University of Alberta

RELIABILITY OF SCAPULAR POSITIONING MEASUREMENT PROCEDURE USING THE PALPATION METER (PALM)

by

Bruno Cezar Roza da Costa

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Physical Therapy

Edmonton, Alberta

Spring 2008

Library and
Archives Canada

Published Heritage
Branch

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque et
Archives Canada

Direction du
Patrimoine de l'édition

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 978-0-494-45797-9
Our file Notre référence
ISBN: 978-0-494-45797-9

NOTICE:
The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:
L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

ABSTRACT

Altered scapular positioning is highly related to shoulder pain and dysfunction. However, there is a lack of reliable and inexpensive clinical tools for measuring the position of the scapula. Therefore, the objective of this study was to investigate whether the PALM is a reliable instrument to measure scapular positioning.

Thirty normal subjects (mean age of 26.5 years) were recruited for a test-rest reliability study. The following dimensions were measured: horizontal distance between the scapula and the spine (intra-rater ICC: 0.69-0.89, inter-rater ICC: 0.74-0.89; intra-rater SEM: 0.56-1.17cm., inter-rater SEM: 0.59-0.98cm.) and the vertical distance between C_7 and the acromion (intra-rater ICC: 0.72-0.78, inter-rater ICC: 0.76; intra-rater SEM: 0.66-0.79cm., inter-rater SEM 0.64cm.).

Based on the results of the present study, it can be stated that measurement of scapular positioning using the PALM is intra and inter-rater reliable and has low measurement error.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

PROBLEM STATEMENT

In different communities, shoulder pain is found to be either the second or the third most common site of musculoskeletal pain and it is the most frequent acute musculoskeletal pain complaint seen in general practice (Picavet and Schouten, 2003; Urwin et al, 1998). Musculoskeletal pathology is the chronic condition with the highest proportion of disability related to mobility (Picavet and van den Bos, 1997).

A recent study (Picavet et al, 2003) showed that the general population of the Netherlands had a 21% prevalence of shoulder pain. The only higher prevalence was low back pain (27%). In 1998, Urwin showed a lower but significant shoulder pain prevalence of 16% in the British general population. Miranda et al (2005), showed the same prevalence for shoulder pain of 14% in the general population of Finland.

Ostor et al (2005) reported that morbidity is a problem that goes along with shoulder pain. Most disabilities caused by shoulder pain are daily life activities such as bathing, dressing and toileting. Furthermore, patients with shoulder pain usually show a slow recovery. Of all the new episodes of shoulder complaints, only 50% show complete recovery within 6 months, and 40% persist up to one year (Kuijpers et al 2004). Macfarlane et al (1998) reported up to 54% of the patients with shoulder pain complained of symptoms 3 years after the first episode. One of the possible reasons for this is the anatomical and biomechanical complexity of the shoulder girdle, which makes diagnosis more difficult. Without an accurate diagnosis, prescription of correct treatment is more unlikely to occur, which would result in a longer period of recovery.

Taking into consideration how dysfunctional shoulder pathology might be, a thorough clinical evaluation is of major importance to a precise diagnosis and effective treatment. Different authors have stated the importance of observing and measuring scapular positioning when evaluating the shoulder complex (Hawkins and Misamore, 1996, Rockwood and Matsen, 1998, Kibler, 1998, Donatelli, 2004, Krishnan, Hawkins, and Warren, 2004, Sahrmann, 2005, Magee, 2002). Also, it has been stated by different authors that observation of the static position of the scapula can play a role in determining a functional diagnosis (Hawkins and Misamore, 1996, Kibler 1998, Donatelli, 2004, Sahrmann, 2005, Magee, 2002). When a faulty position is observed, inference can be made about muscle imbalance, presence of neuropathy, incorrect muscle recruitment, congenital deformity of the scapula, among other pathologies (Hawkins and Misamore, 1996, Rockwood and Matsen, 1998, Kibler, 1998, Donatelli, 2004, Sahrmann, 2005, Magee, 2002).

If the scapula, in the resting position, is found to be protracted, it might be a possible cause for a patient's shoulder pathology. Protraction of the scapula occurs when the medial border of the scapula moves away from the vertebral column around the thoracic wall, and internally rotates (Culham and Peat, 1993). A protracted scapula is considered to be potentially harmful for the shoulder joint. Solem-Bertorft and associates (1993), using magnetic resonance imaging, observed a significant decrease in the subacromial space during protraction of the scapula. Even a few millimeters decrease in the subacromial space can be considered significant since there is only 11 millimeters available (Azzoni et al, 2004).

Decreasing the subacromial space can lead to shoulder impingement syndrome

(Rockwood and Matsen, 1998). Impingement syndrome is one of the most debilitating conditions of the shoulder (Ostor et al 2005). Seventy-four percent of patients with shoulder pain present with signs of shoulder impingement, and it is considered to be the main cause of shoulder tendinitis (Ostor et al., 2005).

Sahrmann (2005) also stated that finding either a retracted or protracted scapula in the scapular resting position could contribute to shoulder pathology. She also claims that these deviations usually do not occur in isolation. If a scapula is protracted, it would also be internally rotated (movement on the transverse plane where the lateral border of the scapula is anterior to the medial side of the scapula). If the scapula is retracted (opposite movement of protraction when medial border of the scapula moves towards the vertebral column) in its resting position, it usually is also inferiorly rotated (movement in the sagittal axis where the inferior angle of the scapula approaches the vertebral column and the glenoid faces inferiorly). Both conditions could contribute to pathology and symptoms such as shoulder impingement syndrome, a rotator cuff tear, thoracic outlet syndrome, anterior subluxation of the glenohumeral joint, shoulder instability, sub-deltoid bursitis, pain in the rhomboids and middle trapezius in the interscapular region, pain in the sternoclavicular joint, tendinopathy of the biceps, infraspinatus and supraspinatus muscles (Sahrmann, 2005).

Although Sahrmann reported 7.5 cm as a normal distance between the root of the spine of the scapula and the vertebral column, the study which was the source of the information only used a sample of 15 participants composed of women between the ages of 19 and 21 (Sobush et al 1996). Thus, the literature is lacking information that reports on the value of the distance of the medial border of the scapula from the vertebral column that would enable one to more readily generalize to a larger population by using a larger sample. In order to identify an incorrect position of the scapula as a possible cause for shoulder pathology, it is essential to have a reference value of scapular position.

