Significant differences ($p < 0.001$) in muscle length were found among all three conditions: resting, active lengthening and passive lengthening.	Finley, et al (2017) additionally performed PM measurements at rest, active lengthening and passive lengthening. These three positions allow for PM length to be recorded at different stages in its full range.

			junction. -Participants standing with relaxed posture. Arm by side, elbow extended		
Cools, et al (2010:678-684)	Descriptive study, cross-sectional design. Objective: to describe variables regarding scapular position, muscle strength and flexibility in young elite tennis players.	-35 elite tennis players -19 boys aged 13.6 (±1.4) years, 16 girls, aged 12.6 (±1.3) years. -all nationally ranked -all but one player were right-handed -no shoulder pain	-PM length measured according to protocol by Borstad 2008, however modified for the study by measuring PM length in the supine position with the elbows extended. -Measurements done at rest. -PM length from the two bony landmarks (coracoid process to fourth rib junction).	-Significant gender ($p=0.006$) and side differences ($p<0.001$) were found. -The length of PM on the dominant side was significantly shorter and the female players had a shorter PM compared to the male players.	Testing position was adjusted to supine in order to avoid postural influences of the thoracic spine and optimise muscle relaxation in all surrounding muscles. Arm by side and elbow extended position: this position is not ideal as it does not eliminate the passive insufficiency influences of biceps brachii on the scapular position.

Struyf, et al (2012a:1-13)	Randomised control trial. Objectives: to compare the effectiveness of a scapular-focused treatment with a control therapy in patients with shoulder impingement syndrome.	22 patients with shoulder impingement syndrome.	-The distance from the fourth rib to the coracoid process. -Measurements done in supine, arm by side. -PM length measured at rest**.**	PMI for control group before and after exercise respectively 8.9 (±1.2) and 9.2(±0.5). PMI for experimental group before and after exercise respectively 9.1 (±2.3) 10.0 (3±0.7).	Measurements were only done at rest. This position caters for PM at rest and not throughout its available range.
Struyf, et al (2014:294-298)	Inter-rater and intra-rater reliability study. Objectives: to examine the inter- and intra-rater reliability of the PMI measurement in both subjects with and without shoulder impingement symptoms.	n=50 subjects (25 patients with shoulder impingement syndrome and 25 healthy subjects).	-PM length measurements adapted from Borstad (2008) and Cools, et al (2010). -Subjects were supine with elbows extended on side of body. -Measurements at rest.	Patients with shoulder impingement syndrome (SIS) symptomatic: between 9.27 (±0.69 SD) and 9.66 (±0.68 SD) asymptomatic: between 9.52 (±1.07 SD) and 9.64 (±0.72 SD) Patients without SIS Dominant: 9.17	

				(0.54) and 8.86 (0.65) Non-dominant: 9.22 (0.59) and 9.21 (0.62)	
Mackenzie, et al (2015a:1-4)	Objective: to investigate the resting PM muscle length in professional male golfers.	45 male golfers 36 control volunteers	-Participants in supine. -Measurements done at rest. -Measurements for the coracoids process and fourth rib.	Golfers: Dominant side:16.67 (1.13) Non-dominant: 15.80 (1.25) Control group Dominant side:16.30 (1.30) Non-dominant: 16.84 (1.31 SD)	

There are inconsistencies that exist in testing technique and positioning methods of participants. Measurements of PM muscle length were performed at rest, active retraction and passive lengthening. Existing research has shown measurements performed in the standing position as well as in supine position (Table 2.2). These techniques and testing positions will be discussed in the section that follows.

In existing literature, there are studies that performed PM muscle length measurements at rest (Borstad and Ludewig 2005:230; Borstad 2006:551-552; Borstad 2008:171; Cools et al 2010:680; Struyf et al 2012a:6; Struyf et al 2014:295-296; Lee et al 2015:256; Mackenzie et al 2015:2; Rosa et al 2016:178). One study measured PM muscle length at rest and passively with a figure-8 strap (Ko et al 2016:274). Another study performed PM muscle length measurements at rest and in active retraction (Rosa et al 2017:22). All these studies did not measure the PM muscle at its optimum length. This is another gap in the literature identified by the researcher. There is only one study to date, which has measured PM muscle length in its optimum length of resting, active retraction and passive lengthening (Finley et al 2017:214). These testing techniques were either performed in a standing position or a supine position. The differences of these two testing positions will be discussed in the section that follows.

Most of the studies positioned their participants in the standing position while performing the measurements (Borstad and Ludewig 2005:230; Borstad 2006:551-552; Borstad 2008:171; Lee et al 2015:256; Ko et al 2016:274; Rosa et al 2016:178; Rosa et al 2017:22; Finley et al 2017:214). Measurements performed in standing did not account for postural influences of the thoracic spine on PM muscle length due to gravitational forces. Therefore, the PM muscle is not effectively measured in a lengthened position while standing. Therefore, this testing position demonstrates poor diagnostic accuracy and may provide inaccurate values for PM muscle length. On the other hand, measurements performed in supine eliminated postural influences of the thoracic spine and optimised muscle relaxation in all surrounding muscles (Cools et al 2010:680; Struyf et al 2012:6; Struyf et al 2014:295-96; Mackenzie et al 2015:2).

In both testing positions (standing and supine), the arm was placed along the participants side with elbows extended. This positioning of the arm by the side in extension, did not adjust for the influence of the biceps brachii on the scapula.

The short head of the biceps brachii originates from the anterior aspect of the coracoid process and inserts onto the radial tuberosity and bicipital aponeurosis (Kendall et al 2005:290). Therefore, an elbow in extension can cause passive insufficiency of the biceps brachii. This may pull the scapula into protraction and further place the PM muscle in a shortened state (Kibler et al 2013:878), providing a false shortened measurement of PM muscle length.

Across all studies in both testing positions (standing and supine), there are inconsistencies in the reported muscle length of the PM muscle (rest, active lengthening and passive lengthening) (Table 2.2). The optimum length of a muscle, necessary for optimum function, may range from a resting position to a fully stretched position (Kendall et al 2005:npn). This insinuates that the measurement of the PM muscle should be done in three different scapula positions, namely, at rest (i.e. no scapula retraction), in active retraction (i.e. with the scapula actively retracted through the use of lower trapezius and rhomboid major and minor), and finally in the passively retracted position (i.e. with the scapula placed into full scapula retraction by a researcher). These distances will be used to determine PMI in the three different positions in the current study.

Testing equipment

In this section, the testing equipment used to measure the length of the PM muscle will be discussed. Table 2.3 provides a summary of the equipment used in the studies.

Table 2. 3 ***Summary of the equipment used in the studies***

Author(s)	Equipment	Comments
Borstad and Ludewig (2005:230)	The Flock of Birds electromagnetic motion capture system (Ascension Technology Corporation, Burlington, VT) miniBIRD sensors were used for kinematic data collection.	The Flock of Birds electromagnetic motion capture system is expensive, not easily accessible and cannot be used in a clinical setting.
Borstad (2006:551)		
Borstad (2008:169-174)	-A 3D electromagnetic motion capture system was used to calculate the length of PM in 11 cadavers, using two measurement techniques. -In addition, a measurement with the electromagnetic system using palpable landmarks was compared to a measurement with both a Vernier® caliper and tape measure. -Results: ICC ranging between 0.82 to 0.87, indicating a very good agreement between the measurements made with the Flock of Birds and the measurements made with the other two clinical instruments.	Even though all this equipment is reliable, the Vernier® caliper is the most reliable and affordable; as it takes into account muscle bulk as compared to the tape measure. The EMG device (Flock of Birds) is expensive and impractical for clinical use.
Cools, et al (2010:680)	Vernier® caliper [ICC 0.83 to 0.87 9 (Borstad 2008:173)]	As previously mentioned, the Vernier® caliper has good reliability. It eliminates muscle bulk, providing an accurate measure of PM length. It is cost effective and can be used in a clinical setting.
Struyf, et al (2014:295)		
Lee, et al (2015:256)	Caliper	The type of used is not discussed. However, from the photographs it is shown not to be a Vernier® caliper. Even though it is not the Vernier® caliper, the principles are still the same.
Mackenzie, et al (2015a:2)	PALM meter [ICC 0.98 (Mackenzie, et al 2015:20)]	Palpation meters are expensive and not easily accessible. However, the device eliminates muscle bulk, therefore, providing an accurate measure of PM length
Finley, et al (2017:214)		
Struyf et al (2012a:6)	Was measured with a measuring tape [ICC 0.82 to 0.86 (Borstad 2008:173)]	Even though it is cost effective, the tape measure is not the best tool to use, as it does not eliminate soft tissue mass. It therefore may provide false length of the PM.
Rosa, et al (2016:117-118)		
Ko, et al (2016:274)		
Rosa, et al (2017:22)		

Testing equipment used to measure the length of PM muscle include:

- the Flock of Birds Electromagnetic Motion Capturing System (EMCS) from Ascension Technologies (Borstad and Ludewig 2005:230; Borstad 2006:551; Borstad 2008:169-174);
- a tape measure (Struyf et al 2012a:6; Rosa et al 2016:117-118; Ko et al 2016:274; Rosa et al 2017:22);
- the Vernier® caliper (300mm) from Insize Co. Ltd (Borstad 2008:169-174; Cools et al 2010:680; Struyf et al 2014:295);
- the Palpation Meter (PALM) (Mackenzie et al 2015a:2; Finley et al 2017:214); and
- other calipers (Lee et al 2015:256).

This testing equipment will be reviewed below.

A comprehensive cross-sectional study utilised the Flock of Birds electromagnetic motion capture system (Borstad 2006:551). Furthermore, a clinical measurement validity study compared the use of the EMCS device (Flock of Birds), tape measure and the Vernier® caliper to measure PMI (Borstad 2008:172). The study proved the use of all three tools to be reliable, with an ICC ranging between 0.82 and 0.87. However, the use of the Vanier® caliper was favoured as it is an affordable resource and it eliminates influences of muscle bulk and body build (Borstad 2008:172-73). The EMCS device is very expensive and not easily accessible. Moreover, it is an impractical device to use in a clinical setting.

The use of a tape measure was utilised in other studies (Struyf et al 2012a:6; Rosa et al 2016:117-118; Ko et al 2016:274; Rosa et al 2017:22). The tape measure has good reliability with an ICC ranging between 0.82 and 0.86 (Borstad 2008:173). However, the use of a tape measure does not account for the individual differences in soft tissue mass and/or muscle mass that may be present between the PM muscle landmarks (i.e. the coracoid process and the anterior and inferior edge of the fourth rib). Although the use of a tape measure is cost effective, it does not display a large amount of specificity for measuring the length of the PM muscle.

Both the PALM palpation meter and the Vernier® caliper, eliminates the influences of body mass and muscle bulk in the anterior chest wall (Mackenzie et al 2015a:2; Finley et al

2017:213-214). The PALM palpation meter has an excellent ICC of 0.98 (Mackenzie et al 2015a:2). Although easily accessible, the use of the PALM palpation meter is not cost effective and therefore not clinically applicable.

The PM muscle plays a vital role in shoulder kinematics. It is believed that a decreased PM muscle resting length would result in a restriction of normal scapula upward rotation, posterior tipping, and external rotation, during arm elevation (Borstad 2006:550). Therefore, the length of the PM muscle needs to be measured to determine its influence on shoulder kinematics. Two techniques (direct and indirect) have been identified in the literature as it relates to PM muscle length. The direct technique, which includes the measurements on PM muscle landmarks, is suggested as the most appropriate to use, with an ICC of 0.96. (Borstad and Ludewig 2005:229). Discrepancies in the measurement of PM muscle length expressed as PMI have been identified in this direct technique, with respect to participant age, testing techniques, positioning and testing equipment. It can be concluded that the most appropriate way of measuring PM muscle length expressed as PMI is by using the Vernier® caliper in supine (to eliminate postural influences), with the arm by the side, the elbow flexed and the arm resting on the abdomen [to eliminate passive insufficiency of the biceps brachii (Kibler et al 2013:878)]. It should be noted that all of the studies testing for PM muscle length on the direct landmarks had their participants' arms on their sides with elbows extended. The only study, which tested PM muscle length indirectly, was the only study that eliminated the influence of biceps brachii on the coracoid process (Lewis and Valentine 2007:3).

2.2 SUMMARY

In conclusion, there are two structures that are influenced by kyphotic posture: PM muscle length, expressed as PMI and the scapular stabiliser muscle function. When a person has a kyphotic posture (functional or structural), the PM muscle can be overactive and shortened. The kyphotic posture may affect the scapular stabilisers which can possibly be lengthened resulting in weakness. This can lead to upper limb dysfunction as both these structures have the ability to decrease the subacromial space when they are not working at their optimum level. Rosa, et al (2017:20-29) conducted a study to evaluate the effects of a stretching protocol on function, muscle length and scapular kinematics in subjects with and without shoulder pain. The study found that the stretching protocol did not change the PM muscle length or scapular kinematics in subjects with and without pain. However, pain levels were improved. It can therefore be hypothesised that scapular stabiliser muscle strength may play a bigger role in shoulder kinematics than PM muscle length alone (PMI). The combination of PMI and scapular dyskinesis in multiple planes is not well explored and presents a gap in the existing literature. The researcher has identified two gaps in the literature; the association of scapular dyskinesis and PM muscle length, as well as the active retraction and passive lengthening testing positions of the PM muscle. Based on these identified gaps and reviewed literature, the methodology of this current study is discussed in Chapter 3.

3 CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

In this chapter, the methodological approach for the study will be discussed. The principles behind the study design, procedures and instrumentation are based on information that was obtained while reviewing published research. The study setting, ethical and legal considerations are also discussed in this chapter.

3.2 STUDY DESIGN

A quantitative, analytical, observational, cross-sectional study design was used. The study did not include any treatment or intervention, therefore a non-experimental design was performed. In the study, a dependant variable was described as the influence of a kyphotic posture and scapular dyskinesis on the PMI. The independent variable was described as the effect of scapular stabiliser activation and thoracic mobility to determine the influence they have on posture and scapula stability.

The design of the study investigates a subgroup based on posture and sex, i.e. ideal and kyphotic posture groups accounting for males and females. Sample size was determined within sex where a difference of 0.05 in PMI between posture groups was regarded as statistically relevant and a standard deviation of 0.6 was assumed.

3.3 STUDY SETTING

The study took place in the Department of Physiotherapy at the Prinshof Campus, Faculty of Health Sciences of the University of Pretoria, South Africa.

