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THE EFFECT OF SPINAL MOBILISATION WITH ARM MOVEMENT AND A MAITLAND MOBILISATION ON RANGE OF MOTION AND MUSCLE ACTIVITY IN OVERHEAD ATHLETES WITH SUBACROMIAL IMPINGEMENT SYNDROME – A RANDOMIZED CLINICAL TRIAL

IGNATIUS RICHARD

A dissertation submitted to the Faculty of Health Sciences, University of the Witwatersrand, in fulfillment of the requirements for the degree of:

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DECLARATION

I, IGNATIUS RICHARD, declare that this dissertation is my work. It is being submitted for Master of Science in Physiotherapy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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October 17,2022

DEDICATION

I dedicate this work to the almighty Lord with a humble heart.

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ABSTRACT

Background: After back pain and neck pain, shoulder discomfort is the third most common orthopaedic issue in Australia. The most frequent cause of shoulder pain is impingement syndrome, which is widespread in overhead sports activities. To treat shoulder discomfort, physiotherapists employ a variety of manual treatment approaches. According to certain researchers, there is a neurophysiological link between the shoulder and the cervical spine. However, there are not too many research that show how manual treatment in the neck may relieve shoulder discomfort. Establishing a connection between the shoulder and cervical spine can aid in a successful and quick recovery.

Purpose: This study aims to determine and compare any changes in shoulder muscle activity and range of movement (ROM) in relation to spinal mobilisation with arm movement and a Maitland technique in overhead athletes with subacromial impingement syndrome.

Method: Athletes from contact and non-contact sports were given an information sheet. Forty athletes were selected to participate in this study after obtaining the signed informed consent form. Ethical approval was provided by the Human Research Committee (HREC) of the University of Witwatersrand, and the protocol was registered in the Pan African clinical trials registry. Each participant completed a questionnaire comprised of personal, sports, and medical history questions. Apart from the questionnaire, participants also completed the Shoulder pain and Stability Index (SPADI) and Visual Analogue Scale (VAS).

Forty athletes were randomised and allocated into two groups, namely the Mulligan and Maitland group, and each group was equal to 20 participants. The group allocation was blindfolded to the researcher. The Electromyography (EMG), Range of Motion (ROM), and VAS scores were the outcomes determined before and after the mobilisations. Mulligan group athletes received the Spinal mobilisation with arm movement (SMWAM) technique on the painful side of C5/6, and the Maitland group received 30 PA oscillations on the painful side of C5/6 level. ROM was measured using the joint range of motion (JROM) 3D sensor and application, and the value was recorded in the data sheet. In addition, the EMG of upper fibres of trapezius, lower trapezius, and serratus anterior were recorded, and raw data were stored in a computer for statistical analysis.

Data were collected and managed in Microsoft Excel 2011 version. The researcher then exported and analysed the data using STATA software version 15. Data were not distributed normally, and non-parametric tests were used. The t-test was used to determine the changes in each group for the VAS, SPADI, ROM, and EMG scores. An ANOVA two-way repeated test was used to compare the difference between the groups over time. A p-value of the study was set at $p<0.05$ to establish a statistical significance.

Results: Each group was analysed separately, and both groups were compared. Apart from main outcomes (VAS, EMG, and ROM), demographic characteristics and SPADI scores were also analysed. There were no significant differences between the groups in age (p=0.4), gender(p=0.3) height (p=0.7) and weight (p=0.9). Data was analysed before and after the mobilisation. There were significant changes in VAS, EMG, ROM, and SPADI post mobilisation compared to pre mobilisation. However, no better technique could be found as the groups had no significant statistical difference. This study supports the neural relationship between cervical vertebrae and shoulder pain.

Conclusion:

This study found a reduction of pain, muscle activity, and increase of ROM in SAIS when mobilising the cervical region. Current medical practice has limited evidence regarding conservative management. However, mobilising cervical vertebrae could contribute to faster shoulder rehabilitation recovery. Both groups, Maitland and Mulligan, showed significant improvement in VAS, ROM, and muscle activity (p- 0.05). However, both techniques were compared statistically and found no significant differences.

Keywords:

Shoulder pain, SAIS, Shoulder impingement, SMWAM, EMG in SAIS

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LIST OF ABBREVIATIONS

ROM	- Range of movement
GHJ	- Glenohumeral joint
SAIS	- Subacromial Impingement Syndrome
EMG	- Electromyography
UT	- Upper Trapezius
SA	- Serratus Anterior
LT	- Lower trapezius
SMWAM	- Spinal mobilisation with arm movement
MWM	- Mobilisation with movement
PASS	- Patient acceptable symptom state
SMT	- Spinal manual therapy
AC	- Acromioclavicular
SC	- Sternoclavicular
STJ	- Scapulothroacic joint
SGHL	- Superior glenohumeral ligament
MGHL	- Middle glenohumeral ligament
IGHL	- Inferior glenohumeral ligament
FHP	- Forward head position
FSP	- Forward shoulder position
SHAM	- An alternative procedure mimics active procedure
SNAG	- Sustained natural apophyseal glide
MDF	- Median frequency
PROMS	- Patient-reported outcome measures
DASH	- Disabilities of Arm, Shoulder, and Hand questionnaire
SPADI	- Shoulder Pain and Disability Index
ASES	- American Shoulder and Elbow Surgeons
CS	- Constant Score
SST	- Simple Shoulder Test
OSS	- Oxford Shoulder Score
SDQ	- Shoulder Disability Questionnaire
WOSI	- Western Ontario Shoulder Instability Index
RCT	- Randomized clinical trial
WEC	- WITS education campus
JROM	- Joint range of motion
MVC	- Maximum voluntary contraction
RMS	- Root mean squared
MDC	- Minimal detectable change
MCID	- Minimum clinically important difference

Chapter 1: Introduction and scope of the research report

1.1 Introduction

Shoulder pain has been identified as one of the most common orthopedic complaints in sports in Australia. It is the third most common musculoskeletal disorder after back and neck pain (Bot et al., 2005). It has been found that shoulder pathology has a higher prevalence rate (p=.001) than any other athlete injury. The shoulder is a highly mobile joint, and in many sports, athletes are required to use extreme ROM (Laudner and Sipes, 2009). There is a high demand for stability and mobility on the rotator cuff muscles in overhead sports. This high demand leads to increased load in the joints and tendons involved and eventually causes tissue breakdown, resulting in overuse injuries (Gregory et al., 2009).

Overuse shoulder injuries are common in overhead sports such as baseball, tennis, rugby, bowling, swimming, basketball, and volleyball (Bedi, 2011). The most common cause of shoulder pain is the pathology of the rotator cuff tendons (Gomall et al., 2004), which commonly leads to impingement syndrome (Akuthota et al, 2004). In 44-65% of people with shoulder pain, the source was found to be impingement (Consigliere et al, 2018). A retrospective study reviewed 121 injured athletes and showed that 27% of the shoulder injuries sustained resulted in subacromial impingement (Laudner and Sipes, 2009).

The etiology of shoulder impingement syndrome is multifactorial and includes anatomical and mechanical causes such as scapular dyskinesia and postural abnormalities (Lewis et al, 2001). In 1972, Charles Neer presented his impingement theory. According to Neer, there are three hypotheses explaining impingement; they are: (a) sub-acromial (or) external, (b) sub-coracoid, (c) internal (or) posterosuperior impingement (Khan et al., 2013). Sub-acromial impingement (SAIS) is the most common type of impingement and can be further divided into primary and secondary impingement. Primary impingement is usually due to bursitis and tendinosis of the supraspinatus tendon, and if untreated, it may lead to a tendon tear (Gregory et al., 2009). Secondary impingement is characterized by compression and abrasion of the bursal side of the rotator cuff muscle, rotator cuff tendons, or long head of the biceps brachii beneath any aspect of the coracoacromial arch (Ludewig and Reynolds, 2009). Secondary impingement is more common among athletes below the age of 35 due to high-intensity training at a younger age (Rhon et al., 2011). Repetitive overhead movements are the most common cause for secondary impingement (Sorensen and Jorgenson, 2000) and can be further aggravated by biomechanical and anatomical variations in the glenohumeral joint (GHJ) (Ludewig and Cook 2002).

Neer, Hawkins, and Kennedy have described the diagnosis of SAIS. Several physical tests are used to test SAIS, such as the Horizontal adduction test, Yergeason test, Painful arc test, and the Drop arm test (Calis, 2000). A systematic review of five studies analysed the physical tests for impingement syndrome (Gumina et al, 2008, Lagnocco, 2003, Naredo, 2002, Calis, 2000 and visceral structures such as myocardial ischemia, pericarditis, or thoracic outlet syndrome (Stephen, 2000). Therefore it is essential to include a cervical examination and a thorough subjective examination to clear any symptoms of visceral dysfunction in patients with SAIS (Michael, 2005). This is supported byMacdonald et al, 2000). A total of 889 shoulders were examined, and it was concluded that the standard tests to diagnose SAIS are the Hawkins Kennedy test, Neer sign, and the Painful arc test (Hanchard et al., 2013,) and the reliability of these tests were acceptable for clinical use (Lori, 2009).

A research study (including two cases), Christiansen (2016) proposed that the cervical region should also be examined and taken into account as a possible factor contributing to SAIS. Wang and Meadows (2010) looked into the impact of C5/6 mobilizations on the strength of the shoulder's external rotator cuff. There were 18 participants in the research who now or previously experienced neck discomfort. The study found that changes in the shoulder external rotators strength were statistically significant ($p= .002$)

There are many therapeutic techniques widely practiced by physiotherapists concerning the shoulder, especially regarding SAIS. Passive mobilisations, such as the Maitland technique, are the most common manual therapy approach in physiotherapy practice (Judy, 2012). It has been found that spinal mobilisations activate mechanoreceptors and proprioceptors in the structures that are mobilised (Suter and McMorland, 2002). This may be due to possible activation of descending tracts of the supraspinal pathways (Sterling et al, 2001; Bialosky, 2009). Spinal mobilizations has also been found to influence sympathetic excitation by producing an immediate hypoalgesic effect in the shoulder area following the mobilization (Lluch, 2018). This may also affect the activity of the surrounding musculature.

Electromyography (EMG) may be used to measure and capture the electrical activity that skeletal muscles produce (Kotila, 2014). Increased upper trapezius (UT) muscle activity is the most prevalent and recurrent symptom in individuals with SAIS, according to a systematic evaluation of EMG in SAIS that included 11 studies with a total of 141 positive impingement cases and 138 control cases. Additionally, the activation of the supraspinatus, teres minor, serratus anterior (SA), anterior, and posterior deltoid muscles did not differ significantly across the groups (Chester et al., 2010). Another systematic review found that three out of six studies indicated increased UT muscle activity, while three out of five studies showed decreased activity. This study included 12 publications that incorporated EMG feedback in patients with SAIS and shoulder instability.

The change in muscle activity may be attributed to neurophysiological effects. Neurophysiological effects of pain are a potential source of positive outcomes in function and peripheral symptoms (Potter, 2005). The regional interdependence model describes how seemingly unrelated impairments in a remote anatomical region can contribute to or be associated with the patients' primary complaint (Wainer, 2007). Shoulder pain can be a misleading symptom as it may be a referred pain from the cervical region or pathology from a study by McClatchie (2009), who found cervical manual therapy to positively influence shoulder pain.

1.2 Problem statement

Only a few studies have investigated the effects of mobilisations (manual therapy) of the neck in patients with SAIS and have documented the instant effects on pain, muscle power, and range of motion (ROM) post-intervention. Spinal Mobilization with Arm Movement (SMWAM) is a manual therapy technique developed by Brian Mulligan, New Zealand, based on the neurophysiological concept of interconnection between the spine and limbs. According to the technique applying a transverse glide over the corresponding spinal level relieves pain, instantly increases ROM, and muscle strength of the painful shoulder movement (Mathur et al, 2017; Seo et al, 2015). A study of this Mulligan technique indicated that Mobilization with Movement (MWM) of the GHJ was effective in SAIS. MWM in this context can be described as applying an accessory mobilization to a joint while the patient performs an active physiological movement. MWM of the GHJ resulted in considerable improvement in flexion and external shoulder rotation ROM of the GHJ (Myers et al., 2015). Contrary to this study, a study using only unilateral Maitland grade 3 cervical mobilizations and followed up over the long-term (56 days), did not show any changes in pain, disability, rate of recovery, and patient acceptable symptom state (PASS) in participants diagnosed with SAIS (Cook et al., 2014). A study on 22 individuals using magnetic resonance imaging (MRI) showed that isometric contraction of the shoulder muscles and movement to 90 degrees of abduction is accompanied by ipsilateral rotation of the cervical vertebrae. This was explicitly observed at the level of the sixth cervical vertebra in relation to the abduction of the shoulder. This finding aligns with the Mulligan concept (Takasaki et al, 2009). However, the effect of this SMWAM technique has not been clinically tested in patients with SAIS to establish a possible effect on pain, ROM, and muscle activity.

1.3 Research question

What are the effects of SMWAM and a Maitland technique on pain, muscle activity of UT, LT, and SA, and shoulder abduction ROM in overhead athletes with SAIS?

1.3.1. Aim of the study

The study aims to compare the effects of a SMWAM technique to a Maitland mobilization technique on pain, muscle activity of UT, LT, and SA, and shoulder abduction ROM in overhead athletes diagnosed with SAIS.

1.3.2. Objectives of the study

1.3.2.1 To compare shoulder pain intensity in overhead athletes with SAIS before and after receiving SMWAM and Maitland mobilisation technique.

1.3.2.2 To compare the muscle activity of UT, LT and SA in overhead athletes with SAIS before and after receiving SMWAM and Maitland mobilization technique.

1.3.2.3 To compare the ROM of the GHJ in overhead athletes with SAIS before and after receiving SMWAM and Maitland mobilisation technique.

1.3.2.4 To compare the change in intensity of shoulder pain, ROM, and muscle activity between the two intervention groups.

1.4 Significance of the study

Treatment of SAIS is a growing demand as 50% of the population experience shoulder pain at shoulder pain is difficult owing to the complexity of the biomechanics of the GHJ and its possible interdependence on the cervical spine. SMWAM has been indicated as a treatment technique for neck pain, especially when the neck pain radiates to the extremity, such as the shoulder area affected in patients with SAIS. Establishing the effects of these manual therapy techniques in treating patients with SAIS will contribute to evidence-based practice.

1.5 Outline of the research report

Figure 1.1 provides a summary of the content that is to follow.