In the present study, values obtained were from a convenience sample of normal individuals and as such may be used as a reference value against which the observed value on the patient can be viewed (Andrews et al, 1996). Values from "normal" individuals are of great importance for both clinical and research purposes. Clinicians need accurate reference values to compare patients with "normal" individuals and to determine whether the value contributes to pathology, and researchers, when studying pathology, need access to accurate values from "normal" individuals to determine possible etiological factors for different conditions. Moreover, when a clinician makes a comparison between values obtained in the clinical setting and the values obtained from normal subjects, these comparisons are only valid if the method used in the clinic reproduces the one used in the study that reported such values of normal subjects (Andrews et al, 1996). A study that reports values obtained from "normal" individuals and presents a measurement technique that is simple to reproduce in a clinical setting is of great importance. This study determined the reliability of a procedure for scapular measurement that is inexpensive and simple to reproduce. If reliability is shown to be good enough, this study will make research investigating scapular positioning more viable. Also, clinicians using these reference values will be able to use the same instrument used in these studies. This is because the instrument used in this study is more affordable.

DEFINITION OF TERMS

1. Protraction of the scapula: this occurs when the medial border of the scapula moves away from the vertebral column.
2. Retraction of the scapula: this occurs when the medial border of the scapula moves towards the vertebral column.
3. Scapular elevation: superior glide of the scapula along the rib cage.
4. Scapular Depression: inferior glide of the scapula along the rib cage.
5. The dominant upper-extremity: the upper-extremity identified by the participant as the one preferred to throw a ball (Andrews et al, 1996).
6. Shoulder activity level: defined by the Shoulder Activity Scale (Brophy et al, 2005).
7. Scapular resting position: the arms hanging at the side of the body.
8. Palpation Meter (PALM): a device that combines the features of a caliper and an inclinometer.
9. Normal posture: the position that a particular individual usually takes while standing. Consequently, each individual presents his/her own normal posture depending on their habitual standing posture (Sobush et al, 1996).

PURPOSE

General purposes

The present study was intended to investigate the intra and inter-reliability of a procedure using the PALM to measure scapular position bilaterally.

Specific purposes

The present study investigated in a convenience sample of normal individuals between 18 and 40 years old (mean age of 26.5 years) whether the proposed procedure using the PALM is reliable to measure on both sides:

1. Horizontal distance between the inferior angle of the scapula and the vertebral column in glenohumeral resting position, 90 degrees of scaption, and complete elevation
2. Horizontal distance between the root of the spine of the scapula and the vertebral column in glenohumeral resting position, 90 degrees of scaption, and complete elevation
3. Normalized horizontal distance between the inferior angle of the scapula and the vertebral column in glenohumeral resting position, 90 degrees of scaption, and complete elevation
4. Scapular vertical distance from the seventh cervical vertebrae in the scapular resting position (Measurement explained in Section 3).

HYPOTHESES

The following hypotheses are the basis of this study:

1. There will be a significant intra-rater reliability between session 1 and 2 for scapular horizontal distance from the vertebral column measurements for investigator 1, 2 and 3.
2. There will be a significant inter-rater reliability between investigator 1, 2 and 3 for measurements of scapular horizontal distance from the vertebral column.
3. There will be a significant intra-rater reliability between session 1 and 2 for scapular vertical distance from the seventh cervical vertebrae measurements for investigator 1
4. There will be a significant inter-rater reliability between investigator 1, 2 and 3

for measurements of scapular vertical distance from the seventh cervical vertebrae

LIMITATIONS OF THE STUDY

This study will be limited to:

1. Measuring scapular vertical distance from the seventh cervical vertebrae and scapular horizontal distance from the vertebral column using a two-dimensional measurement device (Palpation Meter).
2. The ability of the examiners to landmark by palpation.
3. The ability of the participant to maintain isometric contraction of the muscles of the tested shoulder while the measurements are taken.
4. A convenience sample.

DELIMITATIONS OF THE STUDY

1. The age of the subjects examined will be between 18 and 40 years old.
2. This study will deal only with static positions of the arm in the scapular plane.
3. This study will deal only with subjects with no known shoulder, thoracic or cervical pathologies.

CHAPTER 2

REVIEW OF THE LITERATURE

SHOULDER ANATOMY

The shoulder is composed by three real joints (sternoclavicular, acromioclavicular, and glenohumeral joint) and one quasi-joint (scapulothoracic joint). This complex of joints is also known as the shoulder girdle.

Glenohumeral Joint

The glenohumeral joint is a multiaxial, ball-and-socket, synovial joint. Its resting position is 55 degrees of abduction and 30 degrees of horizontal adduction, and its close packed position is full abduction and lateral rotation. The glenohumeral joint capsular pattern is lateral rotation, abduction, and medial rotation (Magee, 2002).

The head of the humerus and the glenoid cavity of the scapula are the bony structures that compose the joint. The glenoid cavity of the scapula is a structure with not enough depth or diameter to involve and stabilize the head of the humerus (Figure 1). It only covers about one third of the humeral head at a given time (Donatelli, 2004). Hence, stabilization of this joint is primarily done by the muscles, ligaments, and a capsule that are intrinsic to this joint. A fibrocartilagenous ring, called the glenoid labrum, increases the contact between the humerus and the glenoid cavity in about 50% (Magee, 2002).

The glenoid tilts superiorly 5 degrees (average), which is important in preventing inferior instability of the glenohumeral joint, and also tilts 8 degrees posteriorly, which is important in preventing anterior dislocation (von Schroeder et al, 2001; Rockwood and Matsen, 1998; Magee and Reid, 1996). This orientation of the glenoid passively prevents inferior and anterior instability by creating a mechanical restriction to inferior and anterior translation of the humeral head. The angle between neck and shaft of the humerus is about 130 degrees. The head of the humerus has 30 to 40 degrees of retroversion in relation to the line joining the epicondyle (Magee, 2002).