3.4 STUDY POPULATION AND SAMPLING

3.4.1 Study population

The population of the study included students, between the ages of 18 and 24 years, enrolled at the University of Pretoria, School of Healthcare Sciences, during the 2018 academic year of study.

3.4.2 Inclusion criteria

The study included male and female students between the ages of 18 and 24 years of The Faculty of Health Sciences.

3.4.3 Exclusion criteria

Students who had previous fractures of the shoulder and/or shoulder girdle, were excluded as these injuries may have an influence on the shoulder girdle function and biomechanics (Levangie and Norkin 2001:218).

Students with a structural kyphosis and scoliosis were excluded because this type of kyphosis causes muscle imbalances and asymmetry in bony structure (Levangie and Norkin 2001:427).

Students presenting with pain in the shoulders interfering with ADL were excluded, as pain influences the function of the scapular stabilising muscles (Moezy, Sepehrifar and Dodaran 2014:2).

Students participating in sport on an elite level were also excluded as elite sport can cause anatomical adaptations in the glenohumeral joint and muscles around the area (Hodgins, Rubenstein, Kovacevic, Padaki, Jobin and Ahmad 2017:1-2).

3.4.4 Sampling methods

A non-probability convenience sampling method was used. The use of this method ensures for a larger sample size of participants. This sampling method was inexpensive and ensured that subjects were readily available. Prior to the recruitment, permission was requested and obtained from the Dean of the Faculty of Health Sciences to access the student database (Annexure B). The participants were recruited via word of mouth, emails and contact details obtained from the contact database which was acquired through the Head of Departments in the Faculty of Health Sciences. Posters (Annexure C) were used as information tools in the emails, and visits to lecture halls were also done for recruitment purposes. Student cell phone numbers were acquired from their Head of Departments and the students were phoned and invited to a session that suited them best.

3.4.5 Sample size

The study design will have a faction posture and sex. The sample size is determined within sex where a difference of 0.5 in PMI between posture groups is regarded as clinically relevant and a standard deviation of 0.6 is assumed (Pourhoseingholi, Vahedi and Rahimzadeh 2013:15). A target sample size was 128 participants, consisting of four groups with 32 participants per posture-sex group. This sample size will have at least 90% power to detect a statistically relevant difference when testing two-sided at the 0.05 level of significance. The target sample was reached and surpassed by 16 participants in one of the four groups (female, kyphotic group).

The sampling frame consisted of a total of 167 participants. Only 144 were included in the study.

3.5 DATA COLLECTION

Data collection took place in the Physiotherapy Department gym. Participants were recruited during class time; the researcher would hand out flyers in the classes and invite the students to participate in the study. Some students were contacted telephonically and invited to participate in the study. Students that showed interest had their appointments scheduled to their convenience. There was a time roster created for each participant to book times to ensure everyone was accommodated.

The participants were given an information leaflet detailing the study (Annexure D). The information leaflet explained the testing procedure, purpose, benefits and risks involved in the study. If the participants showed interest in participating, a consent and demographics form (Annexure E) was given to them. Participants were made aware, before signing consent, that the study required him/her to wear shorts; to expose the upper body to an extent; to be touched on the upper body for the purpose of identifying and locating the skin landmarks; and to be marked on with a skin marker on the PM landmarks, thoracic spine and scapula as well as numbering on the right arm and scapula. The participants were informed that they can withdraw from the study at any point if they felt uncomfortable.
The data collection was done over a period of nine days.

3.5.1 Research team

The research team consisted of seven members. The primary researcher, research assistant A, who is a qualified physiotherapist, with a PhD and vast knowledge similar to the intended study. Research assistants B to F were undergraduate physiotherapy students, whose undergraduate research topic was similar to the current study. As the skills required by this research was similar to the skills utilised in their own undergraduate research study, the researcher ensured that the students added an additional quality to data collection.

3.5.2 Quality control

All the researcher assistants had a one hour group training session, where they were prepared on their duties for the study to ensure precision and competence. Their training was done prior to the pilot study. Their duties assigned in the pilot study remained the same in the main study. The research assistants remained at their assigned station and they continued to perform the same technique to ensure quality control throughout the data collection. Additionally, to ensure reliability and quality control in the study, research assistant A, the qualified PhD physiotherapist (with great insight on the shoulder joint and is a movement analysis lecturer), was the only researcher that palpated and marked the origin and insertion of the PM muscle and scapula landmarks.

3.5.3 Measurement tools

Measuring tools used were plumbline, shoulder quadrant, tape measure, calibrated scale, Vernier® caliper and scapular dyskinesis. All these tools are cost effective and readily available in South Africa. Validity and reliability of these tools are reflected in Table 3.1 below.

Table 3. 1: Description of measuring tools, techniques, validity and reliability of the tools

Measuring tools	Measuring techniques	Validity &reliability
Demographics	Complete information sheet	
Posture	Plumb line	Kendall, et al (2005:49)
Exclude shoulder pain that affected function in ADL	Shoulder quadrant	Hengeveld and Banks (2014:185)
Height Weight	Tape measure Digital calibrated scale	
PM landmarks Evaluation of PM muscle length (Vernier® caliper) Insize Co. Ltd.,300mm	Skin mark of anatomical markers Measure from coracoid process to costosternal fourth rib	Validity was confirmed by Borstad (2008:8) with a reliability of ICC 0.96 Validity was confirmed by Borstad (2008:8) with a reliability of ICC 0.96
Resting scapula position Dynamic scapula position	Evaluation of scapula position on thoracic wall (Lewis et al 2002:27) Evaluation of dynamic scapula position through abduction and flexion of the shoulder joint (McClure et al 2009:161)	Validity ($p < 0.005$) was confirmed by Lewis, et al (2002:29-30) with a reliability of ICC 0.88 by Nijs, et al (2005:13) Validity ($p < 0.001$) was confirmed by Tate, McClure, Kareha, Irwin and Barbe (2009:169-171) with a reliability of a Kappa of 0.54

		(McClure et al 2009:9)

3.5.4 Pilot study

A pilot study was conducted on 18 April 2018 in the Department of Physiotherapy at the University of Pretoria. There were 11participants recruited from the Department of Physiotherapy. The aim of the pilot study was to eliminate any possible errors or setbacks that may occur during data collection. The researcher and six research assistants participated in the pilot study and assumed the same roles in the pilot study as they would in the main study, which required 128 participants. The study was conducted in station format as described in *Measurement Methods/Techniques*. The data collected in the pilot study was not included in the main study. The inclusion and exclusion criteria were the same as for the main study.

The following difficulties were encountered during the pilot study:

- Missing information on the demographics sheet resulted in clinical hours being added. It was also discovered that there was no place to record the participants' weight and shoulder quadrant results. This information was added (see demographics sheet, Annexure E).
- It was found to be more efficient to add participant numbers to all papers prior to the study, to eliminate confusion.
- An extra landmark of the Acromioclavicular Joint (ACJ) was added to make viewing of dynamic scapular motion more effective.
- It was decided to do all land markings for both the PM muscle and scapulae at the first station as a time saving attempt and to ensure smooth transition between the stations.

3.5.5 Measurement methods/techniques

There were six stations allocated and in each station data was collected. It took each participant at least ten minutes to complete all six stations. Each station was separated by screens to respect privacy of the participants. From the start the participants were required to be in shorts and bikini top (if they were female) and bare-chested (if they were males).

Participants were allowed to wear their shirts to cover their upper bodies before moving to the next station and remove it once more when they were at the next station; so as to ensure their comfort. In the station where the PM muscle length was measured, their abdomens were covered with a towel and only the shoulder girdle was exposed, to ensure the comfort of the participants. The stations were arranged as follows:

Station 1 - Demographic information and marking of PM muscle and scapula landmarks

Prior to commencement, a demographic information sheet and consent form was completed by the participants (Annexure D and E). After completing the forms, the first screening for exclusion criteria was done; these included participants over the age limit of 24 years, participants with previous fractures or surgery of the shoulder girdle, and elite athletes. There were 17 participants that were excluded at this point. There was one participant with a combination of being an elite athlete and having a previous shoulder surgery. There were 10 other elite athletes, who participated in sports at a national level. There were two participants that had previous shoulder surgeries and three participants who were over the age of 24 years.

Each participant that could continue was assigned a number, written on the demographic sheet. The participant's number was then marked on the right scapula using the skin pencil. A black skin pencil was used on lighter skin and a white skin pencil was used on darker skinned participants. The participants had their landmarks drawn by research assistant A.

The landmarks for PM muscle length were the medial inferior angle of the coracoid process and lateral to the sternocostal junction of the inferior aspect of the fourth rib (Figure 3.2a and 3.2b). The landmarks for the resting scapula were made on the spine (T3, T4 and T8), root of the spine of scapula, inferior corner of scapula and superior boarder of scapula and acromioclavicular joints (Figure 3.3). These landmarks were used in the dynamic scapular motion assessment to assist in making the analysis easier and more consistent.

All the information gathered from station two to six was documented on the data information sheet.

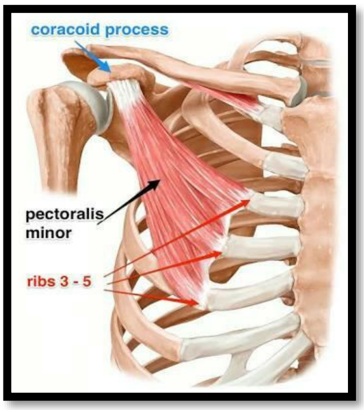


Figure 3.2a: Pectoralis minor

Figure 3.2b: Pectoralis minor landmarks

Figure 3.3 Scapula landmarks on a resting spine, posterior and oblique views

Station 2 - Postural analysis

A basic postural analysis was done by research assistant B following the prescribed plumb line (Kendall et al 2005:60) (Figure 3.4) (Permission Granted-Annexure F). The plumbline was made with a solid line drawn on a wall. Analysis focused on the general shoulder and scapula alignment, resting scapula position and thoracic posture. The participants were allocated in the kyphotic posture (defined in chapter 1 as an increased flexed curving of the thoracic portion of the spine) category if they presented with rounded shoulders, anteriorly titled scapula and thoracic kyphosis. The categorisation was done in this manner as each of these positions has an influence on the resting length of the PM muscle. Participants were allocated in the ideal category when they did not present with any of the aforementioned postures of the shoulders, scapula and thoracic spine. No participants were excluded at this point, as no one presented with a structural kyphosis. The participants' posture was indicated on the data collection table (Annexure G).

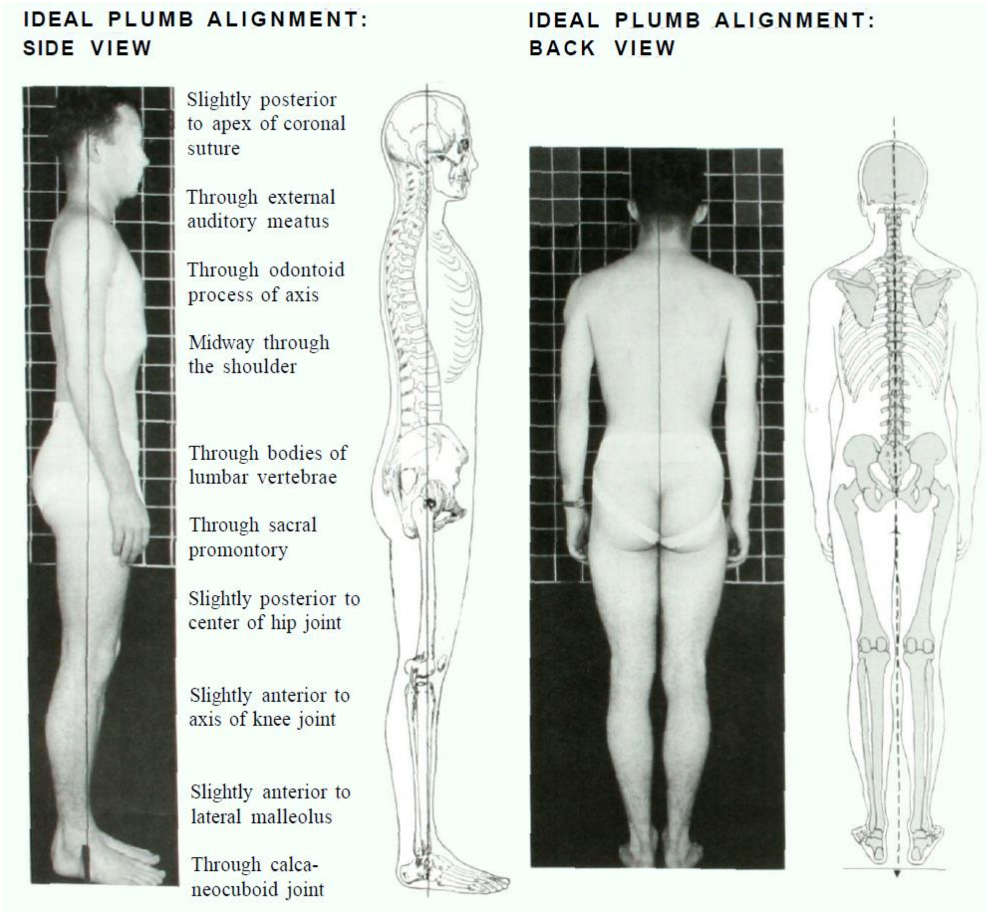


Figure 3.4:Plumbline (Kendall et al 2005:60)

Station 3 - Exclusion of shoulder pain

The shoulder quadrant test as described by Hengeveld and Banks (2014:185) was done by research assistant C on both shoulders to eliminate intra articular shoulder pathology (Figure 3.5). If a participant presented with a positive shoulder quadrant test; where shoulder pain interfered with their ADL, they were excluded from the study and referred for further assessment and treatment by another physiotherapist. Participants, who presented with a positive quadrant test but did not have pain in their ADL, were included in the study. The reasoning behind this inclusion is if the participant presented with a positive test for pain or discomfort, they were asked if this pain is a known pain. If pain was not a known pain and pain did not restrict them in any way in their ADL and they did not complain about the pain in their demographic forms, then they were included. If any of these aforementioned factors were reported as present, then the participants were excluded. The reasoning behind the exclusion is if the participant's pain interfered with their ADL, it would have a negative influence on their scapular dyskinesis tests as they would struggle to perform weighted upper limb movements. There were six participants excluded due to shoulder intra-articular pain that interfered with ADL. The results of the quadrant test were documented on the demographics sheet (Annexure E).