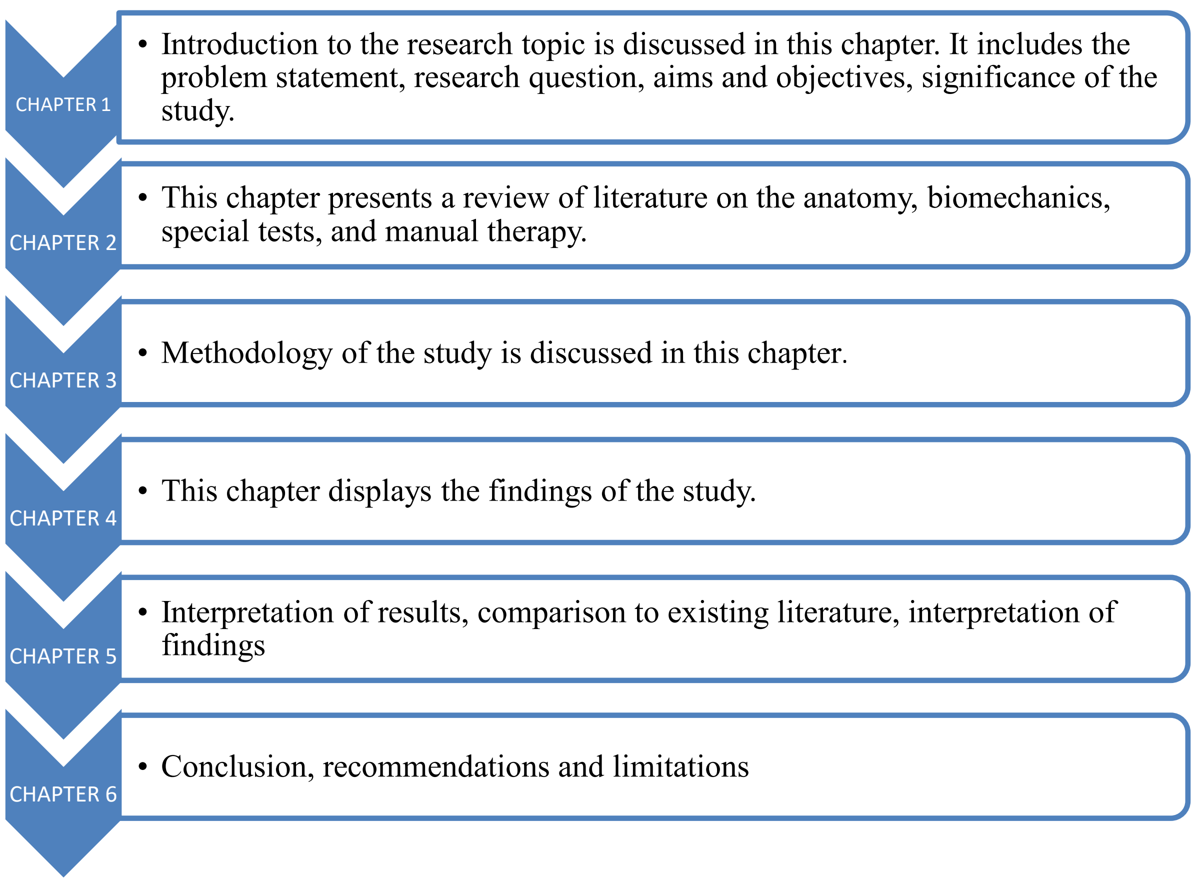


Figure: 1.1 – Outline of the research

Chapter 2: Literature review

2.1 Introduction

The research on subacromial impingement syndrome (SAIS) in athletes and the potential neurophysiological connection between the cervical spine and the glenohumeral joint is reviewed in this chapter (GHJ). The anatomy and biomechanics of the GHJ, as well as the causes and risk factors for SAIS, will be covered. Additionally, a variety of therapy options and evaluation techniques to gauge patients' muscle activity, function, and range of motion (ROM) will be reviewed.

Evidence was gathered from English-language papers published between 2000 and 2022 in online databases of sports medicine and scientific literature, such as PubMed, Cochrane, Science Direct, and Google Scholar. Keywords used in the search were shoulder impingement, impingement syndrome, subacromial impingement, spinal neurophysiology, neural pain theory, rotator cuff injury, shoulder pain, Electromyography (EMG) in impingement syndrome, manual therapy, Maitland, SMWAM, mobilisation with movement (MWM), spinal manual therapy (SMT).

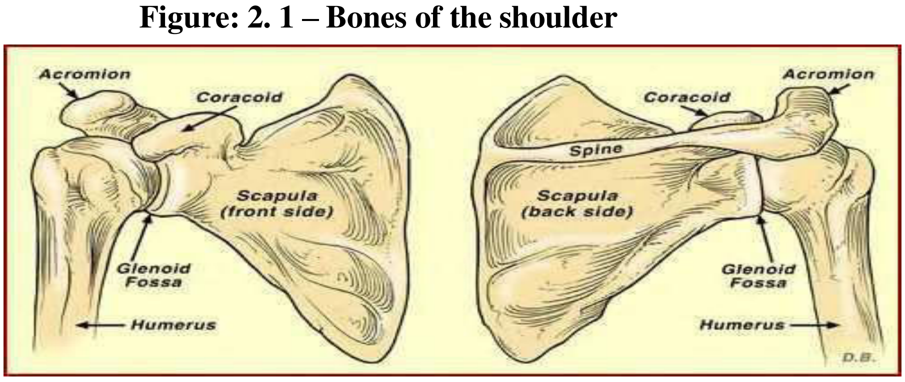
2.2 Anatomy and biomechanics of the shoulder joint

The shoulder complex is the most mobile part of the human body, with anatomy and biomechanics that allow extensive ROM while providing stability for the upper lim(Niyetkaliyev et al, 2017).

2.2.1 Anatomy

The shoulder girdle consists of three bones: the clavicle, scapula, and humerus (Figure 2.1), four joints (Figure 2.2), the acromioclavicular (AC), sternoclavicular (SC), glenohumeral joints (GHJ), (Khan et al, 2013), and scapulothoracic joint (ST) (Stryuf, 2014). Shoulder muscles are divided into the large muscles like the pectoralis major and deltoid; and small muscles like the rotator cuff muscles. Rotator cuff muscles provide considerable support to the GHJ (McCausland, 2020).

Figure: 2. 1 – Bones of the shoulder



(https://scienceaid.net/Bones of_the_Shoulder_Arm_and_Hand)

The GHJ is the most mobile joint in the body (Khan et al, 2013). The humeral head lies within the glenoid fossa to form the ball and socket joint. The shallow nature of the glenoid fossa provides little stability to the shoulder during movement. The shallow glenoid cavity can accommodate only 30% of the surface area of the humeral head (Pandya et al, 2018). Therefore, the GHJ relies primarily on static and dynamic stabilisers throughout the movement due to the small glenoid labrum and fossa relative to the large head of the humerus (Cunningham and Ladermann, 2017; Terry and Chopp, 2000).The ACJ is a plane synovial joint that connects the acromion of the scapula to the clavicle. The coracoclavicular ligament is the primary stabiliser, and further stability is provided by the superior and inferior acromioclavicular ligaments (Miniato et al, 2020).The SCJ is the only joint in the shoulder complex which connects the upper limb and axial skeleton. The clavicle and manubrium sterni connect at this joint and are further stabilised by the costoclavicular ligament (Miniato et al, 2020).

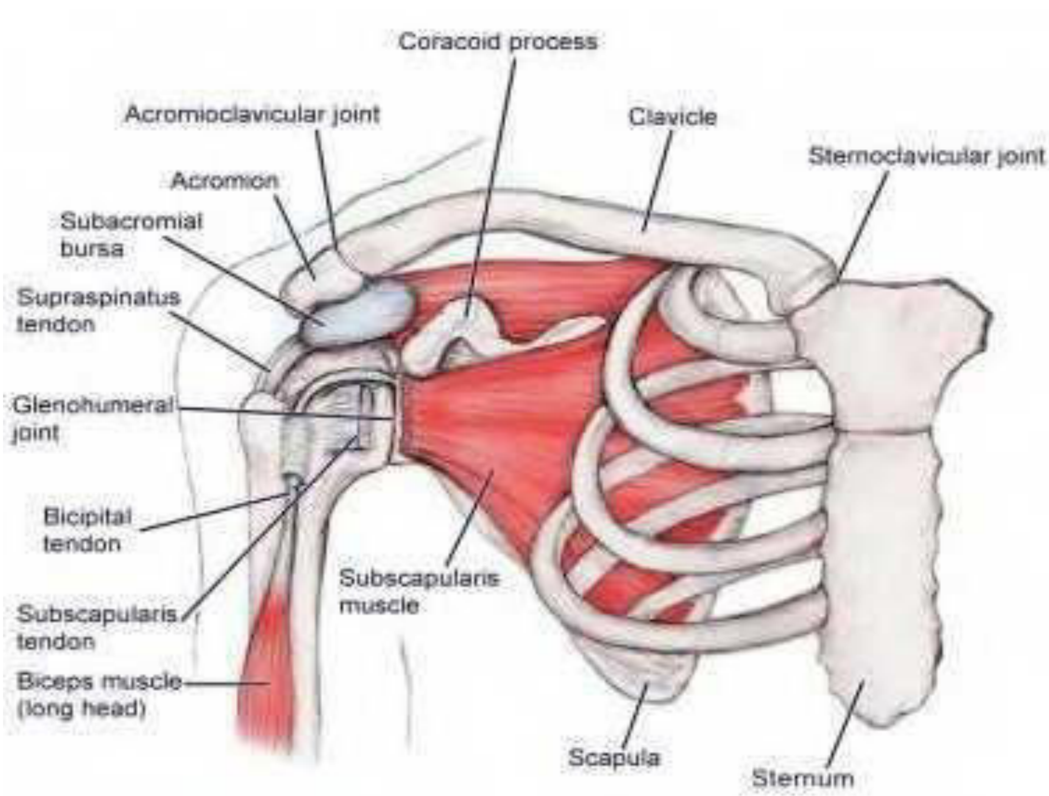


Figure: 2. 2 – Shoulder joint
(https://emedicine.medscape.com/article/1899211-overview)

The STJ is not a true joint. The STJ articulation represents the anterior concave scapula and convex posterior thoracic cage (Terry and Chopp, 2000). The STJ makes the shoulder a closed kinematic chain by constraining the scapula to move over the thorax (Niyetkaliyev et al, 2017). The scapula plays avital role in GHJ function. Movement in the STJ is vital as it moves along with the GHJ throughout the shoulder ROM. The STJ also elevates the acromion from the moving rotator cuff to prevent SAIS. The STJ is the link between the upper and lower segments of the kinetic chain and transfers the high energy and strong forces from the proximal to the distal segments (Forthomme et al., 2008). The static stabilisers include the glenoid labrum, joint capsule, and ligaments (Terry and Chopp,

2000) and provide passive stability to the GHJ (Stryuf, 2014). The glenoidal labrum is a fibrocartilaginous rim and increases the depth of the glenoid cavity. The shoulder capsule provides further passive stability through the superior glenohumeral ligament (SGHL), middle glenohumeral ligament (MGHL), and inferior glenohumeral ligament (IGHL) (Cunningham and Ladermann, 2017). However, during repetitive overhead actions, especially in overhead athletes, the static stabilisers can become hyper-elastic, leading to shoulder instability resulting in SAIS (Di Mario, 2004).

Due to the restricted function of static stabilisers , the shoulder significantly relies on its dynamic stabilisers. The intricate interaction of muscle forces managed by the proprioceptors feedback process within the capsule and surrounding soft tissues is how the dynamic stabilisers offer stability (Kit, 2018). The rotator cuff (Supraspinatus, infraspinatus, subscapularis and teres minor) ,periscapular (pectoralis minor, serratus minor and rhomboids), biceps brachii, latissmus dorsi and trapezius muscles as well as other muscles make up the dynamic stabilisers (Cunningham and Ladermann, 2017). The rotator cuff muscles attach to the proximal humerus from the scapula (Vollans, 2016). The humeral head is compressed into the glenoid fossa during shoulder abduction, strengthening the stability of the functional shoulder (Pandya et al, 2018). The periscapular muscles support the scapula.

2.2.2 Biomechanics of the shoulder joint

The shoulder requires basic mechanical characteristics such as stability, mobility, ROM, and strength for normal functioning (Kontaxis and Johnson, 2009). Especially shoulders of the overhead athletes need effective stability and mobility mechanisms to perform repetitive overhead shoulder movement (Borsa et al, 2008). The scapula is part of the foundation of shoulder movements as it maintains the length-tension relationship (Cook et al, 2014). The glenoid fossa of the scapula acts as a socket in the ball and socket joint. However, compared to the hip joint, the glenoid cavity provides less support in terms of stability (Brox, 2003). The primary role of the scapula is to move in coordination with the humerus throughout the ROM of the upper limb. The scapula keeps the glenoid positioned under the head of the humerus in conjunction with the rotator cuff muscles, which centres the head of the humerus (Kibler et al, 2003). This coordination is important in sports where the demand on the shoulder is exceptionally high, and the quality of movement depends onthe interaction between the scapula and GHJ (Forthomme, 2008). The scapula position is critical inshoulder abduction from 80° to 140°, as this is the ROM where most patients with SAIS experience pain (Brox, 2003).

The functional or dynamic stability is provided by dynamic stabilisers (Park et al, 2015), which simultaneously helps the shoulder to reach the greatest ROM (Glenn, 2000). At rest, the static stabilisers provide stability (Brian, 2019). The stability of the shoulder joint largely depends on the dynamic stabilisers, and dysfunction of these stabilisers can lead to various shoulder pathologies, such as SAIS (Ellenbecker and Cools, 2010). The moment produced by each muscle destabilizes the joint at a particular range or magnitude, but the controlled action of the dynamic stabilizers provides the joint with stability throughout the ROM (Park et al, 2015). It is the impaired or uncoordinated function of the shoulder muscles that can influence the function of the shoulder complex (Struyuf et al., 2014). Rotator cuff muscles impart dynamic stability, especially the balance between the subscapularis anteriorly and the infraspinatus posteriorly, often referred to as the rotator cuff force couple. The force couple function of the rotator cuff is critical to maintaining concavity compression and concentric rotation of the humeral head (Fuller et al, 2011).

The role of SA in relation to every fibre of the trapezius during scapular rotation also affects the humeral head's position (Mcmullan, 2003). The shoulder abduction coupling force is created by the UT and SA muscles (Kibler et al, 2003). The scapula's proximity to the thorax affects the force coupling action's optimal length-tension relationships, particularly for the SA and trapezius (Moeller et al, 2014). The scapula rotates upward over the thorax during routine shoulder motions when the arm is raised in flexion, abduction, or scaption (McClure et al, 2001). Reduced upward rotation and posterior scapular tilting are typical symptoms of dysfunction, which narrow the subacromial space and exacerbate SAIS (Myers et al, 2006; Shah et al., 2017).

The subacromial space is formed by the humeral head inferiorly, the anterior edge, and under the surface of the anterior third of the acromion, the coracoacromial ligament, and the acromioclavicular joint superiorly (Michener et al, 2003). The subacromial space is also known as the supra-humeral space or supraspinatus outlet (Di Mario, 2005). The subacromial space contains the tendons of the rotator cuff (supraspinatus, infraspinatus, and teres minor), the long head of the biceps, and the subdeltoid/acromial bursa.