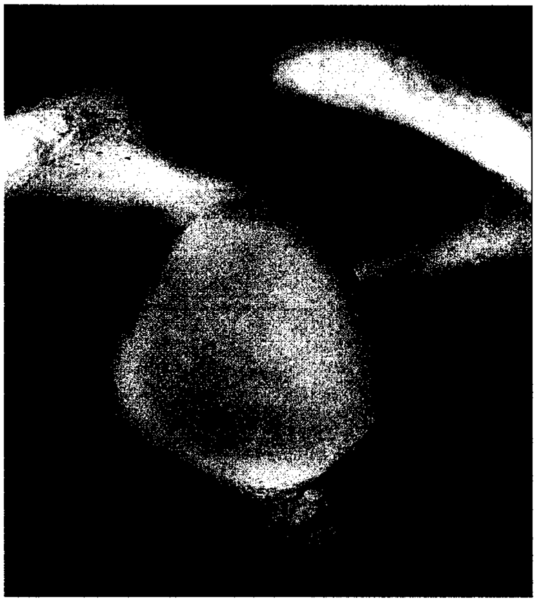


Figure 1. The glenoid cavity (*From* Prescher A: Anatomical basics, variations, and degenerative changes of the shoulder joint and shoulder girdle. Eur J Radiol 35(2), 2000. p. 96)

The superior, inferior, and middle glenohumeral ligaments are the main ligaments in this joint. The superior glenohumeral ligament's main function is to limit inferior translation in adduction, but it also restrains anterior translation and lateral rotation up to 45 degrees of abduction. The middle glenohumeral ligament restrains lateral rotation between 45 and 90 degrees of abduction. The inferior glenohumeral ligament complex has attachments on the anterior and posterior sides of the glenoid and is a hammock like structure. This complex is considered to be the primary stabilizer against anteroinferior shoulder dislocation. At 90 degrees of abduction, it supports the humeral head limiting inferior translation. The anterior band of the complex tightens during lateral rotation and the posterior band tightens during medial rotation (Magee, 2002).

The coracohumeral ligament plays an important role in sustaining the glenohumeral joint. The rotator cuff interval, which is an area unprotected by the active stabilization of the rotator cuff muscles, is reinforced by the coracohumeral ligament. Its main function is to limit inferior translation and to help limit lateral rotation below 60 degrees of abduction. The coracoacromial ligament forms an arch located above the head of the humerus stopping it from superior translation (Magee, 2002; Donatelli, 2004) (Figure 2).

The muscles that cross the joint are divided into intrinsic (one joint muscles) and extrinsic (multiple joint muscles) (Rockwood and Matsen, 1998). The intrinsic muscles are important stabilizers of the glenohumeral joint:

- Deltoid
- Supraspinatus (rotator cuff muscle)
- Infraspinatus (rotator cuff muscle)
- Teres minor (rotator cuff muscle)
- Subscapularis (rotator cuff muscle)
- Teres major
- Coracobrachialis

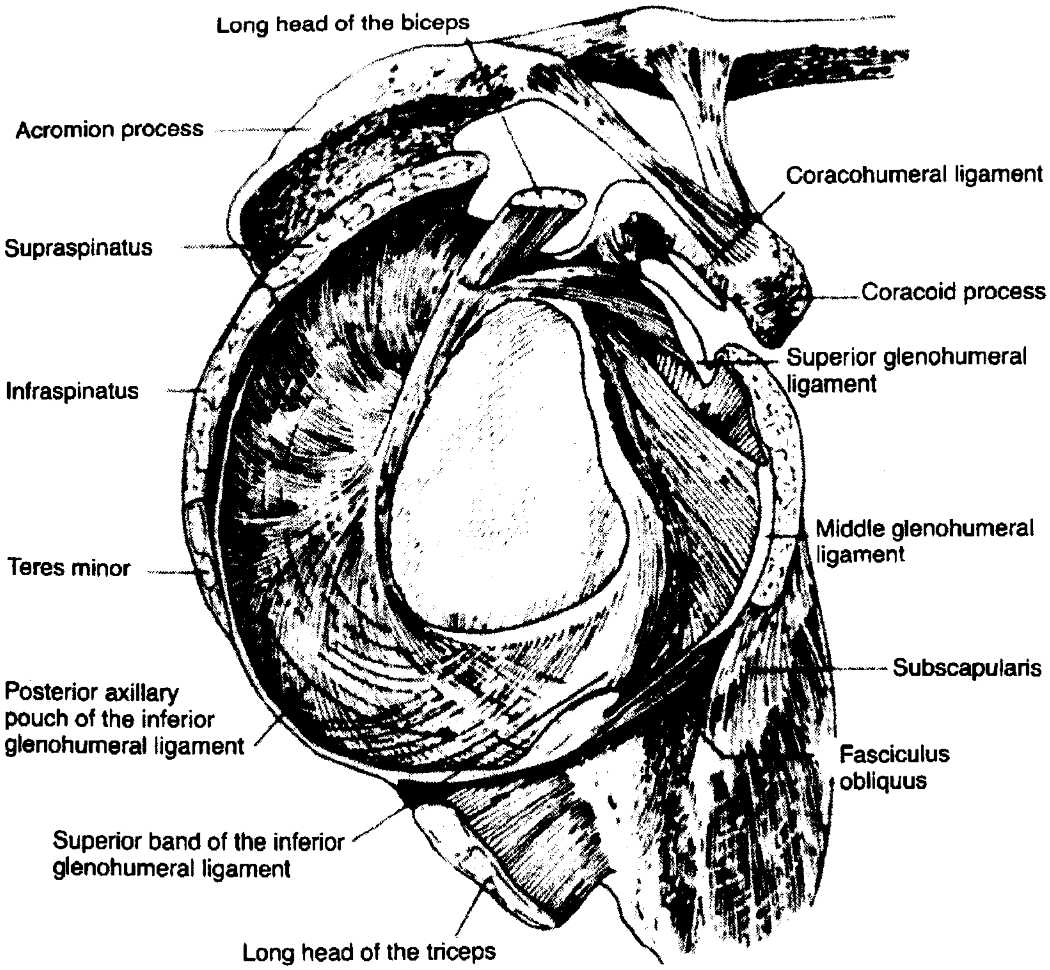


Figure 2. This picture shows some of the main stabilizing muscles and ligaments of the glenohumeral joint. (*From* O'Brien SJ, et al: Developmental Anatomy of the Shoulder and Anatomy of the Glenohumeral Joint. *In* Rockwood CA, Matsen III FA: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p.19.)

The rotator cuff muscles play an important role in glenohumeral joint movement and stabilization by during contraction causing compression of the humeral head in the glenoid cavity (Figure 3). The deltoid is divided into three portions: anterior, middle and posterior. The deltoid contributes to dynamic stability with the arm in the scapular plane, and has a decreased contribution with the arm in the coronal plane. The middle and posterior portions generate more stability since they create more compression forces and less shearing forces than the anterior portion (Donatelli, 2004).