Figure 3.5: Shoulder quadrant

Station 4 - Height and weight

The participants' height was measured with a tape measure by research assistant D (Figure 3.6). The tape measure was attached to the wall with prestik. The tape measure was placed 50cm from the floor, to accommodate tall participants. The reading of height that was recorded was added to the 50cm to account for the distance of the tape measure from the floor. The participants stood with their backs against the wall and their height was measured. This assisted in preventing false readings due to postural habits. The participants' weight was measured with a digital scale (Kambrook, Body Fat, Electronic Scale, EF 912). The participants were requested to take their shoes off to get an accurate weight reading. The weight of the participants was required by the researcher, in order to know which weights to provide participants in the assessment of scapular dyskinesis. The weight was documented on the demographics sheet (Annexure E).

Figure 3.6: Height measurement

Station 5 - PM muscle length test (PMI)

Objective, controlled measurement of the PM muscle length was done using a standardised Vernier® caliper (Figure 3.7) by the main researcher. Research assistant A had already marked the landmarks in the first station. These markings were used as measurement reference points. The PM muscle was measured in three different positions. In each position the measurements were performed three times. The distances were reported and captured by a scribe on a data capturing sheet (Annexure G). The average of the three measurements in each range (resting, active retraction and passive lengthening) was used for analysis.

Both hands were placed on the abdomen with the shoulders slightly abducted and in a relaxed position of elbow flexion. This was to eliminate passive insufficiency of the biceps brachii muscle. The first measurement was done in the resting PM muscle length position. The participants were advised to be completely relaxed while the researcher performed the measurements between the two anatomical points with a Vernier® caliper on both sides.

The second position measured was the active retraction of the PM muscle. The participants were requested to retract their scapulae to full range of motion or to the point where they start to compensate with lumbar extension and then the researcher measured the distance between the two anatomical points with a Vernier® caliper on both sides.

The final measurement was done in the passively stretched(lengthened) position of the PM muscle. Research assistant E assisted with the passive lengthening (the origin was fixed and the insertion moved away) of the PM muscle while the researcher captured the measurements between the two anatomical points with a Vernier® caliper on both sides.

Figure 3.7: Measurements using a Vernier® caliper

Station 6 - Scapular dyskinesis

The landmarks of the scapulae made by research assistant A in station 1 were used in the assessment of the dynamic scapula movement.

For the dynamic scapula movement, simultaneous active glenohumeral joint abduction (Figure 3.8a) and flexion (Figure 3.8b) was performed by the participant with weights, to a three second count. The weights were dependent on the participants' weight. Participants weighing under 68.1 kg used 1.3 kg weights, and 2.3 kg weights were used for those weighing more than 68.1 kg (McClure 2009:162). The participants performed five repetitions of flexion and abduction.

Research assistant F took a video recording from behind, three metres from the student participants (McClure 2009:161). The videos were later reviewed by two qualified physiotherapists to determine the presence of scapular dyskinesis. One of the physiotherapists was the main researcher; the second physiotherapist was a colleague who was concurrently doing similar research on spinal cord injured (SCI) individuals. The second physiotherapist was a moderator as she only viewed twenty percent of the videos while the main researcher viewed all of the videos.

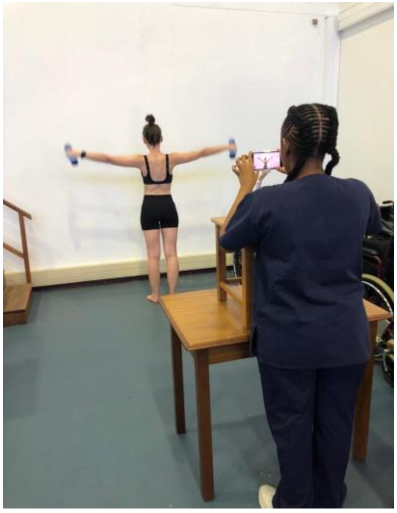
Video analysis

The main researcher viewed the videos of all 144 participants, while the second physiotherapist viewed 30 videos for quality control and reliability. Of those 30 videos, there was agreement on 20 videos. The remaining 10 videos had minor discrepancies in the type of scapular dyskinesis that was present. The researcher and the second physiotherapist had a session where they both viewed those 10 videos again separately, and from this second viewing the results were an exact match. It should be noted that the two viewers did not consult each other after the first viewing of the videos. There was no interaction between the two viewers at the second viewing.

Scapular dyskinesis is evaluated as described by McClure, et al (2009:162):
Scapular dyskinesis was split into three categories for analysis. The first category was no dyskinesis (normal), meaning the scapular motion during the five repetitions of arm elevation and lowering was normal. The second category was subtle dyskinesis, which is described as mild evidence of abnormality, not consistently present on at least two (or less) of the five repetitions. The third category was obvious dyskinesis, which is described as clearly evident abnormality in scapular motion on at least three (or more) of the five repetitions. The abnormalities of scapular motion that was observed where tipping, winging or dysrhythmia.

A two-step approach was followed. Firstly, the left shoulder was independently analysed for dyskinesis in flexion and abduction, respectively. Secondly, the results of flexion and abduction were analysed in combination on the left shoulder. The results of the combination were then used to determine scapular dyskinesis. The same process was followed for the right shoulder.

Participants were categorised as having no dyskinesis (normal) if both flexion and abduction was rated normal, or one was normal and the other was subtle dyskinesis. Subtle dyskinesis was present if both flexion and abduction movements were rated as having subtle dyskinesis. Obvious dyskinesis meant that either flexion or abduction or both was rated as obvious dyskinesis.



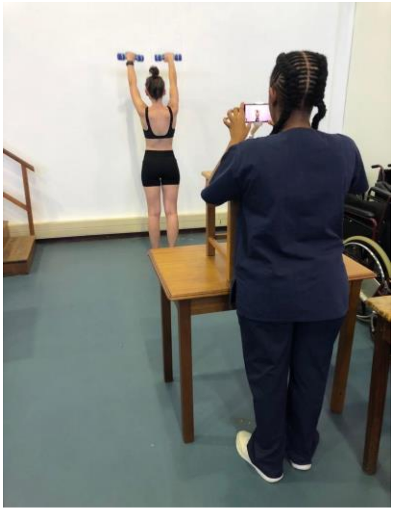


Figure 3.8 a & b respectively:Dynamic Scapular motion with shoulder abduction and shoulder flexion

3.5.6 Variables

In the study the influence of a kyphotic posture and scapular dyskinesis (dependent variables) on the PMI was determined. The effect of scapular stabiliser activation and thoracic mobility (independent variables) was evaluated to determine the influence they have on posture and scapula stability.

3.6 ETHICAL AND LEGAL CONSIDERATIONS

The research protocol was submitted for approval to the Faculty of Health Sciences Research Ethics Committee, contact details 012 356 3084 / 012 356 3085. Approval was granted on 28 March 2018, ethics reference number 114/2018 (Annexure H).

No remuneration was offered for participation. All participants were notified that pictures will be taken throughout the data collection process and may be used in any publication. The participants gave consent prior to any pictures being taken. It was made clear to participants that their identities would be kept anonymous in the pictures. A video recording was taken to observe for scapular dyskinesis. The consent of the participant was given prior to taking the video (Annexure D). The participants were made aware that the recording would be viewed by the researcher and another qualified physiotherapist at a later stage to determine whether scapular dyskinesis was present.

The research team undertook to ensure that all participants were treated fairly and that no discrimination, abuse or harassment of any kind took place during the entire research process. There were also no foreseeable risks or discomfort of the participants that took place during the study. The participants' information was recorded on a data capture sheet (Annexure G) where the identity of the participants was kept anonymous (a number was allocated to each participant) and safely stored to guarantee confidentiality. Information was only available to the researcher and processed by the statistician. The research report contained no personal information of any of the participants and the final results will be made available to the participants on request. Data will be stored at the University of Pretoria, Department of Physiotherapy, in an electronic copy as well as hard copy for a period of 15 years.

3.7 DATA MANAGEMENT AND ANALYSIS

Data was collected and recorded on a data collection table (Annexure I). Each participant had a unique number allocated to them. The data sheets were screened and cleaned for analysis by the researcher. All non-numeric value variables (gender, hand dominance) were coded (posture: 1- ideal, 2- kyphotic; gender: 1-male, 2- female; dominant hand: 1- right, 2- left) and the data was transferred to an excel spreadsheet. Cross- checking of the data was done by the researcher after it had been transferred to an excel spreadsheet. An electronic copy of the excel spreadsheet was submitted to the statistician for processing.

3.8 SUMMARY

Chapter 3 described the research methodology and study design used in the study. A total of 23 participants were excluded. The 144 participants included in the study were evaluated over a period of nine days, with signed informed consent obtained from all 144 participants.

Analysis of results gathered during data collection will be discussed in Chapter 4.

4 CHAPTER 4: RESULTS

4.1 INTRODUCTION

In this chapter, the results obtained from the data collection are presented by means of tables and graphs. The aims of the study was to assess scapular dyskinesis in association to the PMI of students between the ages of 18 and 24 years, presenting with ideal and kyphotic postures, and to measure the PM muscle length in the resting position, as well as in the actively retracted and passive lengthening positions of students between the ages of 18 and 24 years, presenting with ideal and kyphotic postures.

The data summary reports mean, standard deviation, median and range of the PMI and scapular dyskinesis. Posture and sex differences were assessed using two-way ANOVA with main factors being posture, sex and interaction between posture and sex. The latter analysis was done using a mixed-effects Maximum Likelihood regression approach. All the testing was done at the 0.05 level of significance.

The results of the study are presented in the following order: demographic data and thereafter according to the five objectives set for the study.

The flow diagram of the study is presented in Figure 4.1

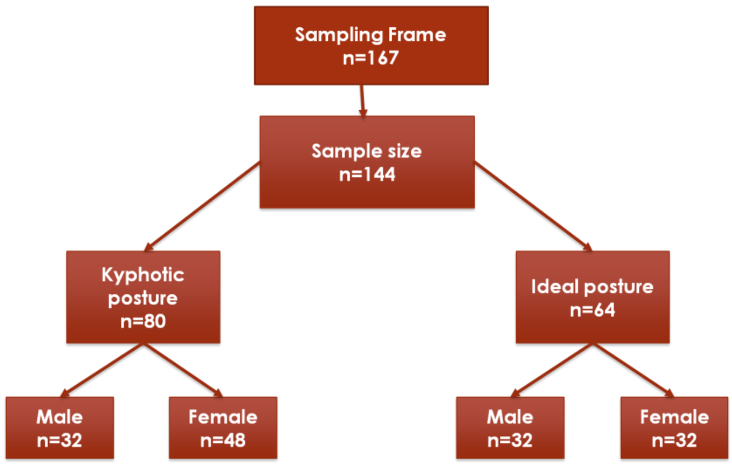


Figure 4. 1: Flow diagram of the study

A total of 167 participants were evaluated. Only 144 were eligible for inclusion in the study. The remaining 23 were excluded due to intra-articular shoulder pain that interfered with ADL, shoulder surgery, elite sports participation and those falling outside the age category. Of the 144 participants, 80 had a kyphotic posture (32 males and 48 females) and 64 had an ideal posture (32 males and 32 females).

4.2 DEMOGRAPHIC INFORMATION OF STUDY PARTICIPANTS

Table 4. 1: Demographic data of the student population between the ages of 18 and24 years

Characteristics	Total (n)	Percentage
	Gender	
Female	n=80	56%
Male	n=64	44%
	Dominance	
Right	**n=130**	**90%**
Females	n=71	55%
Males	n=59	45%
Left	**n=14**	**10%**
Females	n=9	64%
Males	n=5	36%
	Posture	
Ideal	**n=64**	**44%**
Female	n=32	50%
Male	n=32	50%
Kyphotic	**n=80**	**56%**
Female	n=48	60%
Male	n=32	40%
	Recreational participation in sport	
Yes	**n=84**	**58%**
Females	n=48	57%
Males	n=36	43%
No	**n=60**	**42%**

Females	n=32	53%
Males	n=28	47%
Registered course		
Physiotherapy	**n=96**	**66.67%**
Females	n=78	81%
Males	n=18	19%
Occupational Therapy	**n=5**	**3.47%**
Females	n=1	20%
Males	n=4	80%
Dentistry	**n=8**	**5.6%**
Females	n=0	0%
Males	n=8	100%
Radiography	**n=13**	**9.03%**
Females	n=0	0%
Males	n=13	100%
Bachelor of Clinical Medical Practice	**n=11**	**7.6%**
Females	n=0	0%
Males	n=11	100%
Medicine	**n=10**	**6.94%**
Females	n=1	10%
Males	n=9	90%
Nursing	**n=1**	**0.69%**
Females	n=0	0%
Males	n=1	100%

The target sample size was 128 participants to obtain a 95% Confidence Interval (CI). The final sample size at the end of the data collection was 144, as there was a large response from the female (16 extra) participants that presented with a kyphotic posture. Of the total sample size, 80 participants were female (56%) and 64 (44%) participants were male. On data analysis, it was observed that 64 (44%) of the sample population presented with ideal posture; 32 females and 32 males, and 80 (56%) participants presented with a kyphotic posture; 48 females and 32 males. Furthermore, the majority of the sample population, 130 (90%) of the participants (71 females and 59 males) was right hand dominant and 14 (10%) of the participants (9 females and 5 males) were left hand dominant. It should be noted that left and right handedness was not a priority as participants were categorised according to dominance.

Of the sample population 84 (58%) reported that they participate in sporting activities (48 females and 36 males), while 60 (42%) of the sample population reported not participating in sport activities (32 females and 28 males).

A larger number of the sample population was enrolled in the Bachelor of Physiotherapy degree, accounting for 66.67%of the sample population. The other five registered degrees account for less than 10% each.

4.3 **OBJECTIVE 1**

The first objective was to determine the existence of scapular dyskinesis in students aged 18 to 24 with ideal and kyphotic postures. The results of this objective are analysed in this section.

The Fisher's exact test was used for the analysis of scapular dyskinesis in the student population with ideal and kyphotic postures. This test is a statistically significant test used in analysis of congruency tables, which displays the frequency distribution of variables. This test is usually used for small sample sizes, however it is valid for larger sample sizes as well (Kim 2017:154). In the case of this study, it was used to analyse a large sample size.

In Table 4.2 the comparison of posture and scapular dyskinesis on the dominant side is presented.