A reduction in the subacromial space width is a predisposing factor in the pathogenesis of impingement syndrome (Michener et al, 2003). Normally the height of this space in adults with no shoulder pathology is between 9 and 10 mm. A reduction in subacromial space results in the impingement of the subacromial structures and further compression of the humeral head against the acromion, causing irritation of pain-producing structures creating shoulder pain syndromes (Di Mario, 2005). In addition, the movement of shoulder abduction reduces the subacromial space and the centering of the humeral head in relation to the glenoid cavity of the scapula (Von Eisenhart-Rothe et al, 2005).

It has been discovered that strengthening the shoulder adductors will widen the subacromial gap, reducing the friction between the structures (Walther et al, 2004). Schmitt and Di Fabio (1999) observed that athletes and younger adults with SAIS had a relative decrease in the subacromial space. The subacromial space is diminished as the GHJ is rotated and abducted. The rotator cuff tendons will be squeezed during these movements if the space is yet further limited by internal disease (Khan et al, 2014).

2.2.3 Biomechanics of cervical segment in SAIS

Many studies have been published about thoracic vertebral structure and function in relation to SAIS, but few studies explain about cervical spine biomechanics and SAIS. Cervical spine mechanics is complex and unique in nature. There is strong muscular, neural interconnection between the cervical area and shoulder. The Suprascapular nerve (C5,C6) starts at the superior trunk of the brachial plexus and crosses the suprapinatus fossa obliquely and enters into the infraspinatus fossa. Research studies have indicated a relationship between the cervical spine and shoulder pain. Position and mobility of the cervical spine influence glenohumeral and scapular kinematics, thereby developing SAIS (Michener, 2003). FHP and FSP are greatly contributed by the position of the cervical spine, which contributes to muscular imbalance and thereby contribute to the development of SAIS. Cervical radiculopathy has been found to be the main reason for shoulder pain and 63.6% of SAIS has been found to test positive to cervical radiculopathy (Walker, 2019)..

2.3 Common shoulder injury in sports

Shoulder pain is one of the most common reported orthopedic complaints in clinics and the third most common reported musculoskeletal condition in adults (Picavet and Schouten, 2003). Shoulder pain is a prevalent complaint in many athletes and could be a career-destroying factor (Bedi, 2011; Di Mario, 2004). A study also found that 8 to 13% of all sports injuries are shoulder injuries; however, the study stated that not all sport injury rates could be recorded as most of them are treated by the team`s medical team or at walk-in clinics (Rogelio, 2015). Another study reported an incidence of shoulder pain in 66% of swimmers, 57% in pitchers, 44% in volleyball players, and 29% in javelin throwers (Pink and Tibone, 2000). In a survey completed by swimmers in the United States of America (USA) Olympic team, 66% (n= 42) reported shoulder pain (Scott, 2005).

Another survey on swimmers between the age of 13-25 found 91% of the sample to have shoulder pain (n=80) (Sein et al, 2010). Contradicting to Sein`s findings, another study revealed that less than 5% (n=55) were referred for shoulder MRI during the Olympics of 2016 from the 11274participants (Murakami et al, 2018). However, a survey among 140 college athletes found SAIS is the most common reported complaint, with 27.1% (p=.001) among shoulder injuries compared to other shoulder pathologies listed in Table 2.1 (Laudner and Sipes, 2009). Although shoulder pain can be associated with many clinical conditions such as Bankart lesions, glenoid, or Hill-Sach lesions (Kit, 2018), it was found that in 75% of patients with rotator cuff pathology, there was an underlying impingement (Morison et al., 2000). It is thought that shoulder impingement, a frequent problem, aids in the rotator cuff disease's development or progression (Michener et al., 2003). Potential reasons for the onset or progression of rotator cuff illness exist in all kinds of impingement (Soslowsky et al., 2002).

Table: 2.1 – Incidence of Common Shoulder Injuries in College Overhead Athletes (Laudner and Sipes, 2009)

Shoulder injury	(n=140)	Percentage (%) of Total Shoulder Injuries
Subacromial Impingement*	38	27.1%
Rotator Cuff Tendonitis*	34	24.3%
Biceps Tendonitis	17	12.1%
Periscapular Strain	13	9.3%
SLAP Lesion	11	7.9%
Anterior Instability	11	7.9%
Acromioclavicular injury	10	7.1%
Multi-Directional Instability	4	2.9%
Pectoralis Major Strain	2	1.4%

Shoulder impingement is an umbrella term with multiple causes and multiple diagnoses (Cid, 2018). There are several kinds of impingement, including subacromial or external impingement and internal impingement, which is further split into anterior, posterior, and coracoid impingement. (Ludewig at al, 2011). Primary or internal impingement can be due to intrinsic factors such as bony abnormalities or trauma and is common among older patients. Subacromial impingement syndrome (SAIS) is a common condition among overhead athletes where repetitive overhead activity may be the main causative factor (Khan et al, 2013). Generally, overhead activities increases the risk of SAIS in athletes who use the arm repetitively above 90 degrees in the horizontal plane. Athletes' training usually relate to their respective field of practice and weight training, where repetitive movements are common. Exercises such as shoulder press and throwing of a medicine ball include repetitive shoulder abduction above 90 degrees and place the shoulder under strain. These athletes therefore more commonly develop SAIS. However, the cause of SAIS can be multifactorial and often involves impaired rotator cuff function (Steven, 2016).

2.4 Causes and risk factors of SAIS

Subacromial impingement syndrome is an encroachment of subacromial tissues in the subacromial space (Michener et al, 2003). Pain, stiffness, and decreased range of motion (ROM) are the symptoms of SAIS due to the narrowing of the space (Keenan et al, 2016). Different theories suggest different factors leading to the narrowing of the subacromial space. However, factors contributing to SAIS are broadly divided into intrinsic and extrinsic factors.

2.4.1 Intrinsic factors

Intrinsic factors are degenerative changes due to age, overuse, trauma, muscle tension, or overload of the subacromial structures, which leads to possible full or partial rotator cuff tendon tears resulting in SAIS (Michener et al, 2003).

2.4.2 Extrinsic factors

Mechanical compression of the supraspinatus tendon by bony (inferior surface of acromion), ligament (coroco-acromial ligament), and joint (acromioclavicular joint) factors classifies as extrinsic factors. Therefore, extrinsic factors can be due to anatomical factors, an abnormal rotator cuff, dysfunction of the scapular musculature, and poor posture (Michener et al, 2003). Examples include mechanical and anatomical factors like rotator cuff overuse/tendinopathy, instability/hypermobile, restricted glenohumeral capsule, and functional scapular kinetics (Lewis, 2001). Irrespective of the underlying reason, postural dysfunction of the upper body (i.e., alteration in the alignment of the head, neck, shoulders, and thoracic spine) has been suggested as one of the key underlying factors to be associated with the development of SAIS (Alizadehkhaiyat et al, 2017).

Narrowing of the subacromial space brought on by abnormal upper body posture, such as increased thoracic kyphosis and forward shoulder position, results in the development of SAIS (Lewis, 2005). The forward head position (FHP) and forward shoulder position (FSP) can affect the shoulder kinematics , resulting in alterations in the subacromial space's pressure and compression (Ludewig et al, 2000). Scapular or clavicular dysfunction , soft tissue tightness, muscular weakness or soft tissue imbalances, muscle exhaustion or thoracic kyphosis all affect how the GHJ functions (Ludewig et al, 2011). Possible cervical dysfunction is connected to such altered muscle function and poor thoracic posture (Pheasant , 2016).

2.5 Diagnosis of SAIS

The SAIS is common in clinical presentation, and it is important to differentiate SAIS from other shoulder pathologies (Koester et al, 2005). A wide range of outcome measures is available to assess individuals with shoulder disorders (Roy et al, 2009). A structured physical examination usually includes a battery of special tests in diagnosing specific pathologies (Khan et al., 2013). Various special tests are available to test SAIS, including the Hawkins-Kennedy test, Neer's test, and Jobe's test. In identifying SAIS, the Hawkins-Kennedy test is more sensitive (72.2%), and Neer's test is more specific (95.3%) (Fodor et al., 2009; Calis , 2000). A meta-analysis ofthe Hawkins-Kennedy and Neer's test showed a sensitivity of 79% and 53%, respectively, and specificity of 79% and 59%, respectively (Hegedus et al, 2008). A combination of eight clinical tests concerning various degrees of SAIS have also been investigated in 1127 patients and indicated the painful arc sign to be the most sensitive test (73.5%) (Park et al, 2006). The sensitivity of the painful arc test has also been established by Lori (2009) as .75 (95% CI [.54,.96]) and specificity as .67 (95% CI [.52, .81]), (Michener et al , 2009).

Three tests were therefore identified for this study based on their validity. Their execution, interpretation, validity, and reliability are discussed further below.

2.5.1 Hawkins-Kennedy Impingement test

The examiner elevates the patient's arm to 90° with the elbow in 90° of flexion and forcefully internally rotates the arm (Figure 2.3). The test is positive if pain occurs with internal rotation (Park et al., 2005).

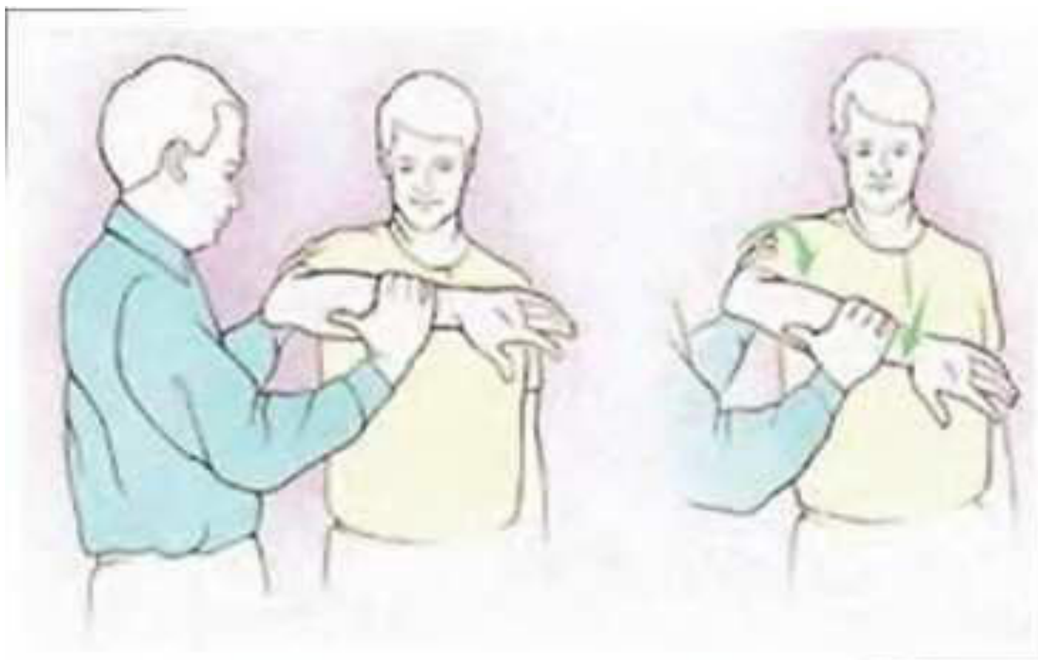


Figure: 2. 3-Hawkins-Kennedy test

(http://www.dramrajani.com/Shoulder/subacromial-decompressionimpingement.html)

2.5.2 Neer’s test

With the patient in the seated position, the examiner stabilizes the scapula with one hand and forces the patient's arm into maximal elevation with the other. The test is positive if the pain is produced (Figure 2.4) (Hegedus et al, 2008).

Figure: 2. 4 **-Neer’s Impingement Sign**

(https://sites.google.com/site/anatomicalportfolio/the-shoulder/shoulder- assessment/neers-test)

2.5.3 Painful-arc test

The patient might either be seated ot standing throughout this examination (Figure 2.5). The patient's arm is rotating freely. Patient may fully the arm in scapular plane . If pain or discomfort felt between 60° and 120° of abduction, deemed positive for supraspinatus impingement. After 120 degrees of abduction, pain should diminish. Acromioclavicular joint dysfunction is indicated by pain at the conclusion of abduction. The Painful arc test for SAIS is considered a fairly accurate test. During the Painful arc test, some patients will move the hand more to the sagittal plane due to pain; some may experience pain from start to mid-range, while some will experience pain while bringing their arm down to neutral (Garving et al, 2017).

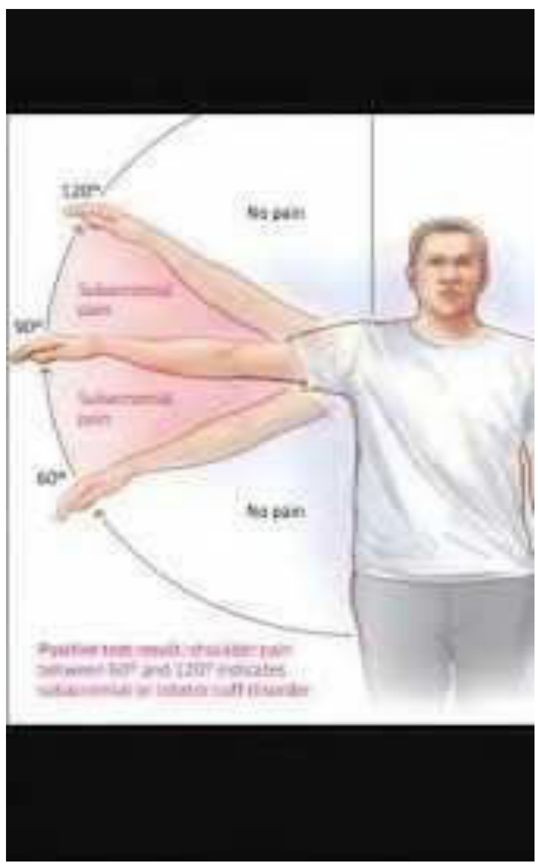


Figure: 2. 5 - Painful-Arc test

(http://dwomlink.info/painful-arc-test.html)

2.6 Manual therapy in shoulder impingement syndrome

Anti-inflammatory medication and physiotherapy are the first choices of treatment for SAIS. Physiotherapy interventions usually consist of manual therapy and exercises (Jose, 2015). Manual therapy is an effective method for reducing pain and increasing ROM (Bae, 2006). A survey regarding evidence-based treatment methods for SAIS conducted among Dutch-speaking physiotherapists revealed that manual therapy is the second preferred choice of treatment after exercise therapy in patients with SAIS (94.1%, n=112). Cervico-thoracic mobilization is the third preferred choice of treatment (73.1%) after GHJ (87.4%) and Scapulothoracic (84.0%) mobilisation (Struyf et al, 2012). Several studies have assessed the effectiveness of various therapeutic procedures aimed towards improving mobility and functionality of the shoulder in SAIS. Among a variety of conclusions, joint mobilization and therapeutic exercises are highly recommended (Michener et al., 2004; Sauers, 2005; Hidalgo- Lozano et al., 2011). Physiotherapists practice different manual therapy techniques in treating patients with SAIS, but the most effective method is still unclear (Michener et al., 2004). Dysfunction of the cervicothoracic region can predict the recurrence and poor outcome of shoulder pain (Agrawal et al, 2020). Physiotherapists often use cervicothoracic manual therapy techniques to treat upper quarter dysfunction and a systematic review supports short term effectiveness of cervicothoracic mobilisation in reducing pain and improving function (Schenk, 2021). In supporting the possible neurophysiological effect of cervical mobilization in SAIS, the SMWAM technique was studied in patients diagnosed with cervical radiculopathy (Pragassame, 2021) and Maitland mobilization on cervical vertebra in relation to shoulder pain (Agrawal et al, 2020). Both techniques are widely known manual therapy techniques apart from soft tissue mobilisation and neural techniques.