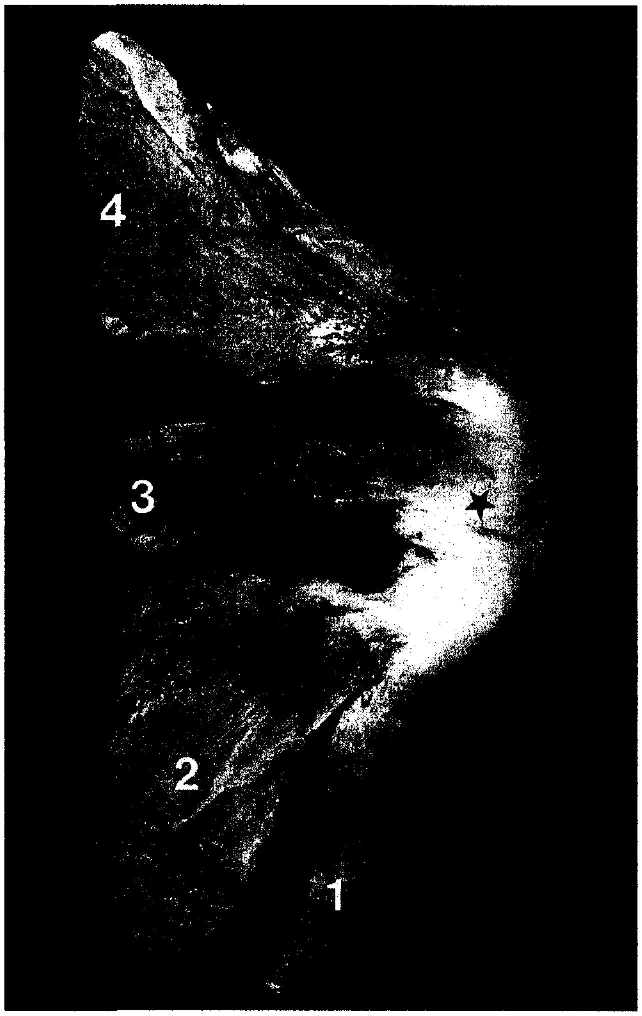


Figure 3. Rotator cuff (star) and adjacent muscles, (1) M. teres minor; (2) M. subscapularis; (3) M. supraspinatus; (4) M. infraspinatus. (*From* Prescher A: Anatomical basics, variations, and degenerative changes of the shoulder joint and shoulder girdle. Eur J Radiol 35(2), 2000, p. 98).

The extrinsic muscles act on the glenohumeral joint and either the scapulothoracic or elbow joint. Their main function is to create movement at the joint:

- Pectoralis major (the glenohumeral joint)
- Latissimus dorsi (the glenohumeral joint and in some cases, the scapulothoracic joint)
- Biceps brachii (the glenohumeral and elbow joint)
- Triceps brachii (the glenohumeral and elbow joint)

The pectoralis major is divided into three portions: the clavicular portion, the sternocostal portion, and the rotated fibers of the sternocostal portion (Rockwood and Matsen, 1998) (Figure 4).

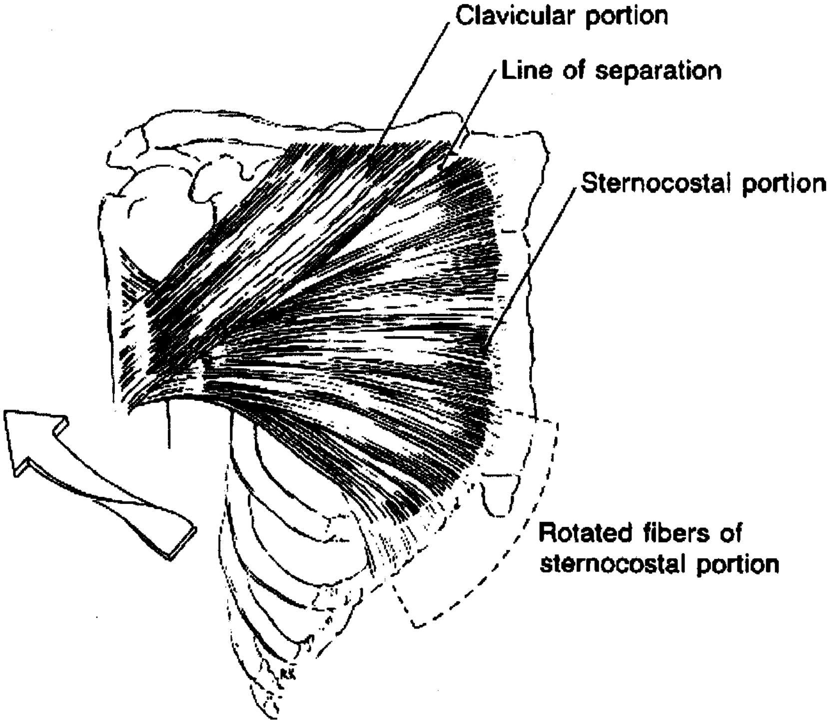


Figure 4. Divisions of the pectoralis major muscle. The 180 degrees of rotation of the lower portion of the sternocostal division is also shown. (*From* Jobe CM: Gross Anatomy of the Shoulder. *In* Rockwood CA, Matsen III FA: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p. 63).

Table 1 shows the action of the intrinsic and extrinsic glenohumeral muscles.

Scapula and the Scapulothoracic Joint

The scapula is situated posteriorly on the chest wall. It is a wide, flat bone in the shape of a triangle with its apex inferiorly and its base superiorly, and has irregular ridges that are important for muscle attachment (Kibler, 1998; von Schroeder, 2001) (Figure 5 and 6). The scapula's medial border is located approximately 7.5cm from the spine and normally it extends from the level of T2 spinous process to the T7 or T9 spinous process, depending on the size of the scapula (Sahrmann, 2005; Magee, 2002).

The scapula in men is significantly larger than in women and the taller the person is, the larger the scapula (von Schroeder, 2001; Anetzberger, 1996).

INTRINSIC	Deltoid	Flexion, Abduction, Extension, Horizontal adduction and abduction, Internal and External rotation	ACTION
	Supraspinatus	Active with any motion involving elevation	
	Infraspinatus	External rotation, Depressor of the humerus head	
	Teres Minor	External rotation	
	Subscapularis	Internal rotation, Depressor of the humeral head	
	Teres Major	Internal rotation, Adduction, Extension	
	Coracobrachialis	Flexion, Adduction	
EXTRINSIC	Pectoralis Major	Flexion, Adduction, Internal Rotation, Horizontal adduction, Scapula depressor	
	Latissimus Dorsi	Extension, Internal rotation, Adduction, Scapula downward rotator	
	Biceps Brachii	Flexion and supination of the forearm	
	Triceps Brachii	Extension of the forearm	

Table 1. Action of intrinsic and extrinsic muscles. (*In* Rockwood CA Jr, Matsen FA III: The Shoulder, ed 1, vol 1. Philadelphia, WB Saunders, 1998, p. 57.)