Table 4. 2: Comparison of posture and scapular dyskinesis on the dominant side

Scapular dyskinesis dominant side	Posture		**Total**
	Ideal	Kyphotic	
Normal(no dyskinesis)	n=5 7.81%	n=15 18.75%	n=20 13.89%
Subtle	n=4 6.25%	n=3 3.75%	n=7 4.86%
Obvious	n=55 85.94%	n=62 77.50%	n=117 81.25
Total	n=64 100%	n=80 100%	n=144 100%

Fisher's exact test p= 0.136

In Table 4.2 the scapular dyskinesis present in the ideal and kyphotic posture groups is presented in the columns. The different categories of scapular dyskinesis in each group are presented in the rows. A total of 64 participants presented with an ideal posture and 80 participants presented with a kyphotic posture. In total 20 participants presented without dyskinesis; seven participants presented with subtle dyskinesis and 117 participants presented with obvious dyskinesis. The grand total is the sum of 144 participants.

According to the Fisher's exact test, there was no significant difference (p=0.136) on the dominant side between the three levels of dyskinesis. However, there is a large variation of scapular dyskinesis in respect of the type of dyskinesis that exists. In a total sample of 144 participants, 124 (86.14%) presented with scapular dyskinesis. There were 117 participants (81.25%) who presented with obvious scapular dyskinesis, 55 (85.94%) of those participants were from the ideal posture group and 62 (77.50%) from the kyphotic posture group. In the subtle dyskinesis category there were seven participants (4.86%). Three (3.75%) presented with a kyphotic posture and four (6.25%) presented with an ideal posture. The remaining 20 (13.89%) participants presented with no dyskinesis (normal), of which 15 (18.75%) were from the kyphotic group and five (7.81%) from the ideal group.

It can be concluded that on the dominant side, the group that presents with a greater percentage of scapular dyskinesis is the ideal posture group and the group that presents with a greater percentage of no scapular dyskinesis is the kyphotic group.

In Table 4.3 the comparison of posture and scapular dyskinesis on the non-dominant side is presented, using the Fischer's exact test. As previously mentioned, the Fischer's exact test is used on a large sample in this study to determine the frequency distribution of scapular dyskinesis according to ideal and kyphotic posture groups.

Table 4. 3: Comparison of posture and scapular dyskinesis on the non-dominant side

Scapular dyskinesis non-dominant side	Posture		**Total**
	Ideal	Kyphotic	
Normal(no dyskinesis)	n=3 4.69%	n=16 20%	n=19 13.19%
Subtle	n=3 4.69%	n=5 6.25%	n=8 5.56%
Obvious	n=58 90.63%	n=59 73.75%	n=117 81.25
Total	n=64 100%	n=80 100%	n=144 100%

Fisher's exact test p= 0.016

In Table 4.3 the scapular dyskinesis present in the ideal and kyphotic posture groups is presented in the columns. The different categories of scapular dyskinesis in each group are presented in the rows. A total of 64 participants presented with an ideal posture and 80 participants presented with a kyphotic posture. There were a total of 19 participants without dyskinesis documented as normal. A total of eight participants presented with subtle dyskinesis and a total of 117 participants presented with obvious dyskinesis. The grand total is the sum of 144 participants.

According to the Fisher's exact test, there was a significant difference (p=0.016) on the non-dominant side between the three levels of dyskinesis. Furthermore, in a total sample of 144 participants, 125 (86.81%) presented with variations of scapular dyskinesis. A total of 117 participants (81.25%) presented with obvious scapular dyskinesis, 58 (90.63%) of those participants were from the ideal posture group and 59 (73.75%) from the kyphotic posture group. In the subtle dyskinesis category there was eight participants (5.56%), of those eight, five (6.25%) presented with a kyphotic posture and three (4.69%) presented with an ideal posture. The remaining 19 (13.19%) participants presented with no dyskinesis (normal), of those 19, 16 (20%) were from the kyphotic group and three (4.69%) from the ideal group.

It can be concluded that on the non-dominant side, the population that presents with a greater percentage of scapular dyskinesis is the ideal posture group and the population that presents with a greater percentage of no scapular dyskinesis is the kyphotic group.

When comparing the dominant and non-dominant sides, though they both present with a degree of scapular dyskinesis, the participants have more control on their dominant side, than the non-dominant side. This may be due to increased use of the dominant side as compared to the non-dominant side.

4.4 PM LENGTH EXPRESSED AS PMIVALUE (OBJECTIVE 2 TO 5)

The length of the PM muscle is expressed as a PMI value. PMI in respect to dominance, gender and posture was assessed in a linear mixed analysis, using mixed-effects maximum likelihood regression. Within the mixed-effect there are fixed and random effects. The fixed effects are dominance, gender, posture and the three testing positions namely; resting, active retraction and passive lengthening. The random effects are the participants. These were tested against each other to determine the outcome variable being the PMI value.

4.5 OBJECTIVE 2

The second objective was to determine the difference in PMI values between the ideal and kyphotic postures. The findings of this objective are analysed in this section.

Table 4. 4: Descriptive statistics for observed PMI, posture in relation to the three testing positions

Position	PMI ideal posture mean (SD)	PMI kyphotic posture mean (SD)
Resting	10.33 (0.61)	9.81 (0.64)
Actively retracted	10.42 (0.61)	9.97 (0.63)
Passively lengthened	11.12 (0.62)	10.48 (0.64)

SD: Standard deviation

In Table 4.4 the mean PMI values for the ideal and kyphotic posture groups is presented in the columns. The three testing positions are presented in the rows. The PMI value in all the three testing positions is shorter in the kyphotic posture group as compared to the ideal posture group. In the resting position, the kyphotic group had a mean PMI value of 9.81 with a 0.64 SD and the ideal group had a mean PMI value of 10.33 with a 0.61 SD. With regards to the actively retracted, the kyphotic group had a mean PMI value of 9.97 with a 0.63 SD and the ideal group had a mean PMI value of 10.42 with a 0.61 SD. In the passively lengthened positions the mean PMI value of the kyphotic group was 10.48 with a 0.64 SD and the mean PMI value for the ideal group was 11.12 with a 0.62 SD.

It can be concluded that the PMI for the kyphotic posture group is smaller than the ideal posture group. This may be due to the PM muscle adaptively shortening due to the bad habitual functional kyphotic posture. To determine if there were any significant differences, the linear predictions were done.

In Table 4.5 the summary of the linear predictions of effect for posture and the three testing positions will be discussed in order to prove the 95% CI (mean± 2 SD). This means that the margin of error is minimal due to the large sample size. The effect is the difference between the kyphotic and ideal posture groups, as well as the differences between the three testing positions (the actively retracted and resting positions; the difference between passively lengthened and resting positions; and the difference between the passively lengthened and actively retracted positions). In this study linear predictions were used to determine the trend of PMI values in the kyphotic and ideal posture groups. The p-values were determined using the chi-squared distribution test, which is used to test independence between two variables (Rana and Singhal 2015:69)

Table 4. 5: Linear predictions of mean effect for posture and the three testing positions

	Linear predicted mean (95% CI)	**In relation to resting position (except posture category, that is general outcome)**		**In relation to actively retracted position**	
		Effect for posture	p-value*	Effect for posture	p-value*
Ideal	10.64 (10.51 ; 10.78)				
Kyphotic	10.08 (9.96 ; 10.21)	-0.557 (-0.738 ; -0.376)	<0.001		
POSITIONS					
Resting	10.04 (9.94 ; 10.13)				
Actively retracted	10.19 (10.10 ; 10.29)	0.154 (0.102 ; 0.207)	<0.001		
Passively lengthened	10.77 (10.67 ; 10.86)	0.728 (0.676 ; 0.780)	<0.001	0.582 (0.419 ; 0.744)	<0.001

*chi-squared distribution test

In Table 4.5 the columns represent the linear predicted mean, the effect and p-values in the resting and active retraction positions. The types of postures and the three testing positions are presented in the rows. One of the most significant findings of the study was the statistically significant difference in the PMI value in respect to kyphotic and ideal postures ($p<0.001$). Another significant finding was the statistically significant difference between resting and actively retracted positions, as well as the actively retracted and passively lengthened positions, with a $p<0.001$. The mean effect was -0.557, with a 95%

confidence that the true, but unknown, margins mean falls between -0.738 and -0.376 for the combined postures. There was also statistically significant differences between resting and passively lengthened positions ($p<0.001$), with a mean effect of 0.728 and a 95% confidence that the true, but unknown, margins mean effect falls between 0.676 and 0.780. Moreover, there was also statistically significant differences between actively retracted and passively lengthened positions ($p<0.001$), with a mean effect of 0.582 and a 95% confidence that the true, but unknown, margins mean effect falls between 0.419and 0.744. This implies there is a minimal margin for error due to the 95% CI.

It can therefore be concluded that there is a statistically significant difference in PMI with respect to kyphotic and ideal postures ($p<0.001$). There is also statistically significant differences with regards to the three testing positions ($p<0.001$).

In Table 4.6 the linear prediction of mean PMI values and 95% CI for the ideal and kyphotic posture groups against the three testing positions are explored. Once more, the margin of error is minimal due to the large sample size and 2 SD is used.

Table 4. 6: Linear prediction of mean and 95% Confidence Interval for Posture in relation to the three testing positions

Positions	Ideal posture linear prediction mean (95% CI)	Kyphotic posture linear prediction mean (95% CI)
Resting	10.33 (10.18 ; 10.47)	9.80 (9.68 ; 9.93)
Actively retracted	10.47 (10.33 ; 10.61)	9.97 (9.84 ; 10.10)
Passively lengthened	11.12 (10.98 ; 11.27)	10.48 (10.35 ; 10.61)

In Table 4.6 the linear prediction mean for the ideal and kyphotic posture groups are presented. The three testing positions are presented in the rows. In the ideal posture group, the mean PMI value at rest was 10.33, with a 95% confidence that the true, but unknown, margins mean falls between 10.18 and 10.47. For the actively retracted position of the ideal posture group, the mean PMI value was 10.47 with a 95% confidence that the true, but unknown, margins mean falls between 10.33 and 10.61. For the passively lengthened position of the ideal posture group, the mean PMI value was 11.12 with a 95% confidence that the true, but unknown, margins mean falls between 10.98 and 11.27.

In the kyphotic posture group, the mean PMI value at rest was 9.80, with a 95% confidence that the true, but unknown, margins mean falls between 9.68 and 9.93. For the actively retracted position of the kyphotic posture group, the mean PMI value was 9.97, with a 95% confidence that the true, but unknown, margins mean falls between 9.84and 10.10. For the passively lengthened position of the kyphotic posture group, the mean PMI value was 10.48, with a 95% confidence that the true, but unknown, margins mean falls between 10.35 and 10.61.

It can be concluded that the PMI values of the ideal posture group was longer than that of the kyphotic posture group, with a small margin of error due to the 95% CI.

In Figure 4.2 a marginsplot is used, to express the interaction of PMI values between the ideal and kyphotic posture groups in respect to the three testing positions. The marginsplot is used to provide a visual summary for PMI values for the ideal and kyphotic posture groups in relation to the three testing positions.

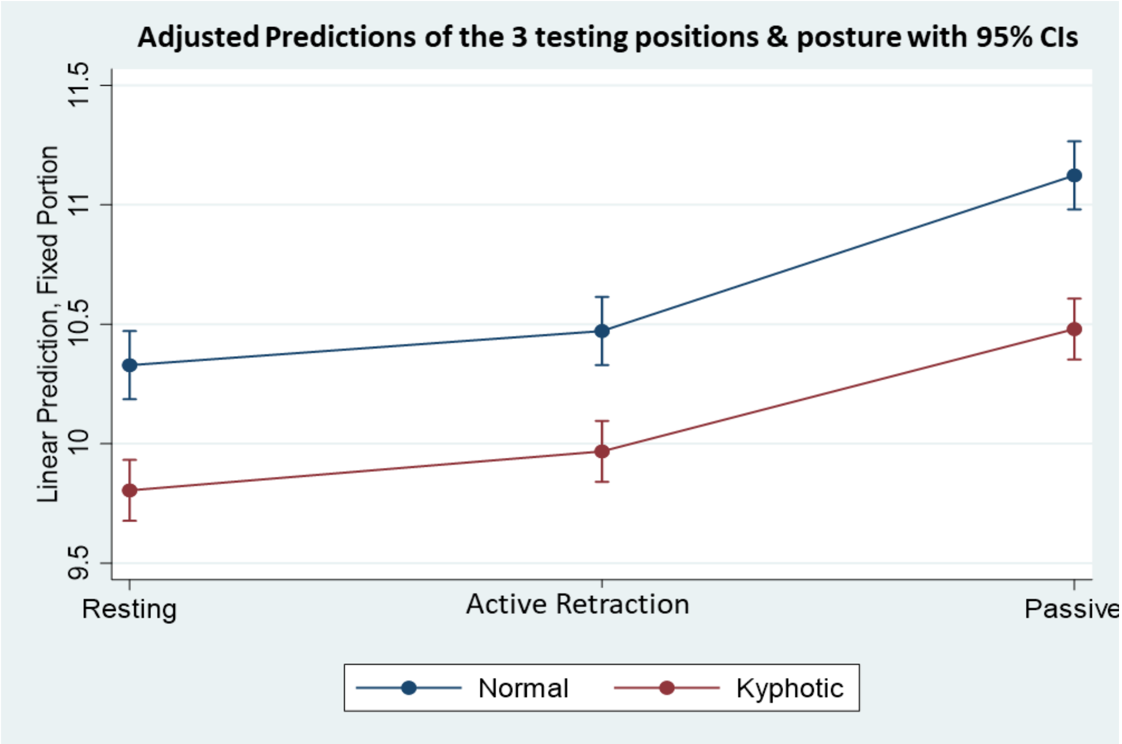


Figure 4. 2: Display of linear predicted mean by posture category in relation to the three testing positions

The ideal posture group has larger PMI values than the kyphotic posture group. Additionally, the PMI values of both posture groups in all three testing positions follow the same trajectory. This implies that even though the PMI for the posture groups is different, PM length is standardised.

4.6 **OBJECTIVE 3 AND 4**

The third objective was to determine the PMI value in the resting position, as well as actively retracted and passively lengthened positions on the dominant and non-dominant sides. The fourth objective was to determine if a difference exists in the PMI value between the dominant and non-dominant sides. The findings of these objectives are analysed and discussed together in this section, as they are related to each other.

In Table 4.7 descriptive statistics were used to provide a brief summary of the mean PMI value on the dominant and non-dominant sides, in relation to the three testing positions.