The two specific techniques relevant to this study are the Mulligan and Maitland techniques discussed below.

2.6.1 SMWAM technique

Mulligan is a manual therapy technique that differs from other manual concepts. Most manual therapy techniques require the patient to remain in a stable position like lying or sitting, while Mulligan's concept entails facilitation of the accessory movement at the joint when the patient actively moves the joint through the painful or offending movement. Different forms of spinal and peripheral mobilisations have been studied in patients with SAIS. MWM is a Mulligan technique indicated in shoulder pain associated with restricted or painful shoulder movements. The MWM was compared with another form of manual therapy technique (SHAM) in patients with SAIS. The MWM is a technique where the postero-lateral glide over the humeral head is maintained while combined with active shoulder flexion and SHAM, defined as an inactive treatment or procedure intended to mimic as closely as possible a therapy (placebo therapy). MWM is more effective than SHAM in relieving pain and achieving pain-free ROM in shoulder flexion and abduction

(Jose, 2015). Another study found SHAM techniques to produce an instant effect on shoulder ROM compared to MWM techniques (Joao, 2016). Both of these studies recorded the outcomes over four sessions and had different conclusions. However, both studies did find that the techniques had no effect on pain intensity.

Figure: 2. 6 - SMWAM technique

(Exelby, 2002)

The SMWAM (Figure 2.6) is another Mulligan technique utilised when patients present with pain over the periphery with possible spinal origin. SMWAM technique is a sustained transverse glide applied and maintained towards unaffected side. Adding painful or restricted shoulder movement further mobilise the neural tissues (Pragassame, 2020). When SMWAM was used in patients with mechanical neck pain, there was an improvement in pain and disability scores ($p<0.0142$) (Chaudhery and Dabholkar, 2017). Furthermore, after SMWAM was applied to the C4 spinous process, there was an increase ($p<0.05$) in muscular strength of the shoulder flexors, extensors, and abductors (Seo et al, 2015).

Sustained natural apophyseal glides (SNAGs) are also Mulligan techniques and the application of a SNAG over the thoracic level (T-7) of the spine in patients with SAIS has been found to have statistically insignificant changes in pain during shoulder abduction. However, shoulder flexion [Wilk's Lamba=.512, $F(2,4)=1.90$ $p<.05$, ηp 2=488, power=.212] and external rotation [Wilk's Lambda=.482, $F(2, 4)=2.14$, $p<.05$, ηp 2=.518, power=.233] demonstrated moderate effects (Andrews, 2018).

2.6.2 Maitland technique

The Maitland technique (Figure 2.7) is an extensively used manual therapy treatment and assessment technique. C5-6 unilateral mobilisations show good intra-tester reliability between shoulder external rotator strength and foramen length measurement (ICC 3,2=0.985). Post hoc tests revealed a significant increase from pre-joint mobilisations to immediately post-joint mobilisations in shoulder external rotator strength (p=.003). Similar findings applied to pre-joint mobilisations compared to 10-minute post-joint mobilisation measurements (p=.001) (Wang and Meadows, 2010).

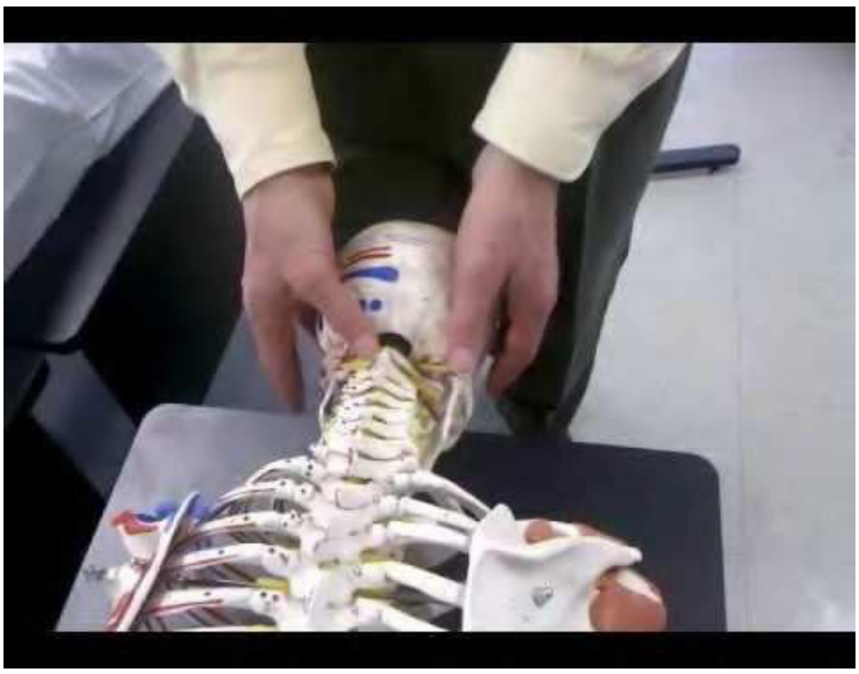


Figure: 2. 7 - Maitland technique

(http://broksitynumben.blogspot.com/2018/12/cervical-neck-ache.html)

2.7 Electromyography

Due to the effects of manual mobilisations on muscle strength and activity, it would seem appropriate to investigate these effects in research. Electromyography (Figure 2.8) is commonly used to quantify muscular activity and fatigue by employing a lower-frequency shift during sustained sub-maximal contraction and the use of a median frequency (MDF) slope as a fatigue index (Hawkes et al., 2015). Excessive activity of the upper parts of the trapezius muscle combined with reduced activity of the lower parts is a common finding among the general population of patients with neck and shoulder disorders, particularly those with SAIS (Chester et al., 2010; Cools et al., 2007; Ludewig and Cook, 2000). Compared to the non-affected shoulder were longer latencies of muscle activation in the affected shoulder in UT, MT, LT, and SA muscles in patients with SAIS (Moraes et al., 2008). Individuals with impingement syndrome presented significant delays in the recruitment of scapular muscles, indicating alterations of dynamic neuromuscular balance (Moraes et al, 2008). When participants with SAIS performed shoulder abduction, there was less EMG activity in the SA *(p*=0.03) compared to the UT, which showed more significant EMG activity (*p*=0.09) (Diederichsen et al, 2009).

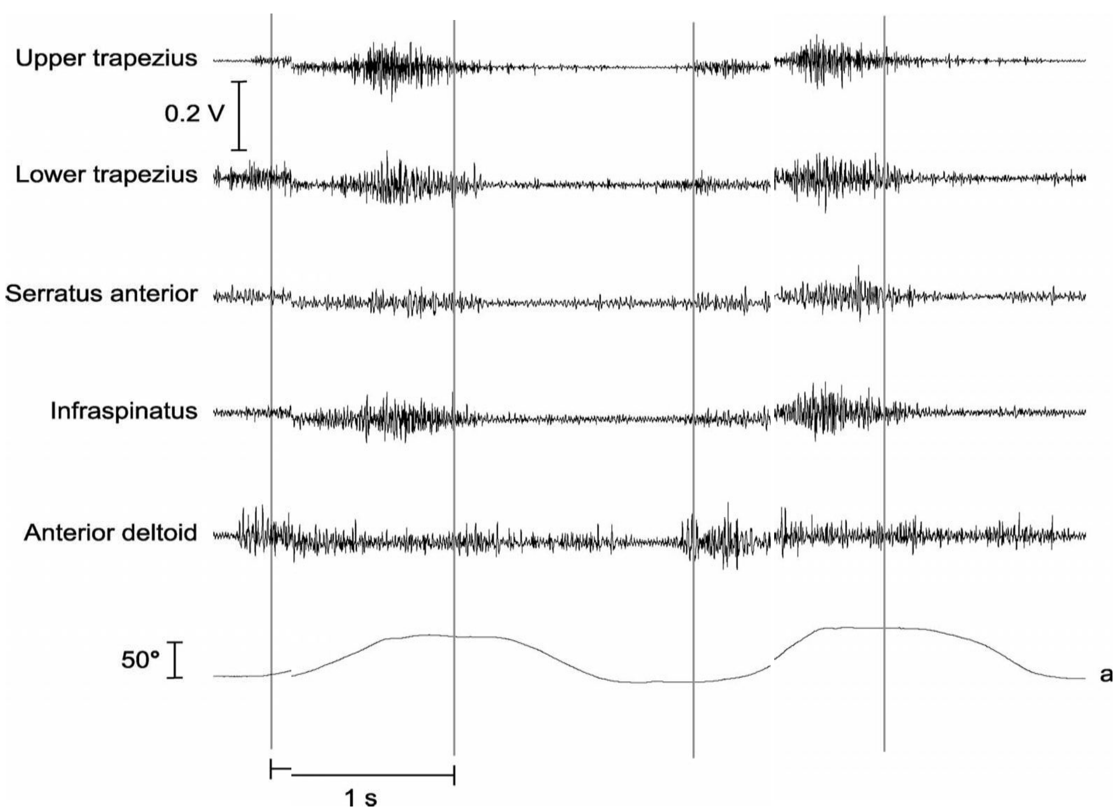


Figure :2.8 – Raw EMG data (Nakamura, 2016)

2.8 Functional outcome measures

The primary outcome of any treatment technique should be identifying functional improvement. Generally, outcome measures are divided into broad categories regarding surgeon-reported measures and patient-reported outcome measures (PROMS). The difference is that surgeon- reported outcomes are both subjective and objective, whereas PROMS are subjective and can be administered remotely (Ritika, 2018). Since our study is non-surgical, PROMS were used and discussed below.

2.8.1 PROMS

Various self-reported functional questionnaires are available, including the Disabilities of Arm, Shoulder and Hand questionnaire (DASH), the Shoulder Pain and Disability Index (SPADI), the American Shoulder and Elbow Surgeons (ASES) Society Standard Assessment Form, the Constant Score (CS), the Simple Shoulder Test (SST), the Oxford Shoulder Score (OSS), the Shoulder Disability Questionnaire (SDQ), and the Western Ontario Shoulder Instability Index (WOSI) (Angst et al, 2011). Sean et al (2015) found the SPADI scale to detect changes over a short period (1 week) and found the test to have low sensitivity. A systematic review of 16 shoulder disability questionnaires found the DASH to have the best rating for clinometric properties and recommended the SPADI and DASH questionnaires for use in outpatient services (Bot et al.,2003) . However, the SPADI scale has better responsiveness in patients with shoulder impingement (SRM=1.08; effect size ES=1.06) and following rotator cuff injury (SRM=1.23) when compared to other pathologies of the shoulder (Robert, 2012). The SPADI contains 13 questions for participants to mark from 0 to 10, which is converted into a score out of 100%. An overall change above eight points in the SPADI is considered a clinically significant difference (Paul, 2004).

2.9 Conclusion

This chapter reviewed various literature and discussed anatomy, biomechanics, background, risk factors, special tests, EMG, and functional questionnaires related to SAIS. The following chapter will focus on the methodology with integrating the relevant literature on methodology.

Chapter 3: Methodology

3.1 Introduction

Chapter 3 describes the study type, design, study setting, source of participants, sample size, and sample selection. Additionally, this chapter will explain the instruments and measurements used to evaluate ROM and EMG. The study procedures are followed by a description of the data recording, reduction, and data analysis. Ethical clearance (Appendix-A) was obtained from WITS Human Research Ethics Committee (M180962), and the study was registered with the Pan Africa Clinical Trials Registry (PACTR201812836521483) attached in Appendix-B.

3.2. Type of study

This was a randomized clinical trial (RCT) reported following the CONSORT guidelines. All aspects are noted on the CONSORT checklist (Appendix-I). RCTs are experiments designed to evaluate interventions to prevent or treat a disease. Randomisation is the golden standard to randomly allocate participants into two or more intervention groups (Gail, 2011). Participants who satisfied the inclusion criteria for this study were randomly divided into two gro ups and the researcher was blinded to the allocation of groups. Each participant group received one of the two different manual therapy techniques described below.

3.2.1 Study setting

The study was conducted at the WITS sports clinic at the WITS education campus (WEC), University of Witwatersrand, Gauteng.

3.2.2 Source of participants

This study used a sample of convenience. Athletes participating in overhead sports at WEC were called to participate in screening after being given an information brochure (Appendix-C) and signing the consent form (Appendix-D). After screening fifty-one athletes, forty were deemed eligible for the study and included.

3.2.3 Sample selection

The researcher screened the athletes for the following eligibility criteria:

Inclusion Criteria

- Three positive tests in the test battery for impingement
- Age between 18-35 years
- SAIS symptoms for a minimum of six weeks to three months
- Athletes participating in overhead sports

Exclusion Criteria

- Athletes who underwent shoulder surgery in the past year
- Injuries of the neck in the past three months
- Bilateral shoulder pain

The researcher screened the participants and then used block randomisation to allocate the participants into two groups. The research assistant performed randomisation, and the researcher was blind to the group allocation.

3.2.4 Sample size

The sample size calculation took into account the results of a previous study that compared muscle activity (EMG) in symptomatic athletes (n=15) and asymptomatic athletes (n=15). Athletes were included after being diagnosed with SAIS (Oliveira et al., 2012).

This study design used a sample size of n=36 with 18 participants in each group to detect the difference between 0.3 and 1 in the EMG ratio of UT/LT and UT/SA before and after manual therapy with a 5% significance level and a study power of 80%. Providing an attrition rate of 10% (n=4), the final sample would be n=40 with n=20 in each group, as calculated by STATA version 15.

3.3 Instrumentation and outcome measures

3.3.1 Range of motion (ROM) testing

This study used Dynamic Body Technology TM sensors and a three-dimensional (3D) joint ROM (JROM) application. All kinetic (angle) measurements were done using two new tri-axial accelerometers from Dynamic Body Technology (http;//dynamicbodytechnology.com) together with 3D JROM iOS app software. 3D JROM technology measures and records the ROM in all three dimensions. The ROM value was recorded on an iPad.