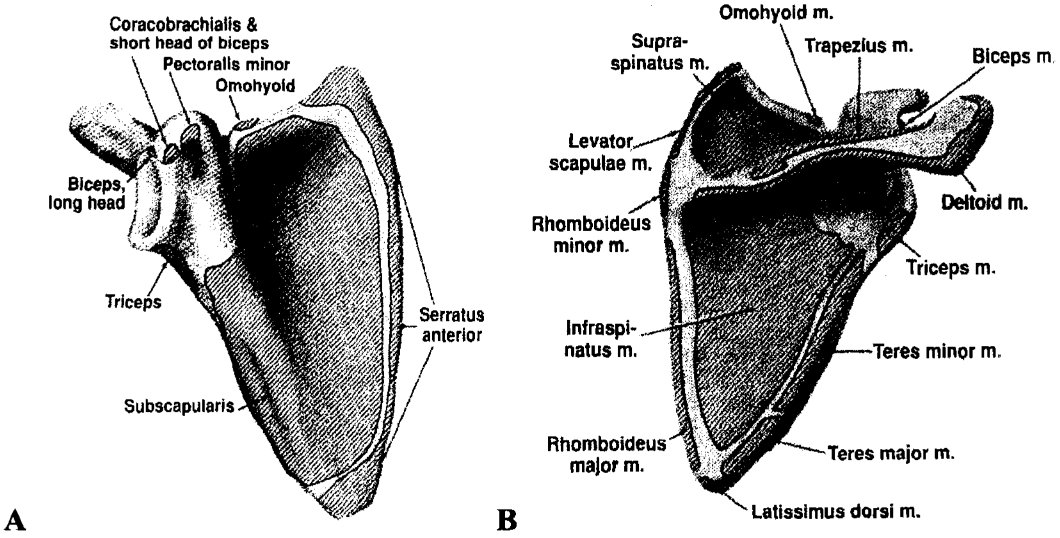


Figure 5. A: Muscles that attach to the anterior surface of scapula and their insertions. B: Muscles that attach to the posterior surface of the scapula and their insertions. (*From* Butters KP: The scapula. *In* Rockwood CA Jr, Matsen FA III: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p. 391-392.)

The scapula, along with the posterior thoracic wall and its muscles, constitutes the scapulothoracic joint. The scapulothoracic joint is not a true joint. Because of this, it does not have a capsular pattern or a closed packed position. Its resting position is with the arm hanging at the side of the body (Magee, 2002; Rockwood and Matsen, 1998).

The acromion is situated on the superior-lateral aspect of the scapula. Three types of acromion processes are described in the literature: type I, flat (18 percent); type II, curved (41 percent); type III, hooked (41 percent) (Magee and Reid, 1996). In 2001, Shah et al. suggested the acromion process is flat at birth, and due to a dysfunctional rotator cuff, intermittent traction on the acromion can occur from the coracoacromion ligament, which leads to degenerative changes on the anterior and inferior surface of the acromion, giving the curved or hooked shape to it (Shah, et al., 2001). Both types could lead to impingement, especially the hooked type (Magee and Reid, 1996; Shah, et al., 2001).

In a resting position, the scapula is 30 degrees internally rotated, tilted 20 degrees anteriorly, and is rotated upwards 3 degrees (Magee and Reid, 1996; Rockwood and Matsen, 1998). This positioning improves function by increasing forward reach, since it facilitates movement on the anterior frontal plane and movements above the head (Magee and Reid, 1996). Mal-positioning of the scapula that alters the position just described could lead to pathologies such as impingement, instability and labral tears.

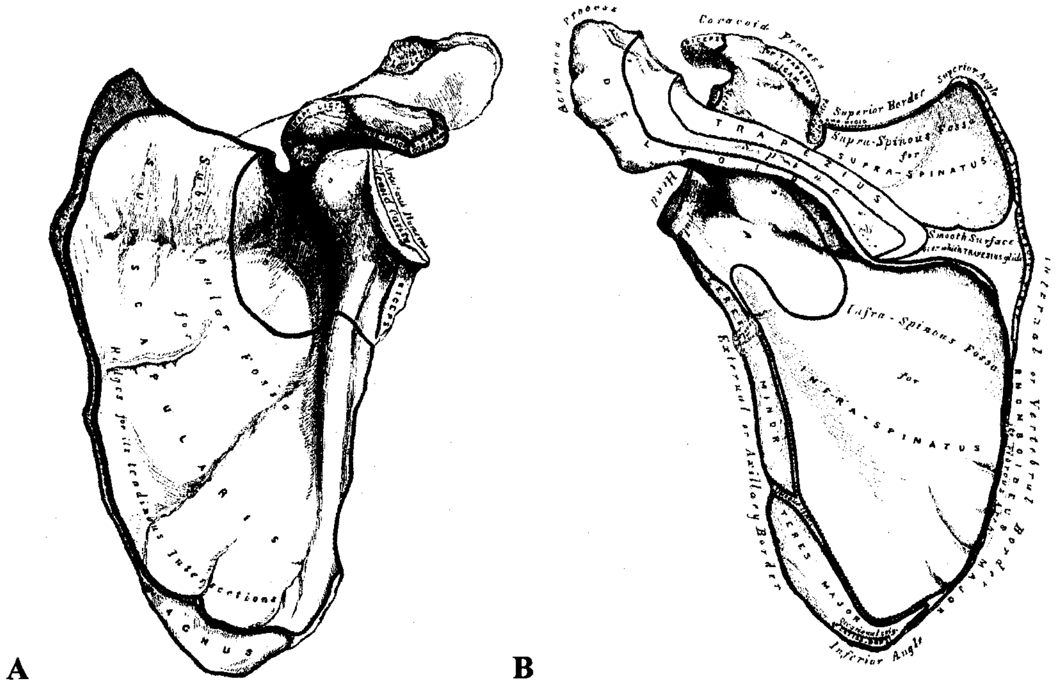


Figure 6. A: anterior surface of the scapula. B: posterior surface of the scapula. (*From* Osteology. *In* Gray HFRS: Gray's anatomy, ed 15. Finland, WSOY, 1985, p. 108-109.)