The p-value was determined using the paired t-test as one-sided comparisons of PMI values were done in the three testing positions, for the dominant and non-dominant sides.

Table 4. 7: Descriptive statistics for observed PMI, dominance in relation to the three testing positions

Position	n	PMI dominant mean (SD)	PMI non-dominant mean (SD)	p-value*
Resting	144	10.00 (0.68)	10.07 (0.68)	0.049
Actively retracted	144	10.16 (0.66)	10.23 (0.68)	0.056
Passively lengthened	144	10.74 (0.71)	10.79 (0.71)	0.130

*One sided comparison tests (t-test)

In Table 4.7 the mean PMI values for the dominant and non-dominant sides is presented in the columns, along with the paired t-test p-values. The three testing positions are presented in the rows. The PMI values in the three testing positions are greater in the non-dominant side than the dominant side. In the resting position, the non-dominant side of the total population (n=144) had a mean PMI value of 10.07 with a 0.68 SD and the dominant side had a mean PMI value of 10.00 with a 0.68 SD. In the actively retracted position, the non-dominant side had a mean PMI value of 10.23 with a 0.68 SD and the dominant side had a mean PMI value of 10.16 with a 0.66 SD. In the passively lengthened position, the mean PMI value of the non-dominant side was 10.79 with a 0.71 SD and the mean PMI value on the dominant side was 10.74 with a 0.71 SD. The paired t-test results show significant differences between two of the three testing positions when compared against dominance (i.e. resting positions compared to each other in the dominant and non-dominant sides, etc.). At rest the p-value was 0.049, indicating a significant difference. In the actively retracted position there was a marginal significant difference; the p-value was 0.056. In the passively lengthened position there was no significant difference, with a p-value of 0.130. These results suggest that at rest postural influences are a contributing factor. In the actively retracted position, the scapular muscle strength may potentially be decreased because at the passively lengthened position there are no differences between the two sides. This implies that the problem may be due to posture and the decrease in muscle strength because at rest, an individual adapts a posture that is comfortable (habitual) for them. Scapular retractor muscle strength (middle fibres of trapezius, rhomboids major and minor) is required in the active retracted position to maintain inner range strength during muscle contraction.

It can therefore be concluded that the PM muscle length expressed as PMI values in the three testing positions is larger on the non-dominant side than the dominant sides in the study population. To determine if there were any significant differences, linear predictions were done.

In Table 4.8 the summary of the linear predictions of effect for dominance and the three testing positions are discussed in order to prove the 95% CI. This means that the margin of error is minimal due to the large sample size. Since a 95% CI is used, there is a use of 2 SD (mean±2 SD). The effect is the difference between non-dominant and dominant sides; the differences between the three testing positions. Linear predictions are used to determine future values of a data set. In the study linear predictions were used to determine the trend of PMI values in the dominant and non-dominant sides. The p-values were determined using the chi-squared distribution test.

Table 4. 8: Linear predictions of the mean effect for dominance and the three testing positions

	Linear predicted mean (95% CI)	**In relation to resting position (except dominance category, that is a general outcome)**		**In relation to actively retracted position**	
		Effect for dominance	p-value*	Effect for dominance	p-value*
Dominant	10.30 (10.20 ; 10.40)	0.630 (0.202 ; 0.106)	0.004		
Non-dominant	10.36 (10.26 ; 10.47)				
POSITIONS					
Resting	10.04 (9.93 ; 10.14)				
Actively retracted	10.19 (10.09 ; 10.30)	0.154 (0.102 ; 0.207)	<0.001		
Passively lengthened	10.77 (10.66 ; 10.87)	0.728 (0.675 ; 0.781)	<0.001	0.574 (0.413 ; 0.735)	<0.001

*chi-squared distribution test

In Table 4.8 the columns represent the linear predicted mean, the effect and p-values in the resting and active retraction positions. The dominant and non-dominant sides, as well as the three testing positions are presented in the rows. There was a significant difference between dominant and non-dominant PMI values with a p-value of 0.004. There were statistically significant differences between the resting and actively retracted positions with a p<0.001 with a mean effect of 0.154 and a 95% CI (0.102 ; 0.207) for the combined values of non-dominant and dominant sides. This means that in the study population (n=144) were the mean effect is 0.154; the researcher is 95% confident that the true, but unknown, margins mean for effect falls between 0.102 and 0.207. There were also statistically significant differences between the resting and passively lengthened position (p<0.001) with a mean effect of 0.728, with a 95% confidence that the true, but unknown, margins mean effect falls between 0.675 and 0.781. Moreover, there was also statistically significant differences between actively retracted and passively lengthened (p<0.001) and an effect of 0.574, with a 95% confidence that the true, but unknown, margins mean effect falls between 0.413 and 0.735. There is a minimal margin for error due to the 95% CI.

The results indicate that there is a significant difference (p=0.004) in dominance in respect to the PMI values calculated. Furthermore, there is statistically significant differences (p<0.001) with regards to changes in the three testing positions.

In Table 4.9 the linear prediction of mean PMI values and 95% CI for the dominant and non-dominant sides against the three testing positions are explored. Once more, the margin of error is minimal due to the large sample size and 2 SD that was used.

Table 4. 9: Linear prediction of mean and 95% Confidence Interval for dominance in relation to the three testing positions

Position	**Dominant linear prediction mean (95% CI)**	**Non-dominant linear prediction mean (95% CI)**
Resting	10.00 (9.89 ; 10.11)	10.07 (9.96 ; 10.18)
Actively retracted	10.16 (10.05 ; 10.26)	10.23 (10.11 ; 10.34)
Passively lengthened	10.74 (10.63 ; 10.85)	10.79 (10.68 ; 10.90)

In Table 4.9 the linear prediction mean for the dominant and non-dominant sides are presented. The three testing positions are presented in the rows. On the non-dominant side, the mean PMI value at rest was 10.07, with a 95% confidence that the true, but unknown, margins mean falls between 9.96 and 10.18. For the actively retracted position on the non-dominant side, the mean PMI value was 10.23 with a 95% confidence that the true, but unknown, margins mean falls between 10.11 and 10.34. For the passively lengthened position on the non-dominant side, the mean PMI value was 10.79 with a 95% confidence that the true, but unknown, margins mean is between 10.68 and 10.90.

On the dominant side, the mean PMI value at rest was 10.00, with a 95% confidence that the true, but unknown, margins mean falls between 9.89 and 10.11. For the actively retracted position on the dominant side, the mean PMI value was 10.16 with a 95% confidence that the true, but unknown, margins mean falls between 10.05 and 10.26. For the passively lengthened position on the dominant side, the mean PMI value was 10.74 with a 95% confidence that the true, but unknown, margins mean falls between 10.63 and 10.85.

It can therefore be concluded that the PMI values in the three testing positions are larger on the non-dominant side than the dominant side, with a small margin of error due to the 95% CI.

In Figure 4.3 a marginsplot is used, to express the interaction of PMI values between the dominant and non-dominant sides in respect to the three testing positions. The marginsplot is used to provide a visual summary for PMI values for the dominant and non-dominant sides in relation to the three testing positions.

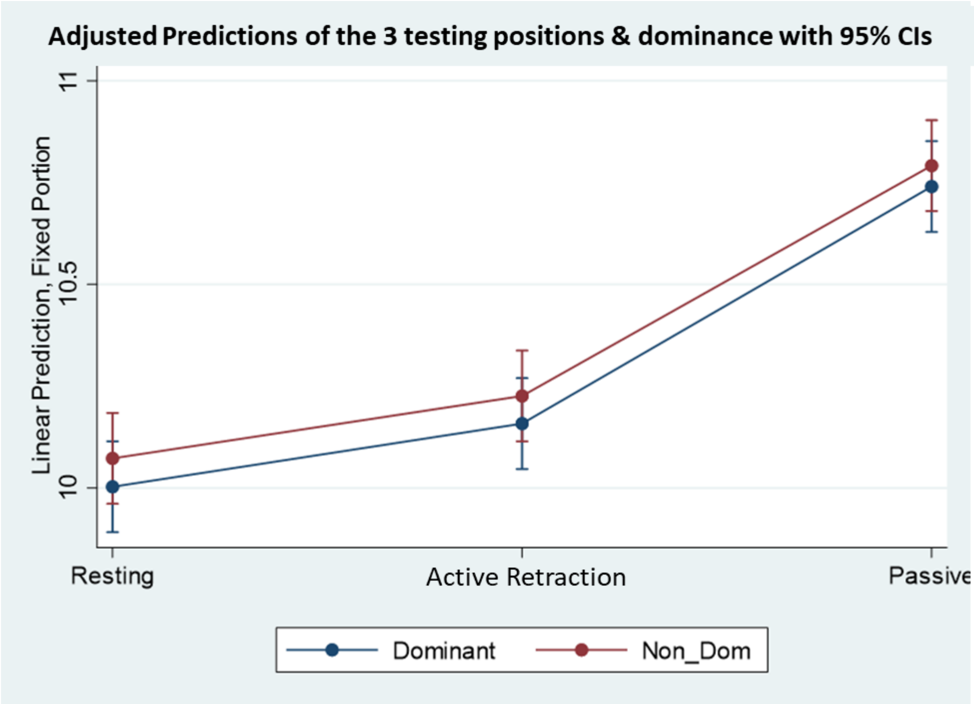


Figure 4. 3: Display of linear predicted mean by dominance category in relation to the three testing positions

The non-dominant side shows larger PMI values than the dominant side in all three testing positions. They both however, exhibit the same trajectory from the resting position to the actively retracted position and from the actively retracted position to the passively lengthened position. This implies that even though the non-dominant side is slightly larger than the dominant side, the PM length is homogenous.

4.7 OBJECTIVE 5

The fifth objective was to determine the difference in the PMI value between males and females. The findings of this objective are analysed in this section.

Descriptive statistics were used to provide a brief summary of the mean PMI values for males and females, in relation to the three testing positions and regardless of posture, as presented in Table 4.10.

Table 4. 10: Descriptive statistics for observed PMI for gender in relation to the three testing positions

Position	PMI males mean (SD) n=64	PMI females mean (SD) n=80	p-Value
Resting	10.19 (0.69)	9.91 (0.65)	0.008
Actively retracted	10.35 (0.67)	10.07 (0.65)	0.970
Passively lengthened	10.93 (0.71)	10.64 (0.68)	0.897

In Table 4.10 the mean PMI values for the male and female groups is presented in the columns, along with the p-value. The three testing positions are presented in the rows. The PMI value in the three testing positions is larger for males than for females. In the resting position, the male population had a mean PMI value of 10.19 with a 0.69 SD and the female population had a mean PMI value of 9.91 with a 0.65 SD. In the actively retracted position, the male population had a mean PMI value of 10.35 with a 0.67 SD and the female population had a mean PMI value of 10.07 with a 0.65 SD. In the passively lengthened position, the mean PMI value of the male population was 10.93 with a 0.71 SD and the mean PMI value for the female population was 10.64 with a 0.68 SD. Even though the PMI values are larger in the male population, the p-value results indicate no significant differences between the three testing positions (i.e. resting position compared to each other in the male and female population, etc.). Therefore, at rest the p-value was 0.008, in the actively retracted position the p-value was 0.970 and in passively lengthened position the p-value was 0.897. Although there was a significant difference in the PMI values between male and female at rest, no significant difference was observed within the other two testing positions. These finding do not have any clinical value as strength and postural preferences were eliminated (passively stretched position) during the testing position, and therefore no significant difference was observed.

It can be concluded that the male PMI is larger than the female PMI in the three testing positions. To determine if there were any significant differences, the linear predictions were done.

In Table 4.11 the summary of the linear predictions of effect for gender and the three testing positions will be discussed in order to prove the 95% CI (mean± 2 SD). The margin of error is minimal due to the large sample size. The effect is the difference between the male and female population; and the differences between the three testing positions. The p-values were determined using the chi-squared distribution test.

Table 4. 11: Linear predictions of the mean effect for gender and the three testing positions

	Linear predicted mean (95% CI)	**In relation to resting position (except gender category, that is general outcome)**		**In relation to actively retracted position**	
		Effect for gender	p-value*	Effect for gender	p-value*
Males	10.49 (10.34 ; 10.64)	-0.282 (-0.462 ; 0.011)	0.005		
Females	10.21 (10.07 ; 10.34)				
POSITIONS					
Resting	10.04 (9.94 ; 10.14)				
Actively retracted	10.19 (10.09 ; 10.29)	0.154 (0.102 ; 0.207)	<0.001		
Passively lengthened	10.77 (10.66 ; 10.87)	0.728 (0.675 ; 0.781	<0.001	0.574 (0.412 ; 0.737)	<0.001

*chi-squared distribution test

In Table 4.11 the columns represent the linear predicted mean, the effect and p-values in the resting and active retraction positions. The male and female categories, as well as the three testing positions are presented in the rows. A significant difference in respect to females and males ($p=0.005$) were observed. There was statistical significant differences between resting and actively retracted positions ($p<0.001$) with a mean effect of 0.154 and a 95% CI (0.102 ; 0.207) for the combined genders. This means that in the study population ($n=144$) were the mean effect is 0.154; the researcher is 95% confident that the true, but unknown, margins mean effect falls between 0.102 and 0.207. There were also statistically significant differences between resting and passively lengthened positions ($p<0.001$) with a mean effect of 0.728, with a 95% confidence that the true, but unknown, margins mean effect falls between 0.675 and 0.781. Moreover, there were also statistically significant differences between actively retracted and passively lengthened positions ($p<0.001$) and a mean effect of 0.574, with a 95% confidence that the true, but unknown, margins mean effect is between 0.413 and 0.735. There is a minimal margin for error due to the 95% CI.

It can be concluded that there is a significant difference in males and females in respect to their PMI. There is also statistically significant differences ($p<0.001$) with all three testing positions.

In Table 4.12 the linear prediction of mean PMI values and 95% CI for the male and female population against the three testing positions are explored. Once more, the margin of error is minimal due to the large sample size and 2 SD that is used.