Before starting the test, the researcher placed the sensor over the lower arm (Figure 3.1). Sensors were strapped firmly to the arm (Table 3.1). The researcher calibrated the test while the participant was standing, and the testing side hand was close to the body. The calibration result displayed as 0^0 on the monitor while the participant was standing. If the value was not 0^0 or the participant made some movement, the researcher re-calibrated the test to ensure accurate measurements. After calibration, the participant was asked to do shoulder abduction in the sagittal plane three times. The maximum ROM and average ROM from the three abduction movements displayed on the iPad were saved. Maximum ROM was recorded for data analysis. The JROM has the memory to save each participant's ROM. The researcher entered the ROM into a data sheet every day.

Table: 3.1 – Placement of sensors

Placement of sensor	Movement/Action	Repetition
Below the bulk of biceps muscle	Abduction	3 Times

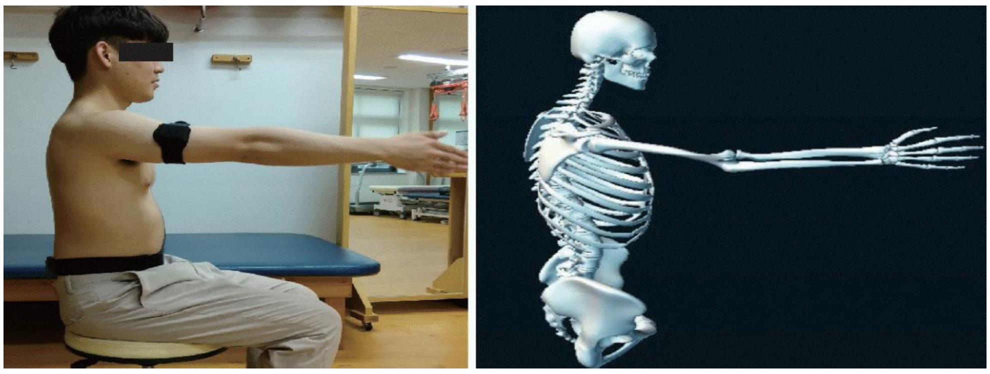


Figure : 3. 1 - Placement of electrode for shoulder ROM (Tae, 2017)

3.3.2 Electromyography/muscle activity measurement

Instrument

The Trigno Wireless EMG system high-performing device with 64 analog output connectors (16 EMG, 48 ACC) was used for EMG measurement. Each EMG sensor has a built-in accelerometer with a transmission range of 20 m with the signal bandwidth 20-450 Hz and a sampling rate of 2000 samples/sec.

Preparation of skin

The hairy surface over the testing surface was shaved using a disposable razor, and the surface was cleaned with a disposable pad composed of 70% Isopropyl Alcohol.

Placement of sensors

The researcher placed sensors parallel to SA, UT, and LT (Diederichsen et al, 2009) over the bellies of the muscles and in the direction of the muscle fibres (www.seniam.org; Hintermeister et al., 1998). Sensors were placed (Figure 3.2) after the successful muscle testing, and the location was marked to place the electrode in the same place all three days to avoid any positional error. This data was captured simultaneously while measuring the abduction ROM. Muscle activity of UT, LT, and SA was recorded as raw data and automatically saved on the computer.

Measurement procedures

Participants were given orientation about the maximum voluntary contraction (MVC) testing positions and abduction. MVC was determined for every muscle each day (see 3.5) for all the participants. The participant was in the sitting position with the arm elevated to 90^0 and resistance applied to the distal upper arm for testing of UT. For measuring the MVC of the LT, participants lay prone with the arm abducted in line with the muscle fibers. Resistance was applied to counter further elevation. The MVC of the SA was measured in sitting by resisting humeral elevation and pushing the arm forward in 135° of elevation (Seo et al, 2015). The MVC was performed three times, with each contraction lasting for three seconds and one minute's rest in between to avoid fatigue (Alizadehkhaiyat et al, 2018). The researcher showed each participant how to perform shoulder abduction in front of the mirror and maintain alignment with the plane during movement execution. After the electrodes were placed on the three muscles (Table 3.2), were attached to the skin with self-sticky tape. The researcher asked the participant to do maximum abduction and recorded the activity of all three muscles. A trained research assistant and the principal investigator recorded the pre- and post-mobilisation muscle activity data in an Excel datasheet (Appendix-H).

Table: 3.2 - Electrode placement for EMG

PLACEMENT OF ELECTRODES
Upper Trapezius Midline between the origin and insertion and over the muscle bulk, as per SENIAM recommendation (Valeria 2012)
Lower Trapezius The electrodes need to be placed at 2/3 on the line from the trigonum spinea to the eighth thoracic vertebra (Valeria 2012)
Serratus Anterior Below the axilla, anterior to the latissimus, placed vertically over the ribs 4 to 6 (Hintermeister et al. 1998)

Data reduction

Raw EMG signals were band pass filtered from 20-500 Hz with a Butterworth filter, and then root mean squared (RMS). The dynamic EMG data of UT, LT, SA were extracted and normalized against the MVC of each of the muscles every day, and an analogue band pass was filtered with a second-order Butterworth filter. The frequencies were cut at 40-500 HZ and were then sampled at 1000 Hz (EMG works 4 Analysis of MATLAB).

Data analysis

Raw EMG data were normalised against the normalized values of each muscle's MVC. The normalised values were used to find the EMG ratio. First, the researcher calculated the muscle activity ratio between UT/LT and UT/SA during abduction. For this, the normalized value of UT is divided by the normalized value of LT and SA, respectively. The ratio is considered low if it is less than 0.3, which means the activation of LT or SA is three times the activation of UT. If the ratio value is close to or more than 1, it is considered to indicate that the two muscles are activated similarly or a more significant predominance of UT over SA and LT (Martins et al., 2008). Then, the maximum amplitude and frequency were recorded during shoulder abduction for data analysis.

Figure: 3.2 - Placement of electrodes over SA, UT, LT (Ben 2008)

3.3.3 Measurement of functional activity (SPADI questionnaire)

Each participant answered the SPADI questionnaire on the first day before starting the study and after completing the three-day follow-up visits (Appendix-E). The values were then converted to a score out of 100% and recorded in the datasheet (Appendix-H). Chapter 2.8 discusses the tool in further detail.

3.3.4 Pain assessment (VAS)

Participants were asked to mark a VAS scale (Validated-Delgado et al. 2018) to determine pain severity by indicating a numerical value between 0 to 10 (with 0 = no pain and 10 = extreme pain) before and after the mobilisation on every occasion (Appendix-F). Researchers recorded the outcome values on a data sheet (Appendix-H).

3.3.5 Demographic information

Researchers provided participants with a self-compiled questionnaire to determine their medical history, demographic information, and activity level (Appendix-G).

3.4 Procedure

3.4.1 Pilot study

Four people were included in the pilot research, which represents 10% of the entire sample size. Participants were randomized into two groups, receiving one of the two treatment techniques. The researcher informed the participants about the entire procedure, including the consent form, demographic assessment, SPADI questionnaire, VAS scale, ROM, and EMG assessment. The same procedures were followed as described for the main study.

The main aim of the pilot study was to streamline the process and discern any bias. There was no difficulty experienced by the researcher or participants throughout the procedure and data collection. No changes were made to the protocol, and the results were included in the main findings.

3.4.2 Main study

Giving out information sheets, the researcher approached participants at several WITS sites and information sheet given to them. The researcher also provided an explanation of the study goals and objectives (Appendix-C). After obtaining informed consent (Appendix-D), the researcher assessed the participant with the Neer's test, Hawkins-Kennedy test, and Painful- arc test (Chapter 2.5) to confirm the diagnosis of SAIS before inclusion in the study. The presence of pain during these tests is considered positive and inclusion criteria for the study. A research assistant then allocated eligible participants to one of the treatment groups through block randomization, using a computerized list. Randomization and stratification were according to the following identified variables: the period of experiencing pain; activity level; primary or secondary impingement; age and gender. The research assistant informed the researcher regarding the group allocated as one and two, where one indicated the Maitland and two indicated the Mulligan mobilization group. When the participant came for the study, the research assistant confirmed the allocated group on the computer and informed the researcher to avoid any possible confusion. The researcher performed the mobilization and was blind to the assessment findings. A second research assistant determined all outcome measures utilizing the described instrumentation, on all occasions, immediately before and after the intervention.

Each participant received the allocated mobilisation technique on three days, every second day, by the researcher. For one group, this consisted of the SMWAM at C5/6 level, three sets of eight repetitions of active shoulder abduction above 90 degrees, which was increased to 10 repetitions every second day for over the six days (Brian, 2014). The entire procedure happened while athlete was sitting and therapist standing behind the athlete. Maitland's grade III unilateral posteroanterior mobilization was performed for the other intervention group, three sets of 30 oscillations on the painful side C5/6 (Geoff, 2005). Maitland mobilization was done while the athlete was in prone lying and the therapist in standing. The entire procedure, including assessment and treatment, took place in the WITS sports clinic, situated in the University of the Witwatersrand.

The study procedures are demonstrated in Figure 3.3.

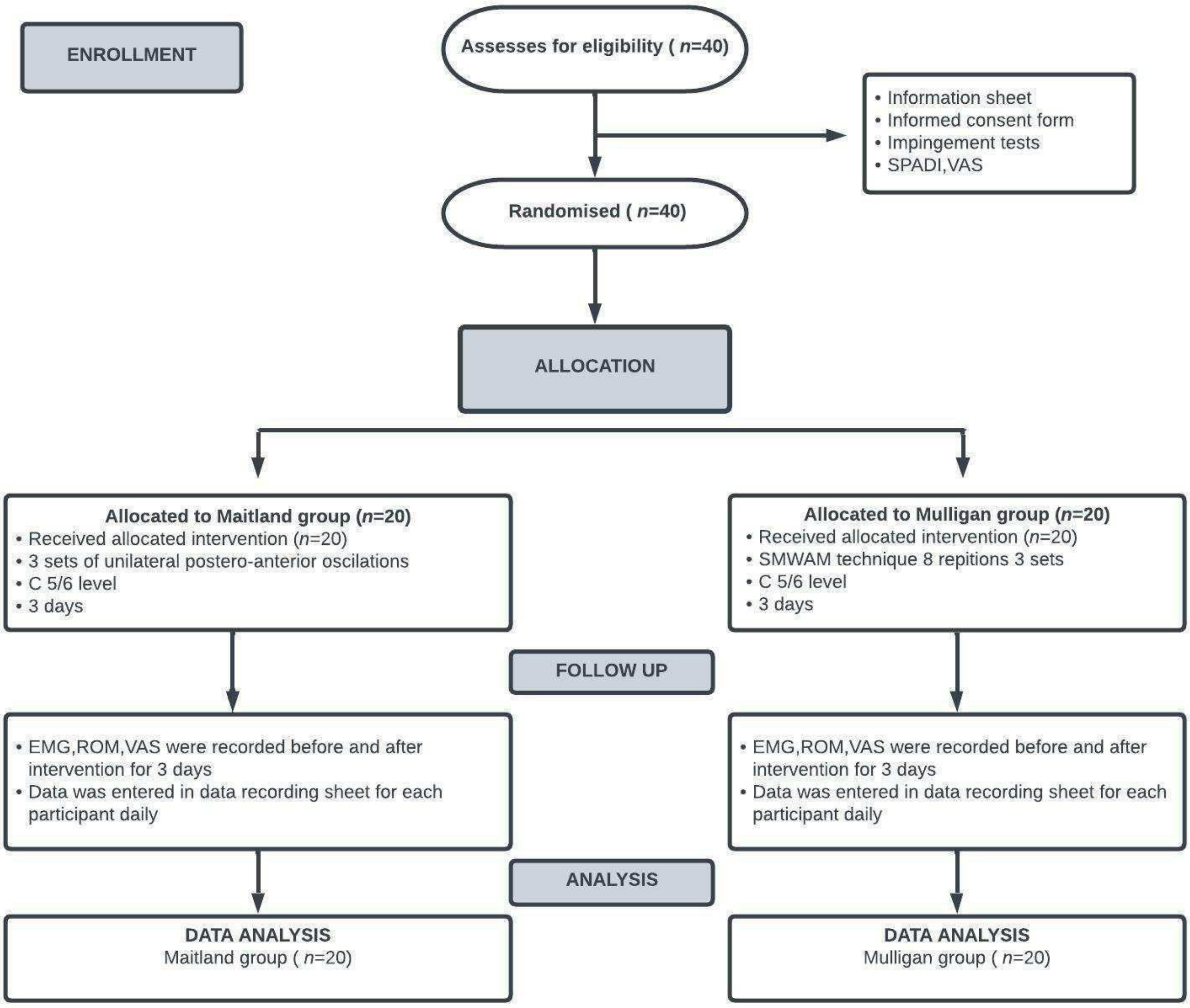


Figure: 3.3 – Flow chart description of the main study

3.4.2.1 The role of the research assistant

The principal researcher met the research assistant twice before commencing the data collection. First, the principal researcher explained the entire experiment procedure to the research assistant. Next, the principal researcher and research assistant performed two mock sessions, including handling equipment, calibration, and data collection. The principal researcher further coordinated activities with the research assistant, such as including and recruiting participants to the study, clarifying queries by the participants, gathering signed consent forms, the completed demographic details, and participant questionnaires. Next, the research assistant allocated participants into groups using a computer random allocation method; however, the researcher was blind to random allocation. Finally, the research assistant collected pre and post-data and recorded each variable in the Excel datasheet.

3.5 Ethical considerations

The University of the Witwatersrand Human Research Ethics Committee provided ethical clearance (Ethics number M 180692) (Appendix-A).

In addition, researchers obtained informed consent (Appendix-D) from the participants before inclusion in the study. Participants were invited to join the study free of will, and no remuneration was given. Participants could withdraw from the study at any time during the study period. Information sought from the participants was intended for this study only and was released only to the concerned participant if requested. A unique numerical value from 1 to 40 replaced the participant's name to secure the participants' data. Only the researcher had access to the identities of the participants. Hard copies of the informed consent form and questionnaires are in possession of the researcher in a secured place. Other than the researcher, no one has access to it. Hard copies were destroyed after three months. Participants' privacy was assured as all information will be protected by a password and stored in a personal computer belonging to the researcher for two years.

3.6 Data analysis

The study used the SPADI questionnaire score, VAS score, EMG data, and shoulder ROM values for analysis. Data was collected and managed in Microsoft Excel 2011 version, and data were exported and analyzed using STATA software, version 15. The VAS and SPADI scores, EMG ratio, and shoulder ROM are continuous variables and summarized using means and standard deviations. Data was not distributed normally; therefore, non-parametric tests were used. The paired t-test was used to determine the changes in each group for the VAS, SPADI, ROM, and EMG scores. An ANOVA two-way repeated test was used to compare the difference between the groups over the period. The level of significance was $p<0.05$.

3.7 Conclusion of the methodology

This chapter has information about the study's design, sample size, inclusion criteria, and exclusion standards. Data gathering, data recording, and statistical analysis have all been documented, along with the process and methodology of the randomised clinical trial. The entire study was cross-checked as with consort 2010 guidelines, and the checklist is attached in Appendix – I. Chapter 4 presents the statistical analysis results, which will be discussed in the final chapter.