The scapula, when compared to other bones in the human body, "floats" on the posterior region of the thorax. It is attached to the axial skeleton at the acromioclavicular joint, and stabilized in the back by muscles that attach to its surface (Kibler, 1998) (Figure 7). This structure of passive, active and also neural stabilization, if working properly, allows the scapula to have a large amount of freedom to glide laterally and rotate upwards on the chest wall, but constrains excessive and undesired movements so that the scapula can perform its roles well (Kibler, 1998; Sahrmann, 2005). Kibler (1998) described the importance of a stable scapula to allow the other structures to ideally perform their stabilizing roles: "Proper alignment of the glenoid allows the optimum function of the bony constraints to glenohumeral motion and allows the most efficient position of the intrinsic muscles of the rotator cuff to allow compression into the glenoid socket, hereby enhancing the muscular constraint systems around the shoulder as well" (p. 326).

The muscles that attach to the scapula are divided into three groups (Kibler, 1998). The first group, responsible for stabilizing the scapula, are:

- Trapezius (superior, middle and inferior fibers)
- Rhomboids (major and minor)
- Levator Scapulae
- Serratus Anterior

In the second group there are bigger and more powerful muscles that originate from the scapula but their main role is moving the arm rather than stabilizing the scapula:

- Deltoid
- Biceps
- Triceps
- Latissimus Dorsi (occasionally attaches to the scapula due to anatomical variations)

In the last group are found the intrinsic muscles of the rotator cuff, which main role is to stabilize the glenohumeral joint:

- Subscapularis
- Supraspinatus
- Infraspinatus
- Teres Minor

Other muscles that do not fit in those groups but have an important influence over the scapula are the Teres Major, Coracobrachialis, Pectoralis Major and Minor muscles.

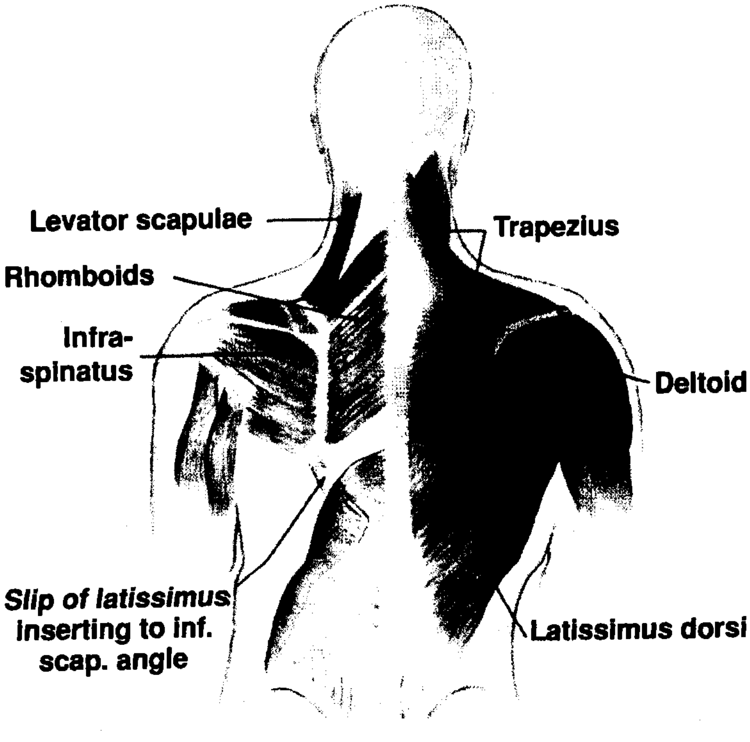


Figure 7. Posterior trunk muscles. On the right side the superficial layer. On the left side the deep layer. (*From* Butters KP: The scapula. *In* Rockwood CA Jr, Matsen FA III: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p. 393.)

Table 2 shows the muscles that stabilize the scapula and their action:

Scapula Stabilizers	**Actions on the Scapula**
Serratus Anterior	• Upward rotator • Abductor
Trapezius	• Upward rotator • Adductor
Levator Scapulae	• Downward rotator • Adductor
Rhomboideus Major and Minor	• Downward rotator • Adductor
Latissimus Dorsi	• Downward rotator
Pectorilis Minor	• Anterior tilt

Table 2. Muscles that stabilize the scapula and their action. (*From:* Sahrmann, S.A., Diagnosis and Treatment of Movement Impairment Syndromes. Sao Paulo, SP: Santos Editora, 2005, p.207).

Acromioclavicular Joint

The acromioclavicular joint is a plane synovial joint. Its resting position is with the arm at the side of the body, and its close packed position is with the arm at 90 degrees of abduction. The joint's capsular pattern is pain at extremes of range of motion, especially horizontal adduction and full elevation (Magee, 2002).

The lateral end of the clavicle and the acromion process of the scapula compose this articulation. This joint is characterized by the variation that occurs with size and shape of the clavicular facets and the presence of an intraarticular meniscus, which usually has a large perforation in its center (Rockwood and Matsen, 1998; Donatelli, 2004). A fibrous capsule surrounds the joint, and it tends to be thicker on its superior, anterior, and posterior surfaces in comparison to its inferior surface. This capsule is not as strong as the sternoclavicular joint's capsule (Rockwood and Matsen, 1998).

This joint relies on its ligaments for stabilization. There are three main supporting ligaments for this joint (Figure 8). The coracoclavicular ligament (composed of the conoid and trapezoid ligaments), and the acromioclavicular ligament, which surrounds the joint and is usually the first ligament injured when stress is applied to the joint (Rockwood and Matsen, 1998; Magee, 2002).