Table 4. 12: Linear prediction of mean and 95% Confidence Interval for gender in relation to the three testing positions

Position	Male linear prediction mean (95% CI)	Female linear prediction mean (95% CI)
Resting	10.19 (10.04 ; 10.35)	9.91 (9.78 ; 10.05)
Actively retracted	10.35 (10.19 ; 10.50)	10.07 (9.93 ; 10.21)
Passively lengthened	10.93 (10.77 ; 11.08)	10.64 (10.50 ; 10.78)

In Table 4.12 the linear prediction mean for the male and female groups are presented. The three testing positions are presented in the rows. In the male population, the mean PMI value at rest was 10.19, with a 95% confidence that the true, but unknown, margins mean falls between 10.04 and 10.35. For the actively retracted position of males, the mean PMI value was 10.35 with a 95% confidence that the true, but unknown, margins mean falls between 10.19 and 10.50. For the passively lengthened position of males, the mean PMI value was 10.93 with a 95% confidence that the true, but unknown, margins mean falls between 10.77 and 11.08.

In the female population, the mean PMI value at rest was 9.91, with a 95% confidence that the true, but unknown, margins mean falls between 9.79 and 10.05. For the actively retracted position of females, the mean PMI value was 10.07, with a 95% confidence that the true, but unknown, margins mean falls between 9.93 and 10.21. For the passively lengthened position of females, the mean PMI value was 10.64, with a 95% confidence that the true, but unknown, margins mean falls between 10.50 and 10.78.

It can be concluded that the male PMI values are larger than the female PMI in all three testing positions, with a small margin of error due to the 95% CI.

In Figure 4.4 a marginsplot is used, to express the interaction of PMI values between the male and female population in respect to the three testing positions. The marginsplot is used to provide a visual summary for PMI values for males and females in relation to the three testing positions.

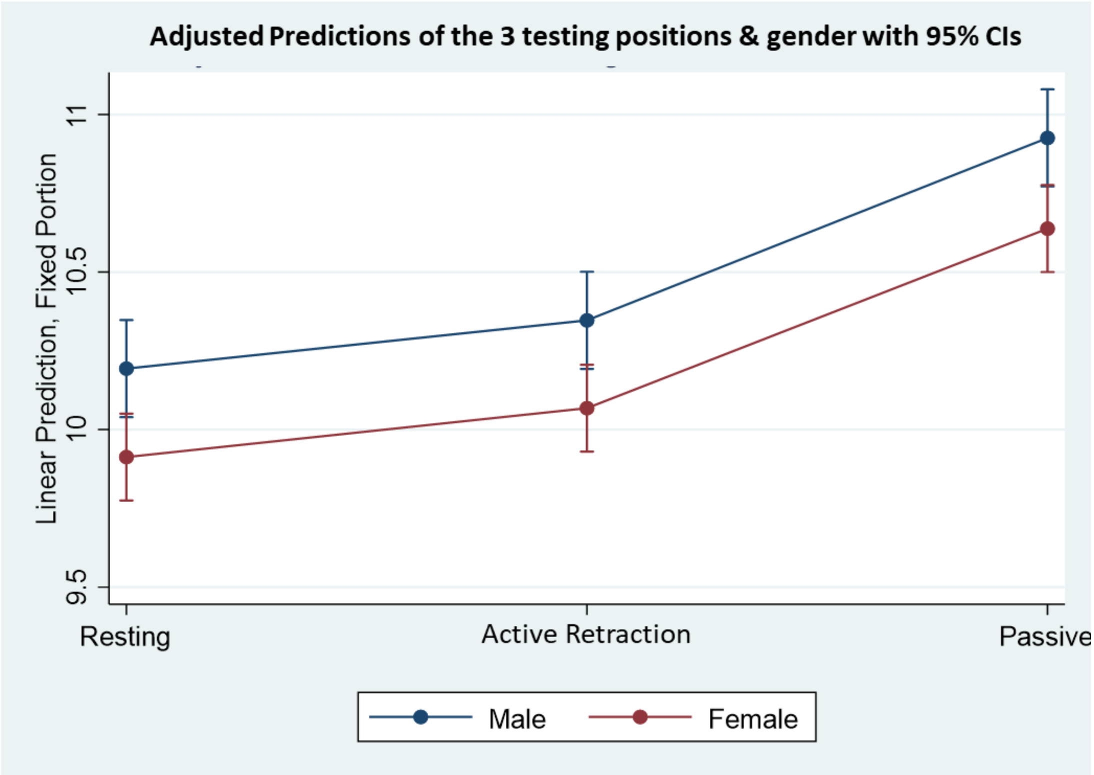


Figure 4. 4: Display of linear predicted mean by gender category in relation to the three testing positions

In Figure 4.4 the male population has larger PMI values than females. Moreover, the PMI values of males to females in the three resting positions follow the same trajectory. This means that even though males have a larger PMI due to body build than the females, the PM length is uniform for both sexes.

4.8 SUMMARY

The results obtained from the study have been reported and analysed in this chapter.

During the demographic data analysis it was noted that more than half of the participants were female; the majority of the participants where right hand dominant; the majority of the participants partook in recreational sporting activities; and that the larger part of the sample population was enrolled in the Bachelor of Physiotherapy degree.

The most significant finding of this study was the statistically significant differences between all three testing positions ($p<0.001$) (Table 4.3, Table 4.6 and Table 4.9). These findings suggest that scapular stabilising muscles may be weakened in the inner range and affect the length of the PM muscle in the resting and active testing positions. Moreover, statistically significant differences were observed in respect to kyphotic and ideal postures ($p <0.001$) (Table 4.9). The kyphotic posture group had shorter PMI values than the ideal posture group in all three testing positions.

There was a significant difference of scapular dyskinesis between the three levels of dyskinesis on the non-dominant side ($p=0.016$). It was also found that within the results, the ideal posture group presented with a larger percentage of scapular dyskinesis than the kyphotic group. There was no significant difference of scapular dyskinesis on the dominant side ($p=0.136$) between the three levels of dyskinesis. However, within the results it was found that the ideal posture group presented with a larger percentage of scapular dyskinesis than the kyphotic group, for the dominant side.

The mean PMI values within the population showed a significant difference between dominant and non-dominant sides ($p=0.004$) in the three testing positions. The dominant side was shorter than the non-dominant side. There was also significant differences between the males to female PMI values ($p=0.005$) (Table 4.3 and Table 4.6). The females had smaller PMI values than males in all three testing positions.

In Chapter 5 the results will be discussed, compared to previous studies and interpreted.

5 CHAPTER 5: DISCUSSION

5.1 OVERVIEW

In this chapter, the results of the study will be discussed, analysed and compared to existing literature. The aims of the study were to assess scapular dyskinesis in relation to PMI values of students aged between 18 and 24 years, presenting with ideal and kyphotic postures; and to determine the PMI value in three different testing positions: resting position, actively retracted position and passively lengthened position of students aged between 18 and 24 years, presenting with ideal and kyphotic postures.

Five main findings have emerged from the study:

I. The first main finding was the statistically significant differences observed in the three testing positions i.e. resting position, actively retracted position and passively lengthened position.
II. The second finding was the existence of scapular dyskinesis in students with ideal and kyphotic postures.
III. The third finding was the statistically significant difference observed in PMI values between the ideal and kyphotic posture groups.
IV. The fourth finding was the difference in PMI values between the dominant and non-dominant sides.
V. The final finding observed was the difference in the PMI values between males and females.

These findings required further analysis and will be discussed in line with the five objectives for the study as stated in the first chapter. However, the flow of the discussion will digress from the order of the objectives, where the main findings will be discussed first.

The first main finding to be discussed is the significant differences observed in PMI values with regards to the three testing positions. There was a statistically significant difference ($p<0.001$) in the PMI value when compared within each of the three different positions. There was a statistically significant difference between the resting and actively retracted positions, the resting and passively lengthened positions, as well as the actively retracted and passively lengthened positions. Finley, et al (2017:215-216) conducted the only study that corroborates these findings. The distinctiveness of these results have shown that the strength of the scapular retractor muscles (middle trapezius, lower trapezius and rhomboids) and scapular stabilising muscles (serratus anterior) play an important role in the optimum length of the PM muscle. This provides valuable information as it shows that if the PM muscle is shortened it is not only shortened biomechanically or physically, it may also be shortened due to the lack of muscle strength of the scapular stabilisers (so the muscle is never lengthened into the full length due to antagonist weakness). Furthermore, results from the paired t-test of the current study show significant differences in the resting (p=0.049) and actively retracted (p=0.056) positions compared to each other for the dominant and non-dominant sides. There was no significant difference in the passively lengthened positions (p=0.130) compared to each other for the dominant and non-dominant sides. There is no other study that reports similar results. The results of the resting and actively retracted positions show that individual positioning and antagonist strength play a role in the length of the PM muscle. The results of the passively lengthened positions compared to each other, for the dominant and non-dominant sides are more proof that scapular stabilising muscle strength and function is a crucial factor. The current study provides results that confirm a gap in existing literature, as measurements were done in the optimum PM muscle length for the resting, actively retracted and passively lengthened positions. These findings cannot be compared to other studies, as those studies only assessed in the resting position (Borstad and Ludewig 2005:230; Borstad 2006:551-552; Borstad 2008:171; Cools et al 2010:680;Struyf et al 2012a:6; Struyf et al 2014:295-296; Lee et al 2015:256; Mackenzie et al 2015a:2; Rosa et al 2016:178), one in the resting and actively retracted position (Rosa et al 2017:22) and one in the resting and passively lengthened positions, using a figure-8 strap (Ko et al 2016:274). Only one study performed measurements of PM length in all three testing positions. However, these results cannot be effectively compared as the PMI was not used by Finley, et al (2017:213-214). Finley and colleagues only measured the length of the PM muscle in centimetres and not as an index that included participants' height and body mass.

The significant difference in the results obtained from the current study suggests that the PM muscle is not at its ultimate length when at rest due to postural changes or habitual posture. The additional range when the passively lengthened position is compared to the actively retracted range implies that the lower fibres of the trapezius, middle trapezius and rhomboids major and minor lack strength in the inner range, along with scapular stability mechanics provided by serratus anterior. Biomechanically, the lower fibres of the trapezius provide upwards rotation, posterior tilt and depression of the scapula. The middle trapezius, rhomboids major and minor muscles stabilise the medial border of the scapula and retract the scapula. The serratus anterior muscle stabilises the scapula especially during arm elevation (Paine and Voight 2013:618-619). Due to these biomechanical factors, it can be argued that weakness of the lower fibres of the trapezius, the rhomboids major and minor and the serratus anterior could be a possible cause for the difference between the PM muscle length of the actively retracted position and the passively stretched position.

In students with a kyphotic posture, stretch weakness could be a contributing factor to the scapular stabiliser muscle weakness. Stretch weakness is defined as weakness that results from muscles remaining in an elongated position beyond its normal neutral resting position, as related to the duration of the elongation and not the severity of it (Comerford and Mottram 2001:17). This position of the scapula on the thorax may be attributed to the closed kinematic chain adapted in individuals with a kyphotic posture, as these individuals are in sustained positions that place scapular stabilisers at stretch. In individuals with ideal posture in the current study, a contributing factor for scapular stabilising muscles weakness may be due to position weakness. Position weakness is defined as when an elongated muscle lacks force efficiency in the inner range due to generating a peak torque towards outer range (Comerford and Mottram 2001:17). An explanation for this is, even though these participants present with ideal posture, their sustained working position at university and in clinical practice requires them to work in a forward posture, with their shoulders mainly in a 45° flexion position, leaning forward into gravity most of the day, which in turn perpetuates rounded shoulder posture. This sustained postural position causes functional resting length changes of the PM muscle in adaptation to the length that the muscle is habitually used to or positioned in (Comerford and Mottram 2001:17). This may also be the reason why these participants have the ability to correct their posture due to motor control that is adapted in an environment. According to the motor control theory, three concepts have to interlink for optimum function (environment, task and individual). Where these three concepts overlap motor control is managed as a person's functional capacity (Shumway-Cook and Woollacott 2007:4). Therefore, students in their functional position, maintain scapula control.

In essence, there should be minimal changes between actively retracted and passively lengthened positions if the lower trapezius and rhomboids muscles are functioning optimally. Results from Lee, et al (2015:260) also suggest that muscle function of the scapular stabilisers contributes to the PM muscle length, where the PMI values improved after posterior scapula tilting exercises (which strengthens the lower trapezius and serratus anterior) and PM muscle stretches. These findings confirm that scapular stabilising muscles play an important role in the PM muscle length. The findings of the current study therefore suggest that scapular stabilising muscle function is a potential contributing factor in the anteriorly tilted scapula and not only the PM muscle. This is because the current study eliminated all biomechanical factors that included the contribution of postural influences, gravity and the biceps brachii on the PM muscle length, by positioning the participants in the supine position with their elbows flexed and arms resting on the abdomen. The findings of this study confirm the hypothesis of the other studies (Borstad 2006:551; Lee et al 2015:258-260; Ko et al 2016:276-277) that explored PM muscle length in relation to static scapula positioning. Borstad (2006:551) found that there was a significant interaction for scapula internal rotation at lower arm elevation angles in the coronal plane only, with individuals with a shorter PM muscle demonstrating a more internally rotated scapula. Lee, et al (2015:258-260) found that the PMI and scapula upward rotation angle, as well as the activity of the scapular stabilisers (upper trapezius, lower trapezius, and serratus anterior muscles), were significantly greater for scapula posterior tilting exercise after PM muscle stretching. Affirming these facts are the results of the scapular dyskinesis findings reported in the current study. These results are discussed in the section to follow.

The second and third findings of the study will be discussed together; as they are directly associated. The scapular dyskinesis observed in the current study confirms the argument of weakened scapular stabilisers. It was observed that on the non-dominant side, scapular dyskinesis was distributed significantly different (p=0.016) for the ideal and kyphotic posture participants. In the category of no dyskinesis, 20% was from the kyphotic posture group and 4.69% from the ideal posture. In the obvious dyskinesis category 90.63% was stemming from the ideal posture group and 73.75% from the kyphotic group. This finding suggests that scapular dyskinesis is present across all posture groups as it is a lack of functional scapular muscle control and not only postural position. The notion that people with ideal postures do not live with scapular dyskinesis is based on the idea that the scapular stabilising muscles are in balance and at their optimal function, which is in actual fact incorrect. The fact, that participants' that presented with a kyphotic posture, also presented with less dyskinesis indicate that you can have scapular muscle control even with a kyphotic posture as the participants in the study presented with a functional kyphosis (confirming the motor control principles as earlier discussed – meaning they have adapted to their environment). This indicates they were able to adapt to their posture with muscle control during active scapula movements. It can be argued that scapular dyskinesis is more of a muscle control issue than it is posture related. Alternatively, it may be due to the fact that patients may have presented with a kyphotic posture without a protracted shoulder girdle, which would have had an increased effect on the scapula positioning. The dominant side had no significant difference on levels of dyskinesis ($p=0.136$). However, it followed a similar presentation as the non-dominant side. This may be due to the fact that the dominant side is used more than the non-dominant side and presents with greater strength and control than the non-dominant side.