Chapter 4: Results

4.1 Introduction

The various dimensions of participants physical and sports were analysed and presented in this chapter, together with the main outcomes measured with the VAS,ROM,EMG and SPADI. The results are presented using tables, graphs and flow diagrams for visual interpretation.

4.2 Participants

Researchers tested athletes between the age of 19 and 25. Fifty athletes were eligible for inclusion. After a brief explanation about the study, 40 athletes signed consent form (Appendix-D). Athletes were divided into two groups using computerized random allocation. The study sample distribution is shown in Figure 4.1

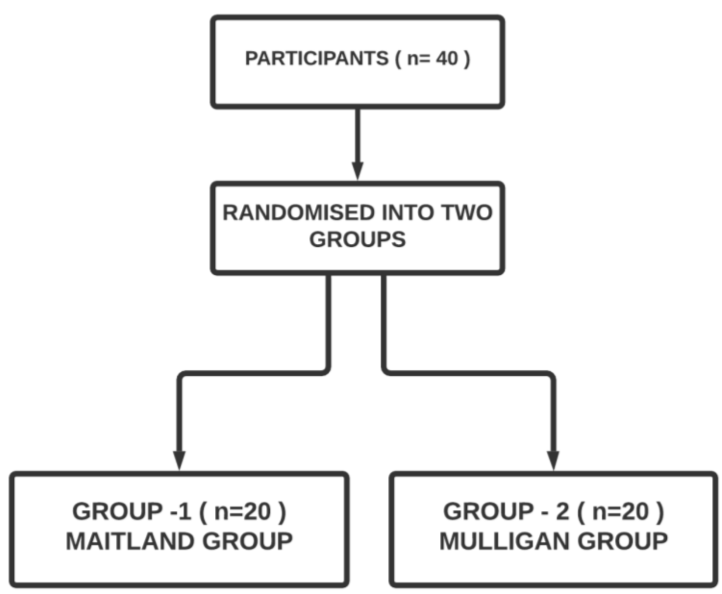


Figure: 4. 1 – Flowchart description randomization

Athletes from different sports, including basketball, rugby, soccer, hockey, boxing, and volleyball, were included in an assessment (Figure 4.2). Shoulder pain was a common complaint with all the athletes. Basketball players n=17 (42.5%) were found to be more involved and hockey was the least involved n=1 (2.5%).

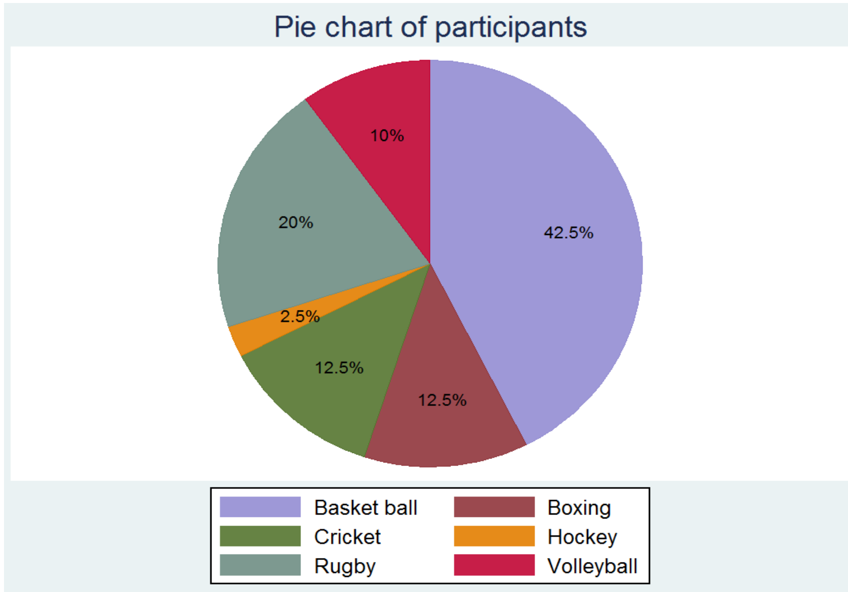


Figure: 4. 2 – Descriptive classification of athletes from different sports who participated in the study

4.3 Demographic information

The characteristics of participants from both groups are shown in Table 4.1. There were no significant differences between the groups in age (*p*=0.4), gender (*p*=0.3), height (*p*=0.7), and weight (*p*=0.9). There was also an equal number of participants in each group.

Table: 4.1 – Summary of descriptive characteristics of participants

Variable		Group 1	Group 2	P value
		Mean (SD)	Mean (SD)	
Age (years)		21.65(4.1)	22.55(3.4)	0.4539
Gender	**Female (%)**	2 (10)	4 (20)	0.3758
	Male (%)	18 (90)	16 (80)	
Weight (kg)		81.85 (18.1)	81.82 (16.6)	0.9953
Height (cm)		181.05 (7.3)	182.15 (11.8)	0.7250

4.4 Physical activity, training, and injury history

This questionnaire (Appendix – G), designed by the researcher, was completed after the screening. Each participant completed the questionnaire during the familiarization session immediately after the briefing about the study. Of the 40 participants, 36 had right shoulder pain (n=36), and four had left shoulder pain (n=4). Thirty participants played sports for three days/week, whereas 10 participants played for two days/week (Table 4.2). Out of the 40 participants, none were advised to undergo surgery. Five participants (n=5) had aggravated shoulder pain following sports trauma, and all other causes (n=35) were from overuse in nature. Compared to other treatment methods such as cupping therapy, physiotherapy was the most recommended option for 25 participants.

Table: 4 2 – Professional level of participants

	GROUP 1	GROUP 2
Level of play (n)	n=11 amateur n=9 professional	n=12 amateur n=8 professional
Mean training time with team per week (hours)	15 hours per week	16 hours per week

(n) – Number of players

4.5 SPADI score

The SPADI questionnaires were completed two times during the three-day intervention period. The first one was before starting the first day, and the second one was after completing the third day of treatment for each participant. The change in each group was calculated separately. Table 4.3 summarizes the before and after comparison for each group. Since the data is approximately normally distributed, a paired t-test was used to find changes in the group (Figure 4.3). An ANOVA two-way repeated test was used to compare the groups and found no significant difference between the groups (F=0.31, p=0.57). However, there were changes within each group and statistically significant p values (<0.0001) (Table 4.3).

Table: 4.3 – The change in SPADI score for both groups

Group	Intervention	Sample size	Standard deviation	Mean	P value
Maitland group	Before	20	13.62	37.63	p<0.0001
	After	20	12.13	25.06	
Mulligan group	Before	20	13.96	41.49	p<0.0001
	After	20	14.94	29.79	

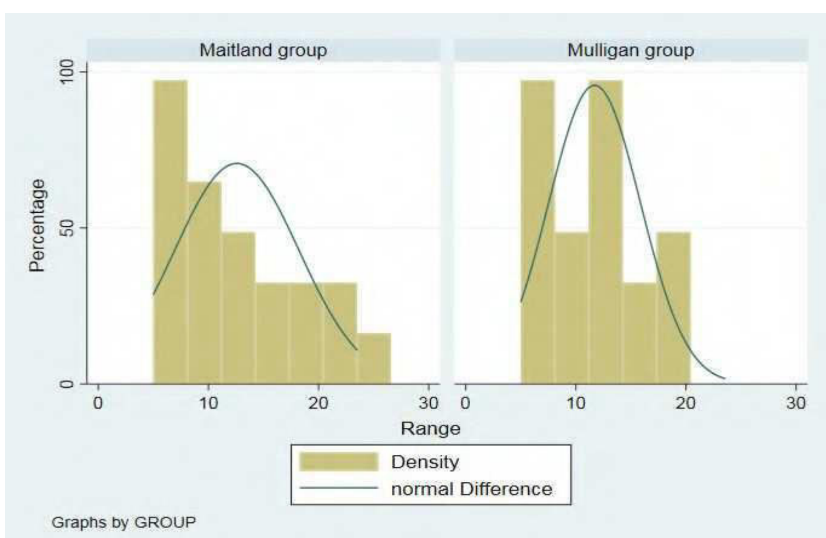


Figure: 4. 3 **– Distribution of SPADI score per group**

4.6 VAS

Researchers collected the VAS score before and after the intervention for analysis. All three days, the pain was assessed before and after the intervention for both groups separately. Means and standard deviations were calculated each day and presented in Table 4.4. To analyse the results between the groups, ANOVA two-way the repeated test was used, and no statistically significant difference was found between the groups in the pain component (F=0.54, p=0.58). However, paired t-test indicated that the group receiving the Maitland mobilisation showed a higher change (mean difference 2.89, p<0.0005) compared to the group receiving the Mulligan technique (mean difference 1.17, p<0.0005), although both was statistically significant.

Table: 4 4 – Paired t-test results comparing pre and post-change

Maitland technique		**Mean (VAS)**	**Standard deviation**	**P value**	**Mulligan technique**		**Mean (VAS)**	**Standard deviation**	**P value**
Day 1	Before	6.1	1.41	<0.0012*	Day 1	Before	7	1.68	<0.0001
	After	4.8	1.23			After	5.55	1.7	
Day 2	Before	5.65	1.03	<0.0001	Day 2	Before	5.8	1.32	<0.0001
	After	4.2	1.57			After	4.55	1.57	
Day 3	Before	5.65	0.98	<0.0001	Day 3	Before	5.25	1.61	<0.0001
	After	3.85	1.13			After	3.9	1.55	

*p<0.05

4.7 ROM

Researchers measured shoulder abduction ROM in degrees before and after the intervention. The pre-ROM was subtracted from the post-ROM measurement, and the difference was taken for analysis. ROM showed significant changes in day one in Maitland group. But the other days in both the groups showed no significant changes. Between-group differences in ROM were analysed using the ANOVA two-way repeated test, and no significant differences between the groups were identified (F=1.85, p=0.16). However, the change was statistically different within each group. The t-test values, including the p values, are listed in Table 4.5.

Table: 4.5 – Paired t-test results comparing pre and post-change in range of motion

Maitland technique		**Mean (ROM in degrees)**	**Standard deviation**	**P value**	**Mulligan technique**		**Mean (ROM in degrees)**	**Standard deviation**	**P value**
Day 1	Before	145.6	14.61	<0.0012*	Day 1	Before	148.7	21.33	<0.0001
	After	154.85	9.61			After	156.4	18.06	
Day 2	Before	149.65	21.02	<0.0001	Day 2	Before	149.95	21.22	<0.0001
	After	159.4	18.48			After	159.9	18.53	
Day 3	Before	150.3	15.36	<0.0001	Day 3	Before	150.45	20.31	<0.0001
	After	159.3	11.43			After	162	16.66	

*p<0.05

In the Maitland group, the ROM increased significantly on the first day. On the second and third days Maitland mobilisation, and on all three days in SMWAM, no significant changes were shown. However, both groups showed significant differences on the third day compared to the first day.

4.8 EMG

Normalised EMG values were calculated for each participant separately. Muscle activity of each muscle for every participant was calculated for the ratio. The average muscle activity (in microvolts (V)) of UT, LT, and SA was calculated for each participant separately for each day and the values listed in Table 4.6, for the Maitland group, and in Table 4.7 for the Mulligan group. Maitland group had statistically significant changes in UT on day three and day one in LT and the values, But no significant changes on other days in Maitland group. However, between-group comparison was done using an ANOVA two-way repeated test and found no significant differences between the groups (F=0.04, p=0.8).

Table: 4. 6 – Activity of individual muscles before and after the intervention: Maitlandtechnique (unit- V)

Maitland technique		**UT MEAN**	**p-value**		**LT MEAN**	**p-value**		**SA MEAN**	**p-value**
Day 1	Before	63.04	=0.32	Before	23.28	=0.04*	Before	76.31	=0.07
	After	56.06		After	28.16		After	52.99	
Day 2	Before	79.54	=0.37	Before	35.33	=0.4	Before	70.00	=0.19
	After	71.39		After	33.48		After	46.46	
Day 3	Before	65.68	=0.02*	Before	34.18	=0.7	Before	62.86	=0.19
	After	34.18		After	32.89		After	47.16	

*p<0.05

Table: 4.7 – Activity of individual muscles before and after the intervention: Mulligan group (unit- V)

Mulligan technique		**UT MEAN**	**p-value**		**LT MEAN**	**p-value**		**SA MEAN**	**p-value**
Day 1	Before	34.04	=0.80	Before	22.04	=0.60	Before	34.33	=0.75
	After	33.43		After	23.02		After	33.21	
Day 2	Before	39.58	=0.30	Before	24.39	=0.73	Before	51.61	=0.43
	After	37.00		After	25.32		After	68.31	
Day 3	Before	49.84	=0.0047	Before	26.97	=0.92	Before	64.64	=0.83
	After	26.97		After	26.81		After	68.58	

Tables 4.8 and 4.9 summarises the optimal ratio between UT, LT, and SA muscles. The ratio was calculated by dividing the normalised value of UT by the normalised value of LT and SA (Chad, 2014). Pre and post muscle ratio values were calculated for each participant each day. Scapular activation ratios are significant changes in Maitland group for two days and day three on Mulligan group. The difference between the pre and post-values was calculated for analysis per group. Table 4.8 summarises the muscle activation ratio of the Maitland group, and Table 4.9 listed below summarises the muscle activation ratio of the Mulligan group.

Table: 4.8 – Scapular muscle activation ratio before and after the intervention for the Maitland group

Maitland technique	UT/LT	Average ratio	p-value	UT/SA	Average ratio	p-value
Day 1	Before	2.15	=0.04*	Before	0.93	=0.75
	After	1.47		After	1.60	
Day 2	Before	1.63	=0.17	Before	1.04	=0.07
	After	1.69		After	1.42	
Day 3	Before	3.20	=0.0005*	Before	1.24	=0.54
	After	2.60		After	0.72	

$*p < 0.05$

Table: 4.9 – Scapular muscle activation ratio before and after the intervention for the Mulligan group

Mulligan technique	UT/LT	Average ratio	p-value	UT/SA	Average ratio	p-value
Day 1	Before	1.79	=0.56	Before	1.09	=0.11
	After	1.68		After	1.02	
Day 2	Before	2.01	=0.32	Before	0.67	=0.53
	After	1.49		After	0.96	
Day 3	Before	1.87	=0.02*	Before	0.86	=0.10
	After	1.01		After	0.49	

$*p<0.05$

4.9 Conclusion of the results

Pain (VAS), muscle activity (EMG), and ROM were the three variables of this research study and were statistically analysed with appropriate tests. Pre and post values were statistically analysed for all three days before and after the manual therapy intervention for each group separately using a non-parametric t-test. Researchers calculated an ANOVA two-way repeated analysis to measure between-group differences.

VAS and ROM show statistically significant differences in comparing the before and after scores of the concerned manual therapy techniques. EMG activity showed different results which is in contrast with the other two variables. EMG ratio reduced after the manual therapy techniques.

Shoulder abduction ROM increased after the manual therapy intervention in both groups. Both techniques have shown the mean difference of 14 degrees, and thereby both techniques have the same outcome. Furthermore, both groups' pain scores reduced before and after the mobilisation.