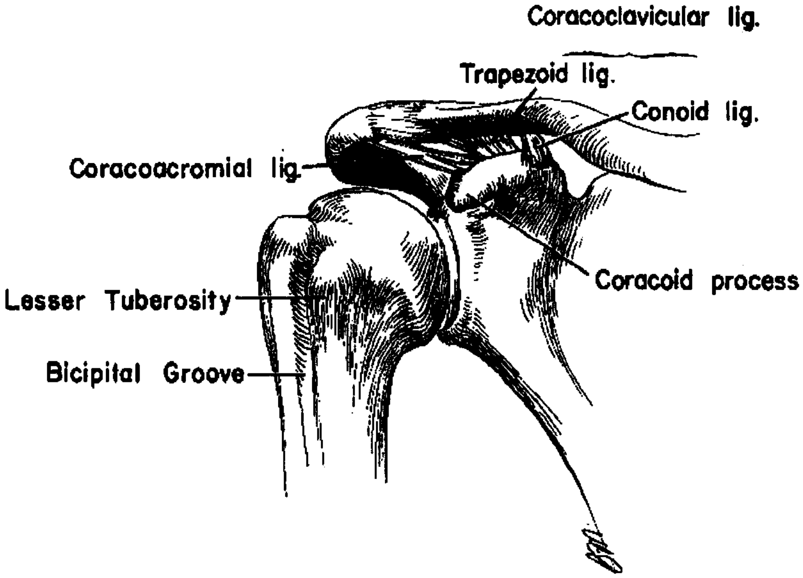


Figure 8. Acromioclavicular joint and its ligaments. (*From* Rockwood CA, Williams GR, Young DC: Disorders of the Acromioclavicular Joint. *In* Rockwood CA Jr, Matsen FA III: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p.485.)

Sternoclavicular Joint

The sternoclavicular joint is a saddle-shaped synovial joint and is the only joint that connects the shoulder girdle to the axial skeleton. Its resting position is with the arm by the side of the body, and its close packed position is with full elevation of the arm. The joint's capsular pattern is pain at extremes of range of motion, especially horizontal adduction and full elevation (Magee, 2002).

The sternoclavicular joint is composed by the medial end of the clavicle, the manubrium of the sternum, and the cartilage of the first rib. There is a disc that separates the clavicle from the sternum, which is essential to the stability of the joint preventing medial displacement of the clavicle. This joint also mainly relies on its ligaments for stability (Figure 9). The interclavicular ligament strengthens the capsule inferiorly and anteriorly, and the costoclavicular ligament connects the clavicle to the first rib. This joint is also stabilized by the joint capsule and reinforcing muscles (Magee, 2002; Donatelli, 2004).

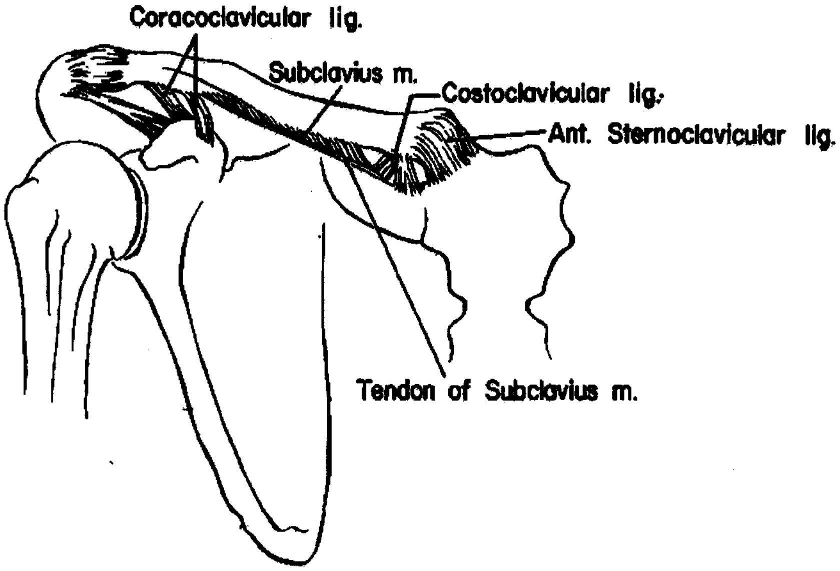


Figure 9. Sternoclavicular and acromioclavicular joints. (*From* Rockwood CA, Wirth MA: Disorders of the Sternoclavicular Joint. *In* Rockwood CA Jr, Matsen FA III: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p. 556.)

SHOULDER KINETICS AND KINEMATICS

Scaption, as previously defined, is the elevation of the arm in the scapular plane. The scapular plane is located between 30 and 45 degrees anterior to the frontal plane (Poppen and Walker, 1976). It has been suggested that the true plane of movement at the shoulder joint occurs in the plane of the scapula (Johnston, 1937; Poppen and

Walker, 1976). Different authors believe that scaption is more functional because the length-tension relationship in this plane of elevation is best for the shoulder abductors and rotators, therefore, more clinically relevant (Johnston, 1937; Poppen and Walker, 1976; Borsa et al, 2003). Also, there is an increase in joint congruity during scaption, which leads to a greater joint stability (Poppen and Walker, 1976). Furthermore, Borsa et al (2003) reported greater scapular upward rotation in scaption and recommended that the scapular plane should be used for overhead rehabilitation exercises. Taking these characteristics of scaption into consideration, Donatelli (2004) believes that this plane of arm elevation is best for testing, since it comprises optimum glenohumeral stability, minimal scapular torsion, avoidance of impingement, and balance of muscle action.

For its relevance to the topic of the study, emphasis will be given to movements of the shoulder girdle during scaption whenever information is available. Since the shoulder girdle involves different joints, each joint movement will be described separately.

Scapulothoracic Joint

Ebaugh et al (2005) described three-dimensional scapulothoracic motion during active and passive arm elevation while simultaneously recording shoulder muscle activity. The study results showed that during active arm elevation in the scapular plane (40 degrees anterior to the frontal plane), the scapula tilted posteriorly, reaching maximum posterior tilt (3.1 degrees) at 90 degrees of arm elevation. At maximum elevation, the scapula was anteriorly tilted (-3.0 degrees).

Data showed that when the arm was elevated 20 degrees in the scapular plane, the scapula upwardly rotated 29.0 degrees, and at maximum elevation, the scapula was rotated upwards 83.7 degrees. Scapular upward rotation motion was constant throughout arm elevation.

The scapula was internally rotated 44.5 degrees at 20 degrees of scaption, and it moved to 42.5 degrees of internal rotation (2.0 degrees of external rotation) at 90 degrees of scaption and ended with 42.9 degrees of internal rotation (1.6 degrees of external rotation) at maximum arm elevation. It can be seen from this information that the internal rotation of the scapula decreased from the initial position to the final position, indicating that there is a movement of external rotation of the scapula throughout elevation of the arm.

Decreased posterior tilt, combined with upward and external rotation of the scapula was observed during passive arm elevation when compared to active arm elevation (Table 3).

Ebaugh emphasized the importance of increased upward rotation and external rotation of the scapula during active movement. Although the changing differences are small, even small differences in degrees could be important to avoid shoulder impingement during full abduction, scaption or flexion. Ebaugh stated that the difference between active and passive movements was due to contraction of the muscles serratus anterior and the superior and inferior portions of the trapezius during active movement.