In the third finding, significant difference in PMI values was observed between the ideal and kyphotic posture groups. The kyphotic posture group had a shorter PMI than the ideal posture group (in all three testing positions) with statistically significant differences ($p<0.001$). These findings support one of this study's alternative hypotheses that states that there would be a difference between PM muscle length expressed as PMI values in students with ideal posture, compared to students with a kyphotic posture. The current study supports the findings of Hinman (2004:413-417) who reported that a kyphotic posture may result in an adaptive shortening of the PM muscle length. The current study affirms the findings by Borstad (2006:553) who found a correlation between PM muscle length and posture, namely kyphotic posture. The thoracic kyphotic index was statistically significant ($p=0.0504$). The thoracic spine index was calculated using the depth of the thoracic spine curve divided by the height of the thoracic spine curve (Borstad 2006:552). These findings fit biomechanical principles which have suggested that a thoracic kyphosis causes muscle imbalances in the upper body, causing upper crossed syndrome, with resulting shortening and tightening of the PM (Page 2011:256; Kim et al 2018:374). In the current study's population, the participants work in a kyphotic forward posture, with the shoulders slightly elevated anteriorly in approximately 45° of shoulder flexion. This sustained postural position causes rounded shoulders, which in the long run may cause an anteriorly tilted scapula. The anteriorly tilted scapula may subsequently cause shortening of the PM muscle and places the scapular stabilisers in a lengthened position. Regardless of all these factors, both ideal and kyphotic posture groups presented with scapular dyskinesis, as all the participants assume the same postural habits in their working environments. Therefore, as previously stated, it is not only individuals with a kyphotic posture that are susceptible to scapular dyskinesis but also individuals with an ideal posture. This once more may be attributed to the motor control principles of the scapular stabilising muscles, where the PM muscle length may be short but scapula movements are controlled.

The fourth finding of this study was the mean PMI values for the three testing positions which ranged between 10.00 and 10.79 (SD ranging from 0.66 to 0.71) for the dominant and non-dominant sides. The current study used a sample with a CI of 95%. Therefore, calculation of a short PMI in each position would be calculated using the mean – 2 SD. Thus, a larger sample was used, covering a general population. According to the results, a short PMI value at rest on the dominant side was 8.64 and on the non-dominant side 8.68. For the actively retracted position on the dominant side, a short PMI value was 8.84 and on the non-dominant side 8.87. For the passively lengthened position on the dominant side, a short PMI value was 9.32 and the non-dominant side 9.35. These PMI values differ to what is stated in previous literature. Borstad and Ludewig (2005:228) stated that a short PMI value at rest was less than 7.65 (mean (8.13) – 1 (0.48) SD). Furthermore, Borstad (2006:554) suggested a short PMI value at rest was 7.42 (mean – 1 SD, not provided) and Borstad (2008:173) stated that a short PMI value at rest was 7.44 (mean (8.24) – 1(0.80) SD). Even though Borstad in general, across studies, has provided guidelines regarding typical resting PM muscle length and has explicitly defined a short PM muscle length as well as a long PM muscle length, these values do not provide information about whether or not the PM muscle is shortened as the PM muscle is not measured in its optimum length (Finley et al 2017:216) because at rest the PM muscle length is not at its true reflection. Additionally, all Borstad's studies are not specific to dominant and non-dominant sides and used a sample of 68% CI, which uses a 1 SD. This finding is based on a very small population and is therefore not the best value to use. There are two reasons why the current study's PMI mean values differ from previous literature, firstly due to the CI (68% vs. 95%) and secondly the discrepancies in testing positions, techniques and equipment as discussed in Chapter 2. In the current study, the influences of the thoracic spine were eliminated by positioning the participants in supine. The influences of the biceps brachii passive insufficiency were also eliminated by positioning the participants' arms in elbow flexion, with hands resting on the abdomen. Therefore, the PMI values are larger because of the 2 SD and the elimination of postural influences and passive insufficiency of the biceps brachii.

The next finding to be discussed is the significant difference in PMI values observed between dominant and non-dominant sides. There was significant differences of the non-dominant side as compared to the dominant side, in all three positions ($p=0.004$). This may indicate that arm dominance plays a role in the length of the PM muscle in the population aged between 18 and 24 years. A contributing factor to these findings could be that all participants are students that actively attend classes. Therefore, the posture they adapt during class time and studying, as well as the posture they assume during practical working hours is dominance dependant and may have an effect on PM muscle length. These results correlate with the findings from the study done by Cools, et al (2010:682-683) and Mackenzie, et al (2015a:4) on tennis and golf players respectively. The results obtained from Cools, et al (2010:682-683) indicated that the PM muscle length of the dominant side proved to be significantly shorter than that of the non-dominant side ($p<0.001$). This could be due to the similarities in age groups, as the population from Cools, et al (2010:682-3) was adolescents between the ages of 12 and 15 years. It should be noted that a contributing factor to the Cools, et al (2010:682) results is that the participants were all tennis players. Tennis is a unilateral sport and it could explain the shortness on the dominant side. Another study which correlates with the current study's findings was conducted by Mackenzie, et al (2015a:4) which compared golfers to a controlled volunteer group who were not golfers. The results showed that the control volunteer group had a significant increase in the PM muscle length on the non-dominant side as compared to the dominant side ($p=0.01$). All participants were over the age of 18 years, which matches the age criterion of this study. On the other hand, the same study showed that male golfers had a significantly increased PM muscle length on the dominant side as compared to the non-dominant side (p=0.01). This could be attributed to the repetitive, unilateral use of the shoulder complex during a golf swing. Similar findings were observed by Struyf, et al (2014:296) on the non-symptomatic group, where the non-dominant side PMI value was longer than the dominant side (no p-value for dominance was provided as this was an inter-rater reliability study). All these results suggest that the PMI of a general population is longer on the non-dominant side as compared to the dominant side. According to biomechanical factors, these findings may be due to the fact that the dominant side is the strongest and most frequently used, therefore it is more susceptible to having a shorter PM muscle length than the less frequently used non-dominant side (Kendall et al 2005:npn). It should be noted that a distinct difference between the current study and existing literature is that in the current study measurements were done in three testing positions. In existing literature measurements were only done at rest and therefore not taking into account the entire PM muscle length. The current study and the two studies of Cools, et al (2010:681-683) and Mackenzie, et al (2015a:2-3) can only be compared for the resting position, as these two studies did not test in the actively and passively lengthened positions. Therefore, this current study has provided a valuable contribution to existing knowledge regarding PM muscle length being measured not only in the resting position, but also the active retraction and passively lengthened positions.

The final finding to be discussed is the significant difference in PMI values observed between males and females. There was a significant difference in the male PMI values as compared to the female PMI values (p=0.005). The male PMI values were generally larger in all three positions as compared to the female values. These findings support one of the study's alternative hypotheses stating that there would be a difference between the PM length expressed as PMI values in males, compared to females. Cools, et al (2010:682) had similar results, where the male PMI value was larger than the female PMI value (p=0.006) at rest. It can be presumed that a male PM muscle length is larger than a female PM muscle length because males generally have a bigger body mass and height than females. However, in the current study there were no significant differences when comparing each testing position between males and females (i.e. rest vs. rest, etc.). This shows that even though males have a bigger body build, the PM muscle length results between males and females are similar. This may also be attributed to the effect of scapular stabilisers lacking strength in the inner range hold.

The uniqueness of the current study lies with the measurement technique and positioning, as this study ensured the elimination of any postural influences and influences that may have been associated with the biceps brachii. The study also measured the PM muscle length in its entirety, in the three testing positions (resting, active lengthening and passively lengthened positions). This is a positive contribution to the physiotherapy fraternity, as the study has provided guidance in the management of shoulder dysfunction. The main finding of the current study is the difference between the actively and the passively lengthened positions. The other implication of the current study is the holistic approach in a complex joint like the shoulder girdle, meaning management of the shoulder girdle should not be only be focused on PM muscle length stretches but also include strengthening of the scapular stabilising muscles. Therefore, future research and analysis should not only focus on the length of a muscle, in this case the PM muscle, but should also focus on the agonist and antagonist synergy that should be evaluated.

5.2 **SUMMARY**

Ultimately these findings suggest that there is a relationship between PM muscle length and scapular dyskinesis, irrespective of an ideal or kyphotic posture. These findings support the study's alternative hypotheses stating there would be an association between PMI values and scapular dyskinesis in the ideal and kyphotic posture groups. To the researcher's knowledge, there are no studies that have explored the relationship between PM muscle length and scapular dyskinesis. The current study has therefore identified a gap in the existing literature (that needs to be further researched) with regards to a relationship that exists between PM muscle length and scapular stabiliser muscle function in the inner range hold. It has been made clear that PM muscle length at rest is due to habitual postural influences and the differences that exist between the active retraction and passively lengthened positions is due to decreased muscle function of the scapular retractors and stabilisers.

Chapter 6 will conclude the study. The main findings of the study and application of the findings will be summarised to give an overview of the dissertation.

6 CHAPTER 6: CONCLUSION

This chapter will provide the conclusion of the study and highlight the main aims and identified findings.

A short PM length has commonly been known to be a cause of shoulder dysfunction (Morais and Cruz 2016:1), especially in individuals with a kyphotic posture due to the rounded shoulder posture, which causes an anteriorly tilted scapula. The student population of this current study are Health Sciences students whose working environment requires them to adopt a kyphotic posture, as they perform tasks in a forward posture, with the shoulders in 45° flexion and shoulders rounded. Therefore, the cause of an anteriorly tilted scapula is vital for the treatment of shoulder dysfunctions that may arise in a student population.

The aims of the study were to assess scapular dyskinesis in relation to PMI values of students between the ages of 18 and 24 years, presenting with ideal and kyphotic postures; and to determine the PMI in three different testing positions, the resting position, the actively retracted position and the passively lengthened position of students between the ages of 18 and 24 years, presenting with ideal and kyphotic postures.

The most significant finding of this study was the differences between the resting and actively retracted positions, the resting and passively lengthened positions, as well as the actively retracted and passively lengthened positions, with a $p<0.001$ (Table 4.5). This may be attributed to weakness of the scapular stabilising muscles (lower trapezius and serratus anterior). These findings were supported by the presence of scapular dyskinesis in the population of the current study.

It was observed that on the non-dominant side, scapular dyskinesis was distributed significantly different ($p=0.016$) for the ideal and kyphotic posture participants, with majority of obvious dyskinesis in the ideal posture group (90.63%) as compared to the kyphotic posture group (73.75%). Contrary to this there were more participants in the kyphotic posture group that presented with no dyskinesis (20%) as compared to the ideal posture group (4.69%). The dominant side had no significant differences in the distribution of scapular dyskinesis (p=0.136). However, it followed a similar presentation as the non-dominant side, where the ideal posture group had more participants with obvious dyskinesis (85.94%), as compared to the kyphotic posture group (77.50%). Once more, there were more participants in the kyphotic posture group that presented with no dyskinesis (18.75%), as compared to participants with ideal posture (7.81%). The differences that exist between the dominant and non-dominant side may be due to the fact that the dominant side is used more than the non-dominant side and presents with greater strength than the non-dominant side. These findings however confirm the main findings of the study, as the results suggest that there is weakness of the scapular stabilising muscles (lower trapezius and rhomboids major and minor, and serratus anterior) in the inner range hold. Hence, the differences that exist between the actively retraced and passively lengthened positions. Furthermore, there were statistically significant differences found between the kyphotic and ideal posture groups (p<0.001). These findings indicate that posture has a direct implication on the PM muscle length. Even though participants in the kyphotic group had a shorter PM length than the ideal posture group, the results of the dyskinesis shows that motor control of the scapular stabilisers is present as the kyphotic posture group had a lesser occurrence of dyskinesis than the ideal posture group. Additionally, it should be noted that the misconception that individuals with an ideal posture do not present with scapular dyskinesis due to their muscles being at optimum function, has been disproved by the results. Scapular dyskinesis is present in both the kyphotic and ideal posture groups. Therefore, a gap in the existing literature has been addressed, as an association between the PM muscle length and scapular stabilising muscle function has been established.

There was a significant difference with the dominant and the non- dominant sides (p=0.004). The dominant side had a shorter PMI than the non-dominant side. This may indicate that hand/arm dominance has an effect on PM muscle length.

There was a statistically significant difference found between male and female PMI values. The male PMI was larger than the female PMI, which could be attributed to a larger body stature in males. However, even though the PMI values of men is larger than that of females, when comparing the three testing positions of the males and females with each other, there were no significant differences. This shows that even though men are bigger than females, their PM muscle lengths are similar.

All these findings prove that there is an association with PM muscle and scapular dyskinesis, irrespective of postural differences (ideal and kyphotic).

The PMI values from the present study (Table 4.4, Table 4.7 and Table 4.10) were different compared to those reported in previous literature. Furthermore, these PMI values cannot be compared to other studies as in those studies PMI was measured either only at rest, or in some cases at rest and in the active retraction position. There is only one study (Finley et al 2017:213-215) that performed measurements in the three testing positions. However, the PMI values cannot be effectively compared, as Finley, et al (2017:215-216) did not use the PMI when measuring PM muscle length and the Finley, et al (2017:213-215) study did not eliminate postural and biceps brachii influences.

The clinical contribution provided by this study is the positioning of participants and the measurement technique of PM muscle length. The participants were positioned in the supine position to eliminate postural influences of the thoracic spine on the PM muscle, as well as the elimination of influences that could be caused by the passive insufficiency of the biceps brachii on the coracoid process of the scapula. Therefore, the elbow was flexed and the arm positioned to rest on the abdomen. This technique ensures that there are no external factors affecting the length of the PM muscle. Furthermore, the gap in existing literature has been dealt with, as measurements of the PM muscle were done in three testing positions (resting, active retraction and passively lengthened) to make sure that the PM muscle length is measured in its optimum length.

Additionally, this study has provided the physiotherapy fraternity with baseline PMI values, with a 95% CI and 2 SD. This current study is part of a larger ongoing research project in which all the sub-studies will be following the same methodology in order to address the inconsistencies in the literature and provide baseline PMI values for different ages. As knowing the baseline PMI values for each age group will assist in knowing what a short PM length is across the different age groups. Therefore, management of the shoulder girdle complex across different age groups will be made more effective.