Apart from the primary variables, the SPADI value was also analysed separately before and after the manual therapy intervention for each group. A statistically significant difference in SPADI value was found within each group (p<0.0001), but no statistical difference between the groups.

CHAPTER 5: DISCUSSION

5.1 Introduction

The study investigated the effects of a SMWAM technique versus a Maitland mobilization technique on pain, ROM, and muscle activity in overhead athletes diagnosed with SAIS. This chapter will discuss the study aims and objectives, the literature, and various aspects of the results. The differences and similarities between the two groups and a possible neurophysiological connection between the cervical spine and shoulder will be referred to as applicable to the findings.

5.2 Participants

5.2.1 Sample size

Sample numbers in recent research analysing EMG activity in relation to SAIS ranged from 7 to 41 people. (Joao, 2014; Bandholm et al, 2008; Laresen 2012; 2013; Han et al, 2013; Yin, 2007; Oliveira et al., 2013). Most of these studies investigated the scapular pattern comparing intervention and a control group. The majority of those studies involved athletes, both symptomatic and asymptomatic. However, they did not study similar techniques to those investigated in this study. Therefore, when evaluating EMG activity, the sample size in our study might be considered to have a sufficient power to prevent type II error of the UT, LT, and SA specifically, based on previous studies' findings and the calculated sample size for this study.

5.2.2 Characteristics of the participants

Randomisation using a computer-based block randomisation method was used to minimize variance in physical characteristics. The results indicated no significant difference between groups regarding demographic characteristics (weight, height, age, and gender). Regarding the sport types involving overhead activities, a previous observational cross-sectional study that assessed EMG in participants with SAIS had 30 male amateur athletes from five sports teams (handball, volleyball, swimming, judo, and jiu-jitsu) (Oliveira et al., 2013). Another study that screened SAIS in 317 athletes included participants from different sports like baseball, swimming, tennis, and volleyball (Laudner and Sipes, 2009). Basketball players (n=17) were the highest participants in this study. However, this study did not specify gender or sports participation in the inclusion criteria.

5.3 Self-reported outcomes of shoulder disability

The SPADI score was compared before and after the intervention per group and between the groups. A paired t-test was used to analyse the within-group changes and indicated a statistically significant ($p<0.0001$) difference in SPADI scores for both groups. This indicates a difference between the first and third day in activity of daily living (ADL). The SPADI questionnaire is a valid measurement of shoulder-specific disability (Roy, 2009). The overall mean difference in the Maitland group was 37.63 and in the Mulligan group was 41.49, which is above the Minimal detectable change (MDC) threshold and Minimum clinically important difference (MCID) threshold. Both the groups' mean changes are above the clinically significant change of eight points (Paul, 2004). A research study that compared MWM and SHAM in the shoulder joint with SAIS found 7.5 and 12.1 differences, respectively, in the overall SPADI score (Joao, 2016). Another research study investigating Mulligans' SNAG technique found a statistically significant decrease in the SPADI value (t(5)-3.25, p=0.05) within 48 hours from the initial visit (Dawn, 2018). However, there was no difference between the effectiveness of the technique.

5.4 Participants' response to pain

VAS scores were measured before and after each session for all the participants. The changes in the Maitland (p=0.0005) and Mulligan (p=0.0005) groups are significant in the modulation of pain. There was, however, no significant difference between the groups in pain modulation (F=0.54, p=0.58). Many studies state that immediate pain threshold changes can be attributed to a local analgesic effect (Lluch, 2018). A literature review also states that passive mobilisations to the cervicothoracic joints, the ribs, or in combination with glenohumeral mobilisation, induced symptomatic relief by reducing pain (Lenker et al, 2012). Mobilising asymptomatic C5,6,7 segments has also been effective in reducing a painful arc in shoulder pain (McClatche, 2009). Joint mobilisations were also found to influence the mechanoreceptors involved in pain modulation due to the stretch of the joint capsule during spinal mobilisation. This reaction triggers large, afferent myelinated fibers to inhibit the exciting nociceptors (Hearn, 2002). The reduction in pain also supports the work of Takasaki et al (2009), where a passive shoulder abduction movement could cause accessory movements at the cervical spine when investigated with an MRI (Inter-rater reliability (ICC=0.95)). This supports the underlying factor that a possible mechanical and neurophysiological connection between the shoulder and cervical segments exists. Both the techniques have shown a difference in the modulation of pain. However, no technique was superior as there is no statistically significant difference between the techniques. The pain was responding to both the manual therapy techniques similarly and in support of vertebrae mechanical corrections or facilitating the pain gate's neural synthesis by mobilisation.

5.5 ROM

There was a significant increase in ROM for both groups. The Maitland group showed slightly higher ROM differences than the Mulligan group. No significant differences between the groups were found (F=1.85, p=0.16).

Research consisting of two case reports which evaluated the retracted neck exercises in SAIS found an immediate improvement of shoulder abduction ROM. Cervical vertebral movement is a potential treatment option in recovery from SAIS (Steven, 2016). Another research study investigating cervical mobilisations in 21 participants found a 12.5^{o} $\pm 15.6^{o}$ difference in shoulder abduction immediately after intervention in a study on adults with shoulder pain (McClatchie et al, 2008). Maitland mobilisation techniques over the cervicothoracic region (C7-T4) and conventional therapy were found to be effective in shoulder abduction ROM compared to the control group who received only the combination of scapula mobilisations, strengthening, and stretching. The difference was a mean value of 25^0 in the experimental group ($F(1,28,0.05=549.924$, $p=0.001$)) (Swami et al, 2016). This supports the change of ROM in the Maitland group. This study also mobilised the lower cervical segment (C5-6), which showed a mean difference of 13.26^o before and after the intervention.

SMWAM also improved ROM with a mean difference of 14.05^o after the third session compared to the first day. A six-week manual therapy intervention for chronic neck, shoulder, and hand pain, indicated that SMWAM increased shoulder ROM and reduced pain (John, 2002). A follow- up after 29 weeks showed positive outcomes as the participant was fully active. Another observational study executed over 8 days found Maitland mobilization to increase shoulder ROM (Agrawal et al , 2020). However, no better technique could be found statistically.

5.6 Muscle activity

Muscle activity (EMG) ratio difference was compared pre and post-intervention, and both groups showed significant change. The EMG pattern of this study is similar to the results from a previous study, where the increased activity of UT, SA, and reduced activity of LT had been observed (Oliveira et al, 2013). The normalised values of LT are less than UT during the shoulder abduction, which supports that LT is an antagonist to UT (Ludewig and Cook, 2000). UT is the first muscle to begin the scapulothoracic movement, followed by the contraction of SA and finished by the middle fibres of trapezius (MT) and LT in both SAIS and the control groups (Moraes et al, 2008). However, this cycle can be altered due to neuromuscular control and result in force couples to change around scapular muscles (Cools et al, 2002). This altered scapular muscle force can influence scapula rotation, further causing the tip of the acromion to move forward, which not only reduces the subacromial space but also increases the likelihood of impingement (Hebert, 2002).

Electrical activity of the muscles, which are altered after the manual therapy interventions, is essential as it can alter the muscle tone instantly. The primary role of UT appears to be in generating retraction of the clavicle at the sternoclavicular (SC) joint; and that of MT and LT in generating external rotation of the scapula at the acromioclavicular (AC) joint (Fey, 2007; Ludewig, 2000). Previous EMG studies in patients with shoulder pathology revealed varying results in muscle recruitment patterns of UT, LT, and SA (Lin, 2005; Reddy, 2000). Generally, changes in muscle electrical activity in our study correlate with the finding of another study which compared 21 symptomatic SAIS and 20 normal subjects and states that muscle activity may be a pathogenic factor in developing SAIS (Louise, 2008).

However, the ideal UT/LT and UT/SA ratios were discovered to vary following the treatments, however the shift was small. After the manual therapy intervention, the increased activity of UT and SA relative to the decreased activity of LT was changed. The Mulligan group saw more UT/LT and UT/SA ratio alterations than the Maitland group. Muscle activity is influenced by a number of things. Factors include the kind of muscle fibre, muscle length, and muscle velocity can have an impact on ratio EMG. It may have an impact on how a muscle's electrical and mechanical activities are related (Thomas, 2008). The result of joint mobilisation demonstrates that inhibitory inputs from the spine are what cause the inhibition of the muscles in the extremities (Suter, 2006). This muscle's activity has changed, which is consistent with excitatory Paraphrase without limits. Change in this muscle activity is evident to support excitatory input with diverted innervation of the spinal accessory nerve, which supplies UT and LT (Kierner, 2001; MacDonald et al., 2000). Another research study also found similar results, namely, increased activity of UT compared to LT in participants with SAIS, which consisted of overhead athletes compared to a control group (Cools, 2007).

5.7 Conclusion to the discussion

Researchers compared the effect of Maitland grade 3 mobilizations and Mulligan SMWAM techniques in overhead athletes with SAIS. Both techniques improved ROM, muscle activity, and pain variables significantly. It was also concluded that there were no appreciable ROM and VAS differences across groups.

CHAPTER 6: CONCLUSION

6.1 Conclusion

One of the main causes of shoulder discomfort, which ranks third in importance after back and neck pain, is SAIS. There is a lot of data supporting the use of manual therapy techniques in the treatment of shoulder discomfort in both the general population and athletes. Exercise treatment was equally successful as surgery, according to a five-year follow-up study (Ketola et al., 2013). However, manual therapy can be added as additional therapy in physiotherapy protocols (Lewis et al., 2020) and remains the choice of treatment among physiotherapists worldwide to treat SAIS. Symptom modification is a main part of the shoulder symptom modification procedure (SSMP), where cervicothoracic procedures and combinations of active and passive movements are also included (Lewis, 2017).

There is, however, no literature to compare two different manual cervical concepts in SAIS. Therefore, this study sought to study cervical SMWAM and Maitland techniques in SAIS. Few experimental studies in SAIS have compared exercise therapy and manual therapy, but not exclusively in overhead athletes. Overhead activity places athletes at high risk to develop SAIS, and many players with limited access to quality rehabilitation need an evidence-based approach for their shoulder pain and return to sport.

Standard manual techniques and emerging challenges in rehabilitating SAIS made us formulate the research question, "What are the effects of SMWAM and a Maitland technique on pain, muscle activity of UT, LT, SA, and shoulder abduction ROM?"

A randomized clinical study was done to evaluate the effectiveness of the aforementioned interventions in SAIS patients. Researchers split forty athletes into two groups. EMG and ROM were measured by the state of the art equipment, whereas pain was measured using the VAS. Results indicated significant pain, muscle activity, and ROM changes in both groups. However, the study did not indicate any significant differences between the effectiveness of the two investigated techniques.

6.2 Recommendations for the future studies

Future research might compare exercises and mobilizations for the cervical area to those for the shoulders. More studies comparing the efficiency of spinal mobilization in SAIS, both short time (minutes) and long time (day) duration and changes in EMG can be monitored. In addition, cervical mobilisation versus GHJ mobilisation can also be compared in the future. Addition of cervical mobilizations along with conventional shoulder rehabilitation protocols can be studied.

6.3 Clinical recommendations

Cervical mobilisations affect the shoulder joint in terms of pain, muscle activity, and ROM. During rehabilitation, cervical mobilisations can be considered part of a management program. Speeding up the rehabilitation process by instantly improving the pain and ROM can be a contributing factor. The decision on when to include the mobilisation during the rehabilitation solely depends on the assessment findings and the shared decision of the clinician and patient since underlying pathology varies from case to case.

6.4 Strengths and limitations

Given the current constraints, the results of this investigation should be regarded cautiously. The sample size was only a tiny number, and an increased population may improve the generalis ability ofthe results. However, based on the power calculation, the number of included participants was sufficient to determine statistical differences. Although the short-term effects such as pain relief should not be underestimated, following up for a longer time period would be ideal for determining the long-term effects of the mobilisations, as well as to test for differences between the groups. However, the study's strength was its design, and more randomised clinical trials should be conducted to establish the effects of manual therapy. Cervical assessment in SAIS can be incorporated with spinal manual therapy and documented. .

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APPENDICES

Appendix A – ETHICS CLEARANCE CERTIFICATE

Appendix B – PAN AFRICAN CLINICAL TRIAL REGISTRY

Appendix C – INFORMATION SHEET

Appendix D – INFORMED CONSENT FORM

Appendix E – SPADI SCALE

Appendix F – VISUAL ANALOGUE SCALE (VAS)

Appendix G – DEMOGRAPHIC QUESTIONNAIRE

Appendix H – DATA SHEET

Appendix I –CONSORT CHECKLIST

Appendix J - TURNITIN REPORT

Appendix K - EDITORIAL CERTIFICATE

APPENDIX – A – ETHICS CLEARANCE CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Mr IR Antonysamy
School of Therapeutic Sciences
Department of Physiotherapy
Medical School
University

E-mail: 832206@students.wits.ac.za

CC: Supervisor: Dr C Brandt <Corlia.Brandt@wits.ac.za>
and <HREC-Medical.ResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 07/01/2019

REF: *R14/49*

PROTOCOL NO: M180962 *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *The effect of spinal mobilisation with arm movement and a Maitland Mobilisation on range of motion and muscle activity in overhead athletes with Subacromial Impingement Syndrome - a randomized clinical trial*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

R14/49 Mr IR Antonysamy

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M180962

NAME: **(Principal Investigator)**	Mr IR Antonysamy
DEPARTMENT:	School of Therapeutic Sciences Department of Physiotherapy Medical School University
PROJECT TITLE:	The effect of spinal mobilisation with arm movement and a Maitland Mobilisation on range of motion and muscle activity in overhead athletes with Subacromial Impingement Syndrome - a randomized clinical trial
DATE CONSIDERED:	28/09/2018
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr C Brandt
APPROVED BY:	Dr N Naran, Deputy Chairperson, HREC (Medical)
DATE OF APPROVAL:	07/01/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date of the meeting when the study was initially reviewed. In this case, the study was initially reviewed in **September** and will therefore reports and re-certification will be due early in the month of **September** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature ____________________ Date ____________________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B – PAN AFRICAN CLINICAL TRIAL REGISTRY

06 December 2018

To Whom It May Concern:

RE: THE EFFECT OF SPINAL MOBILISATION WITH ARM MOVEMENT AND A MAITLAND MOBILISATION ON RANGE OF MOTION AND MUSCLE ACIVITY IN OVERHEAD ATHLETES WITH SUBACROMIAL IMPINGEMENT SYNDROME – A RANDOMISED CLINICAL TRIAL

As project manager for the Pan African Clinical Trial Registry (www.pactr.org) database, it is my pleasure to inform you that your application to our registry has been accepted. Your unique identification number for the registry is **PACTR201812836521483**.

Please be advised that you are responsible for updating your trial, or for informing us of changes to your trial.

Additionally, please provide us with copies of your ethical clearance letters as we must have these on file (via email or post or by uploading online) at your earliest convenience if you have not already done so.

Please do not hesitate to contact us at +27 21 938 0835 or email epienaar@mrc.ac.za should you have any questions.

Yours faithfully,

Elizabeth D Pienaar
www.pactr.org Project Manager
+27 021 938 0835

APPENDIX C – INFORMATION SHEET

INFORMATION DOCUMENT- Athlete
Study title - EFFECT OF SPINAL MOBILISATION WITH ARM MOVEMENT AND A MAITLAND MOBILISATION ON RANGE OF MOTION AND MUSCLE ACTIVITY IN OVERHEAD ATHLETES WITH SUBACROMIAL IMPINGEMENT SYNDROME – A RANDOMISED CLINICAL TRIAL

Dear Athlete,

I, Ignatius Richard Antonysamy, am researching Subacromial impingement syndrome of the shoulder joint, which commonly affects the shoulder joint in overhead activity, particularly with athletes. Subacromial impingement syndrome can be defined as intense pain over the shoulder and limits the shoulder movement if untreated, can further lead to shoulder muscle tear. In this study, we want to learn whether cervical (neck) mobilization can be helpful in sub-acromial syndrome and how it can be helpful in speedy recovery in sports injuries. The mobilization of cervical bones is less than 15 minutes non-invasive procedure.

I would be most grateful if you would be willing to participate in this research project. The project is scheduled to commence in November 2018 to March 2019.

Who is eligible to take part in this study?
Male and female athletes of any sporting discipline who are suffering from Subacromial syndrome. Athletes who underwent shoulder surgery in the last year and had any trauma to the neck like whiplash injuries cannot participate in this study.

What is involved in this study?
Testing will be done whenever you can come to the WITS sports clinic, where you will be given a simple questionnaire and demographic information sheet to know the severity of your pain. Next, you will perform an Electromyogram (EMG), which is a non-invasive method that will record the electrical activity of your shoulder muscles to find out its relevance to your pain. After EMG, you will perform a simple cervical manipulation to check pain differences over the shoulder. This entire procedure will take less than 30 minutes/session Level of pain will be monitored through mobile call at your preferred time. Participation is voluntary, and refusal to participate will not involve any penalty or loss of benefits to which you are otherwise entitled. You may withdraw from this study at any time without suffering any repercussions.

Are there any risks of taking part in this study?
Usually, it is a pain-free procedure. However, soreness over the neck region (due to hand contact of the researcher) is possible, which usually subsides overnight.

What are the benefits of taking part in this study?
Your results can be discussed with you. You will not receive a monetary award for taking part in this study.

Will information be handled as confidential?
Every effort will be made to secure your personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law. To ensure the confidentiality of participants, each

athlete will be assigned a study number. The researcher will keep the key to the study numbers assigned on a laptop with password protection. Names of the participants are written only in the consent form and not on the questionnaire. Additionally, consent forms are to be kept separately from the questionnaires. All information will be used only for the purpose intended in this study only. The data collected will not be re-used for any other purpose other than this study. The data will not be shared with anyone in any form.

For further information, you are welcome to contact me on 0613546654 or 832206@students.wits.ac.za

For more information on or for the reporting of ethical concerns, you may contact the chair of the Human Research Ethics Committee of the University of the Witwatersrand, Professor Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail at Clement.Penny@wits.ac.za. The telephone numbers for the committee secretariat are 011 717 2700/1234 and e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Kind regards

Ignatius Richard Antony Samy,
Physiotherapy Department,
University of the Witwatersrand.

APPENDIX D – INFORMED CONSENT FORM

INFORMED CONSENT FORM – ATHLETES

STUDY TITLE: THE EFFECT OF SPINAL MOBILISATION WITH ARM MOVEMENT AND A MAITLAND MOBILISATION ON RANGE OF MOTION AND MUSCLE ACTIVITY IN OVERHEAD ATHLETES WITH SUBACROMIAL IMPINGEMENT SYNDROME – A RANDOMISED CLINICAL TRIAL

I____ (cell number______________________ and e-mail address ______________________) hereby agree to participate in the study as described to me in the information sheet. I hereby agree to complete the Shoulder pain and disability index (SPADI) questionnaire and to the consent to the Electromyogram (EMG) procedure and consent for the physical application of spinal mobilization with arm movement or Maitland's mobilization.

I am aware that I will not be exposed to any risk other than soreness and localized pain that usually subsides in a day, and I can withdraw from the study at any time without suffering any repercussions. I understand that there are no monetary benefits for my participation and that participation is voluntary, and I am not in any way obliged to take part.

Signature of athlete _

Date _

Signature of researcher

APPENDIX E – SPADI SCALE

Shoulder Pain and Disability Index (SPADI)

Please place a mark on the line that best represents your experience during the last week attributable to your shoulder problem.

Pain scale

How severe is your pain?

Circle the number that best describes your pain where 0 = no pain and 10 = the worst pain imaginable

At its worst	0	1	2	3	4	5	6	7	8	9	10
When lying on the involved side?	0	1	2	3	4	5	6	7	8	9	10
Reaching for something on a high shelf?	0	1	2	3	4	5	6	7	8	9	10
Touching the back of your neck?	0	1	2	3	4	5	6	7	8	9	10
Pushing with the involved arm?	0	1	2	3	4	5	6	7	8	9	10

Total pain score /50 x 100 = %
(Note; If a person does not answer all questions, divide by the total possible score, e.g., if 1 question missed, divide 40)

Disability scale

How much difficulty do you have?

Circle the number that best describes your experience where 0 = no difficulty and 10 = so difficult it requires help

Washing your hair?	0	1	2	3	4	5	6	7	8	9	10
Washing your back?	0	1	2	3	4	5	6	7	8	9	10
Putting on an undershirt or jumper?	0	1	2	3	4	5	6	7	8	9	10
Putting on a shirt that buttons down the front?	0	1	2	3	4	5	6	7	8	9	10
Putting on your pants?	0	1	2	3	4	5	6	7	8	9	10

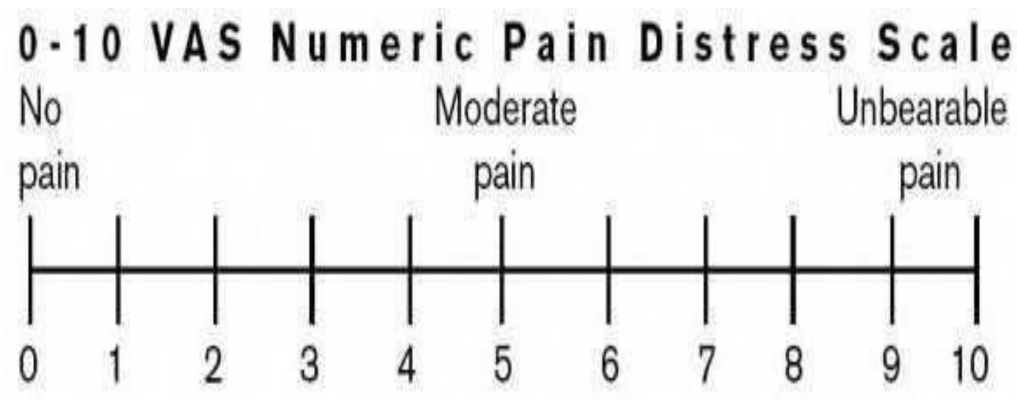
Placing an object on a high shelf?	0	1	2	3	4	5	6	7	8	9	10
Carrying a heavy object to 10 pounds(4.5 kilograms)	0	1	2	3	4	5	6	7	8	9	10
Removing something from your back pocket?	0	1	2	3	4	5	6	7	8	9	10

Total disability score: / 80 x 100 = %
(Note: If a person does not answer all questions, divide by the total possible score, e.g., if 1 question is missed, divide by 70)

Total Spadi score: 130 x 100 = %
(Note: If a person does not answer all questions, divide by the total possible score, e.g.,. if 1 question is missed, divide by 120)

Minimum Detectable Change (90% confidence) = 13 points
(Change less than this may be attributable to measurement error)
Source: Roach et al. (1991). Development of a shoulder pain and disability index.

APPENDIX F – VISUAL ANALOGUE SCALE (VAS)



- **Participants will be asked to choose a number indicating their level of painfrom 0 is no pain and 10 is extreme pain**
- **Every participant will be asked to give a number on the VAS scale beforeand after the session**

APPENDIX G - DEMOGRAPHIC QUESTIONNAIRE

MEDICAL HISTORY

Please tick the appropriate answers or complete the blank space provided.

Patient number: Date: dd/mm/yy

E-mail id:

Contact no:

1. **Age/ sex _**

2. **Weight: (kg)**

3. **Height: (cms)**

4. **Language : (Tick)**

English	
Afrikaans	

T

5. **Are you sportsmen? YES/ NO**

5.1 Which sport do you play?

Cricket	
Rugby	
Swimming	
Tennis	
Basketball	
Others	

If others, please specify _

6. **What is your highest level of participation?**

Social	
Provincial	
National	
International	

6.1 How many years are you playing?

> 6 months	
> 1 year	
> 2 years	
> 3 years	
> 5 years	

6.2 How many days/week do you play?

1	
2	
3	
4	
5	
6	
7	

6.3 How many hours/day do you play?

1hour / day	
2 hours/day	
3hours / day	
4 hours/day	
>5 hours/day	

7. Do you suffer from any of these illnesses?

Headache	
Migraine	
Recent whiplash injury	
Head spinning complaints	

8. When did you experience shoulder pain?

> 1 month	
> 6 months	
> 1 year	

9. Side of shoulder pain

Right	
Left	

10. Did you miss any games/seasons due to this pain?

YES	
NO	

11. If yes, how many games/seasons did you miss?

>1	
>2	
>3	
>4	

12. Have you received any treatment for shoulder pain?

YES	
NO	

If yes, please answer the following

Physiotherapy	
Electro-Therapy	
Exercise Therapy	
Massage	
Cupping	
Advised for surgery	

ON EXAMINATION:

Neer impingement sign	Positive / Negative
Hawkins – Kennedy test	Positive / Negative
Painful arc test	Positive / Negative

APPENDIX H - DATA CAPTURING SHEET

DAY	DAY-1	DAY-2	DAY-3
DATE			
SPADI			
VAS BEFORE			
VAS AFTER			
EMG UT BEFORE			
EMG UT AFTER			
EMG LT BEFORE			
EMG LT AFTER			
EMG SA BEFORE			
EMG SA AFTER			
SHOULDER ABDUCTION BEFORE			
SHOULDER ABDUCTION AFTER			
NEER SIGN			
PAINFUL ARC TEST			
HAWKINS_KENNEDY TEST			
EMG RATIO UT/LT BEFORE			
EMG RATIO UT/LT AFTER			
EMG RATIO UT/SA BEFORE			
EMG RATIO UT/SA AFTER			

SPADI – Participants will be asked to fill out this self-questionnaire before commencing on the first day and final day

VAS – Each participant will be asked to mark any value between 0 and 10 before and after administering the technique, and this will be required to do every session.

EMG – EMG response will be recorded before and after every session
Shoulder abduction – Shoulder abduction ROM will be recorded before and after every day in degrees
IMPINGEMENT SIGN’S – Impingement tests will be carried out every day and responses will be recorded as positive or negative

APPENDIX I - CONSORT CHECKLIST

3.2 CONSORT 2010 checklist of information to include when reporting a randomised trial*

Title and abstract			
	1a	Identification as a randomised trial in the title	Yes
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance, see CONSORT for abstracts)	Yes p 65
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	Yes p 1
	2b	Specific objectives or hypotheses	Yes p 4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	Yes p 22
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	
Participants	4a	Eligibility criteria for participants	Yes p 22
	4b	Settings and locations where the data were collected	Yes p 23
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	Yes p 23
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	Yes p 23
	6b	Any changes to trial outcomes after the trial commenced, with reasons	Yes p 27
Sample size	7a	How sample size was determined	Yes p 23
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation: Sequence	8a	Method used to generate the random allocation sequence	Yes p 23

generation	8b	Type of randomisation; details of any restriction (such as blocking and block size)	Yes p 23
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	Yes p 31
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	Yes p 28
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	Yes p 28
	11b	If relevant, description of the similarity of interventions	NA
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	Yes p 31
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	Yes p 31
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Yes p 32
	13b	For each group, losses, and exclusions after randomisation, together with reasons	Yes 29
Recruitment	14a	Dates defining the periods of recruitment and follow-up	
	14b	Why the trial ended or was stopped	
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Yes 33
Numbers analysed	16	For each group, the number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Yes 28,29
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Yes 36,37,38
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing prespecified from exploratory	Yes p 35
Harms	19	All important harms or unintended effects in each group (for specific guidance, see CONSORT for harms)	-
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	Yes 63
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	Yes 64
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	Yes 64

Other information

Registration	23	Registration number and name of trial registry	Yes p 22,64
Protocol	24	Where the full trial protocol can be accessed, if available	Yes
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	NA

APPENDIX J - TURNITIN REPORT

THE EFFECT OF SPINAL MOBILISATION WITH ARM MOVEMENT AND A MAITLAND MOBILISATION ON RANGE OF MOTION AND MUSCLE ACTIVITY IN OVERHEAD ATHLETES WITH SUBACROMIAL IMPINGEMENT SYNDROME – A RANDOMIZED CLINICA

ORIGINALITY REPORT

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PRIMARY SOURCES

1	pdfs.semanticscholar.org Internet Source	1%
2	www.chiro.org Internet Source	1%
3	Huang, Han-Yi, Jiu-Jenq Lin, Yueliang Leon Guo, Wendy Tzyy-Jiuan Wang, and Yu-Jen Chen. "EMG biofeedback effectiveness to alter muscle activity pattern and scapular kinematics in subjects with and without shoulder impingement", Journal of Electromyography and Kinesiology, 2012. Publication	1%
4	www.science.gov Internet Source	<1%
5	Scott A. Burns, Joshua A. Cleland, Kristin Carpenter, Paul E. Mintken. "Interrater reliability of the cervicothoracic and shoulder physical examination in patients with a primary complaint of shoulder pain", Physical Therapy in Sport, 2016 Publication	<1%

APPENDIX K – EDITORIAL CERTIFICATE

Author: Ignatius Richard

Document Title: THE EFFECT OF SPINAL MOBILISATION WITH ARM MOVEMENT AND A MAITLAND MOBILISATION ON RANGE OF MOTION AND MUSCLE ACTIVITY IN OVERHEAD ATHLETES WITH SUBACROMIAL IMPINGEMENT SYNDROME – A RANDOMIZED CLINICAL TRIAL

Date Issued: February 13, 2022

Virga Editing and Proofreading Service

This document certifies that the above manuscript was proofread and edited by James Virga's Editing and Proofreading Service. One academic editor edited the document for proper English, language, grammar, punctuation, spelling, and overall style. The editor endeavoured to ensure that the author's intended meaning was not altered during the review. The author(s) may accept or reject any changes upon receipt of the edited document. This editorial service was provided via fiverr.com.

Kind regards,
James Virga