In conclusion, it has been suggested that PM muscle length has a direct impact on scapula alignment, which ultimately affects shoulder kinematics. The study has shown that it is not only the PM muscle that plays this role, but also potentially the stability that the scapular stabilisers (lower trapezius and serratus anterior) provides. There were two gaps identified in the current study, namely the association of scapular dyskinesis and PM muscle length, as well as the active retraction and passively lengthened testing positions of the PM muscle. These gaps have been addressed.

Recommendations and limitations for this study will be presented in Chapter 7.

7 CHAPTER 7: RECOMMENDATIONS AND LIMITATIONS

In this chapter, the recommendations and limitations of the study will be discussed.

7.1 RECOMMENDATIONS

From the study the following recommendations are made:

1. Test the PM muscle length in standing and in supine, with elbow flexed in resting, actively and passively lengthened positions; as standing is viewed as a functional position and the difference between the two positions will be of clinical value.
2. Test scapular kinematics (dyskinesis) in a symptomatic and non-symptomatic population, to see if there are any differences in the dyskinesis between the two groups.
3. Differentiate between kyphotic posture and protracted shoulder girdle, as the shoulder girdle has a larger effect on the scapula positioning. A person may present with a kyphotic posture without a protracted shoulder girdle.
4. Test muscle strength of the scapular stabilisers in a kyphotic posture versus ideal posture along with scapular dyskinesis, in order to obtain a true indication of the stabiliser muscle strength, as dyskinesis only evaluates scapular kinematics.
5. Ensure a better distribution of the sample population across the Faculty of Health Sciences to obtain a greater variety and more equal distribution in the sample, rather than the majority representing only one department.

7.2 LIMITATIONS

The following limitations were noted during the study:

1. The study did not differentiate between a kyphotic posture and rounded (protracted) shoulders, as a person may have protracted shoulders without a kyphotic posture and vice versa. The protracted shoulder girdle has a larger effect on the scapula positioning.

2. The study did not have an equal distribution of participants across the Faculty of Health Sciences. The majority of the participants were physiotherapy students as they were easily accessible during recruitment.
3. The study did not use a Stadiometer, which according to WHO guidelines is a more accurate means of measuring the height of participants.
4. The study did not exclude cervical pain, as cervical pain may have an influence on scapular dyskinesis.

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9 ANNEXURES

9.1 ANNEXURE A: PERMISSION LETTER FOR USE OF IMAGE

Mary E Magarey
PhD, FACP, FASMF
Specialist Musculoskeletal Physiotherapist
Specialist Sports & Exercise Physiotherapist
As awarded by the Australian College of Physiotherapists
Fellow of the Australian Sports Medicine Federation

Australian Specialist Shoulder Physiotherapy Education

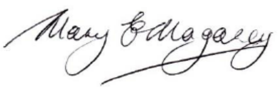
To Whom It May Concern

I give my permission for Muhle Komati to include the image of the force couples around the scapula, an image created for my own PhD work, from the paper:

> **Magarey, M.E., and Jones, M.A. 2003. Dynamic evaluation and early management of altered motor control around the shoulder complex. Manual Therapy. 8(4):195–206.**

For use in the thesis associated with his/her dissertation for the Masters degree at the University of Pretoria, provided it is appropriately cited.

Muhle Komati
BPhysT (UP)
OMT 1
0833134749
mamsemola@gmail.com



Dr Mary Magarey FACP, FASMF
Specialist Musculoskeletal Physiotherapist
Specialist Sports & Exercise Physiotherapist

3 South Terrace
Nuriootpa SA 5355

Email| mary.magarey@unisa.edu.au
Australia

9.2 ANNEXURE B: APPROVAL LETTERS FROM DEPUTY DEAN AND DEAN

16/03/2018

The Chair
Research Ethics Committee
Faculty of Health Sciences
University of Pretoria

Ethical approval for student research project

This serves to confirm that I am supportive of the following Master's of Physiotherapy student

Muhle Komati 24042847

who has applied for ethical approval for their project entitled:

PECTORALIS MINOR INDEX (PMI) RANGE AND SCAPULAR DYSKINESIS IN UNIVERSITY STUDENTS PRESENTING WITH A KYPHOTIC POSTURE AND IDEAL POSTURE

I have no objection to them requesting the Faculty of Health Science students between the ages of 18 and 24 to participate in the study by being physically assessed.

Kind regards

Prof D Manning
Deputy Dean: Education

16/03/2018

The Chair
Research Ethics Committee
Faculty of Health Sciences
University of Pretoria

Ethical approval for student research project

This serves to confirm that I am supportive of the following Master's of Physiotherapy student

Muhle Komati 24042847

who has applied for ethical approval for their project entitled:

PECTORALIS MINOR INDEX (PMI) RANGE AND SCAPULAR DYSKINESIS IN UNIVERSITY STUDENTS PRESENTING WITH A KYPHOTIC POSTURE AND IDEAL POSTURE

I have no objection to them requesting the Faculty of Health Science students between the ages of 18 and 24 to participate in the study by being physically assessed.

Kind regards

Prof C de Jager
Dean Faculty of Health Sciences

9.3 ANNEXURE C: RECRUITMENT POSTER AND FLYER

Are you a student between the ages of 18 and 24?
And you do not experience any shoulder pain?
If so, we invite you to participate in our study where we will be measuring the length of a muscle in the shoulder (Pectoralis minor muscle)

Your participation will be highly appreciated and it will add value to the appropriate Physiotherapy treatment of shoulder pathology.
10 minutes of your time will be required when you participate in the study. You will be at no risk and will not experience any discomfort during the assessment.
Participants will be required to wear shorts and bikini tops (females) and bare chested (males). Your privacy and comfort will be respected

For more information please contact me on 0833134749 (Muhle Komati) or Dr Elzette Korkie (Supervisor) on 0828901793
Venue of assessment: Physiotherapy Dept.
Date of assessment

9.4 ANNEXURE D: INFORMED CONSENT FORM

PATIENT OR PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

STUDY TITLE: Pectoralis minor index (PMI) range and scapular dyskinesis in University students presenting with a kyphotic posture and an ideal posture

Principal Investigator: Muhle A Komati

Institution: Department of Physiotherapy, University of Pretoria

DAYTIME AND AFTER HOURS TELEPHONE NUMBER(S):0833134749
Dear Participant

I hereby invite you to take part in our purposeful medical research study, as the information gathered from this study will help provide clarity for physiotherapists in evaluation and treatment of shoulder pathology. Many patients visit therapists because of shoulder or back pain caused by incorrect posture. The purpose of this study is to determine pectoralis minor muscle (shoulder muscle) length in the relaxed, actively and passively lengthened position and the correlation of scapular stabilisers- scapular dyskinesis (weakness of shoulder blade muscles) to pectoralis muscle length. This will improve the treatment standard provided by therapists in this field. This study may not directly benefit you as a participant; however, the long-term therapeutic benefit is of essence to you and to others with shoulder abnormalities or pain.

During the study, you will only be identified by a participant number and your name will not appear in any documentation. On the day of the study you will be required to wear shorts and undress your upper body (females must wear a bikini top). You will be allowed to wear a shirt as you travel in between stations. Screening for postural analysis and shoulder pain with be done prior to the measurements of pectoralis muscle length, height and weight are done. Thereafter markings will be made on your skin (front and back of upper trunk) with a skin marker (this will involve minimal physical contact by an investigator) in order for the investigator to perform the measurement. Only you and an investigator on each station (six stations) will be present inside the enclosed measurement area, with the exception of two investigators in the shoulder measurement station. The second investigator will assist with the passive lengthening of the shoulder muscle. With your consent, a video will also be taken to assess the movement of the shoulder blades while performing elevation of the arms with weights in your hands. Your face will not be included in the video to maintain your anonymous status. Furthermore, with your consent pictures will be taken throughout the stations, your face will be blurred out to maintain anonymity. The same number allocated to you from the demographics form will be written with a skin marker on your right arm. We can assure you that no participant will experience any discomfort or harm during this process. The video recording will be later assessed by the principal investigator and another qualified physiotherapist.

Your participation in this study is entirely voluntary, you are under no obligation to participate and you have the right to withdraw at any time without any penalty, even in the middle of a measurement. There is no foreseeable risk or discomfort that you will go through during the study. The process requires ten minutes of your time. This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

Note: The implication of signing the informed consent form means that any information derived from your participation may be used for publication by the researchers. Pictures and videos taken during your participation may be used in the thesis and publication documents. You will not be identified by name in any publication that comes from this study.

Note: For participants where scapular dyskinesis will be identified, an exercise leaflet will be emailed to them. Followed by a date that will be communicated to those participants for a free consultation.

If you have any questions about the study or are unsure about your participation please feel free to ask me, Muhle Komati on 0833134749.

Consent to participate in this study

I have read or had read to me in a language that I understand the above information before signing this consent form. The content and meaning of this information have been explained to me. I have been given opportunity to ask questions and am satisfied that they have been answered satisfactorily. I understand that if I do not participate it will not alter my management in any way. I hereby volunteer to take part in this study. I have received a signed copy of this informed consent agreement.

....	....
STUDENT NAME	DATE
....	....
STUDENT SIGNATURE	DATE
....	....
INVESTIGATOR'S NAME	DATE
....	....
INVESTIGATOR'S SIGNATURE	DATE
....	....
WITNESS NAME	DATE
....	....
WITNESS SIGNATURE	DATE

9.5 ANNEXURE E: DEMOGRAPHIC INFORMATION

Name and Surname	
Contact Number:	**Email address:**
Age:	
Registered course:	**Year of study:**
Sex ○ **Male** ○ **Female**	**Dominant Hand:** ○ **Left** ○ **Right**
○ **Average hours in class per day:** ○ **Average practical/clinical hours per day:** ○ **Average study time per day:**	
Do you experience any shoulder pain? ○ **Yes** ○ **No**	**Have you had any previous shoulder surgeries?** ○ **Yes** ○ **No**
Do you participate in any sport? ○ **Yes** ○ **No** **If yes, please complete bottom table**	

Sport	Once a week	More than once a week (specify number in brackets)	Level of participation. i.e. club, UP, National

Shoulder quadrant test: ○ **Yes, interferes with activities of daily living (ADL)** ○ **Yes, does not interfere with ADL** ○ **No**	
Participants weight	
Number allocated to participant:	

9.6 ANNEXURE F: WOLTERS KLUWER PERMISSION LETTER

RE: Kendall, F.P., McCreary, E.K., Provance, P.G., Rodgers, M.M. and Romani, W.A. Permissions Book R [ref:_00Dd0dixc._5000V1JqdjD:ref]

1 message

RLP - Book Permissions <permissions@lww.com> <permissions@lww.com> Fri, 28 Jun 2019 at 17:09
To: mamsemola@gmail.com <mamsemola@gmail.com>

Hello Muhle.

Thank you for contacting us. Your request to use the figures from p. 60 of Kendall: Muscles: Testing and Function with Posture and Pain 5e:

1. Ideal Plumb Alignment: Side View
2. Ideal Plumb Alignment: Back View

in your dissertation Pectoralis Minor Index (PMI) Range and Scapular Dyskinesis in University Students Presenting with a Kyphotic Posture and an Ideal Posture at the University of Pretoria is granted for both print and e-formats. Any posting online must be password protected, and we do not permit posting of our content to commercial/social media websites, such as ProQuest, YouTube, ResearchGate or Facebook.

I have attached a copy of our Terms and Conditions. Please consider those, and this email, your grant of permission. Thank you.

Sincerely,

Caren Erlichman

Caren Erlichman

Wolters Kluwer Permissions

Wolters Kluwer

Two Commerce Square

2001 Market Street

Philadelphia, PA 19103

www.wolterskluwerhealth.com

www.lww.com

9.7 ANNEXURE G: DATA COLLECTION SHEET FOR INDIVIDUALS

Resting PMI

Allocated Number	Plumbline Posture	Height (cm)	Pectoralis Minor Length									
			Left 1	Left 2	Left 3	Left Average	PMI Left	Right 1	Right 2	Right 3	Right Average	PMI Right

Active PMI

Allocated Number	Plumbline Posture	Height (cm)	Pectoralis Minor Length									
			Left 1	Left 2	Left 3	Left Average	PMI Left	Right 1	Right 2	Right 3	Right Average	PMI Right

Passive PMI

Allocated Number	Plumbline Posture	Height (cm)	Pectoralis Minor Length									
			Left 1	Left 2	Left 3	Left Average	PMI Left	Right 1	Right 2	Right 3	Right Average	PMI Right

9.8 ANNEXURE H: ETHICS APPROVAL LETTER

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

29/03/2018

Approval Certificate
New Application

Ethics Reference No: 114/2018

Title: PECTORALIS MINOR INDEX (PMI) RANGE AND SCAPULAR DYSKINESIS IN UNIVERSITY STUDENTS PRESENTING WITH A KYPHOTIC POSTURE AND AN IDEAL POSTURE

Dear Mrs Muhle Komati

The **New Application** as supported by documents specified in your cover letter dated 22/03/2018 for your research received on the 22/03/2018, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 28/03/2018.

Please note the following about your ethics approval:
- Ethics Approval is valid for 1 year
- Please remember to use your protocol number (**114/2018**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:
- The ethics approval is conditional on the receipt of **6 monthly written Progress Reports**, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

*** Kindly collect your original signed approval certificate from our offices, Faculty of Health Sciences, Research Ethics Committee, Tswelopele Building, Level 4-60*

____

Dr R Sommers; MBChB; MMed (Int); MPharMed,PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

☎ 012 356 3084 deepeka.behari@up.ac.za / fhsethics@up.ac.za http://www.up.ac.za/healthethics
✉ Private Bag X323, Arcadia, 0007 - Tswelopele Building, Level 4, Room 60 / 61, 31 Bophelo Road, Gezina, Pretoria

9.9 ANNEXURE I: DATA COLLECTION SHEET FOR STATISTICAL PROCESSING

Identity (ID)	Gender	Dominant hand	Shoulder pain	Height (cm)	Pectoralis minor length									
					Left 1	Left 2	Left 3	Left Average	PMI Left	Right 1	Right 2	Right 3	Right Average	PMI Right
1.	Male=0	Right=0	Yes=0											
2.	Female=1	Left=1	No=1											
3.														
4.														

*PMI= Pectoralis Minor Index

Please Note: there will be 3 of these tables for relaxed position, actively lengthened and passively lengthened positions respectively