	POSTERIOR TILT OF THE SCAPULA	UPWARD ROTATION OF THE SCAPULA	EXTERNAL ROTATION OF THE SCAPULA
TWENTY DEGREES OF SCAPTION	**Active:** 0.38^0 **Passive:** -0.34^0	**Active:** 29.0^0 **Passive:** 28.9^0	**Active:** -44.5^0 **Passive:** -46.4^0
MAXIMUM ELEVATION	**Active:** -3.0^0 **Passive:** -5.5^0	**Active:** 83.7^0 **Passive:** 80.8^0	**Active:** -42.9^0 **Passive:** -48.6^0

Table 3. Means in degrees for scapular active and passive motion. (*From* Ebaugh DD, McClure PW, Karduna AR: Three-dimensional scapulothoracic motion during active and passive arm elevation. Clin Biomech 20(7), 2005, p. 704).

In another study about three-dimensional scapular orientation and position (Ludewig et al, 1996), somewhat different movement patterns were observed. Arm elevation was also observed in the scapular plane. However, in this study, scapular plane was considered to be 30 degrees anterior to the frontal plane, instead of 40 degrees anterior to the frontal plane as in the previously mentioned study, and the arm was elevated only up to 140 degrees. The scapula movement pattern in this study also revealed increased upward rotation of the scapula following arm elevation. However, posterior tilting and external rotation of the scapula constantly increased until 140 degrees of arm elevation was reached, differing from the other study where they either decreased or stayed constant.

In normal arm abduction, the scapula moves laterally in the first 30 to 50 degrees of elevation (Kibler, 1998). Depending on the size of the person and the intensity of shoulder activity, translation of the scapula in protraction and retraction could occur over distances of 15 to 18cm (Kibler, 1998). The literature lacks studies that describe protraction and retraction of the scapula more thoroughly, and in different planes of elevation.

Clavicular Movement

Concomitant movement occurs between the scapulothoracic joint and the acromioclavicular joint and the sternoclavicular joint. If abnormal scapulothoracic joint movement occurs, abnormal movement at one or both of these joints must occur (Ludewig, et al, 2004). Therefore, it is important to understand their relationship in order to identify and correct possible shoulder abnormal patterns of movement leading to pathologies.

Ludewig and associates (2004) reported values for clavicle motion during arm elevation in the sagittal, scapular, and frontal plane observed on an asymptomatic shoulder group. Clavicular movements (elevation, posterior rotation and retraction) were associated with scapular movement and constantly increased during all arm elevations, except for retraction of the clavicle during flexion (Figure 10). Values are presented on Table 4.

Although some of the measurements presented relatively high variability, Ludewig's study was one with a large sample size that observed these variables during dynamic movements of arm elevation. One of the possible reasons for such a high standard deviation in this study is greater heterogeneity among participants (age ranged from 18 to 50 years). Also, although using a large sample size, it might not have been large enough to compensate for such heterogeneity. High standard deviation values in this study are probably not due to measurement error since intraclass correlation coefficient values in this study were excellent, ranging from 0.94 to 0.98.

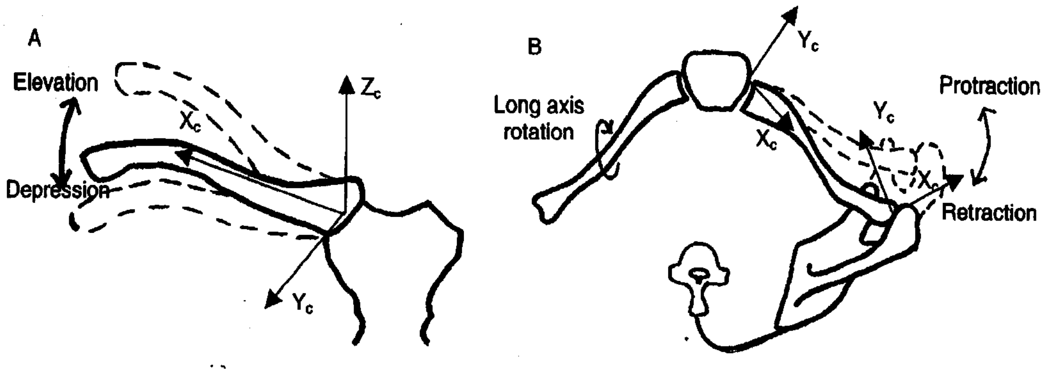


Figure 10. Clavicular axes and motions: Xc = clavicular x axis, Yc = clavicular y axis, Zc = clavicular z axis, Xs = scapular x axis, Ys = scapular y axis. A: anterior view of the sternum and clavicle. B: shoulder girdle superior view. (*From* Ludewig PM, Behrens SA, Meyer SM, et al: Three dimensional clavicular motion during arm elevation: reliability and descriptive data. J Orthop Sports Phys Ther 34 (3), 2004, p. 141)

Scapulohumeral Rhythm

Simultaneous movement occurring in the scapulothoracic joint during arm elevation at the glenohumeral joint is called scapulohumeral rhythm. This movement is coordinated, and the ratio 2:1 (2 degrees of movement in the glenohumeral joint to 1 degree of movement in the scapulothoracic joint) is the main consensus found in the literature (Michiels and Grevenstein, 1994; Halder, et al., 2000; Inmann, et al., 1944; Bagg and Forrest, 1998; Hamill and Knutzen, 2003). Inman et al (1944) were the first to suggest that for every 2 degrees of movement in the glenohumeral joint, 1 degree of movement occurred in the scapulothoracic joint. They reported that 120 degrees of humeral movement and 60 degrees of scapula movement occurred during arm elevation and that the ratio of 2:1 remains remarkably constant throughout arm elevation (Figure 11).

	CLAVICLE ELEVATION	**CLAVICLE POSTERIOR LONG-AXIS ROTATION**	**CLAVICLE RETRACTION**
HUMERAL RESTING POSITION	**Mean=** 1.6^{0} **Standard deviation=** $\pm3.3^{0}$	**Mean=** 0.5^{0} **Standard deviation=** $\pm2.5^{0}$	**Mean=** 18.2^{0} **Standard deviation=** $\pm5.8^{0}$
110^{0}OF HUMERAL ELEVATION (Sagittal plane)	**Mean=** 15.0^{0} **Standard deviation=** $\pm6.0^{0}$	**Mean=** 31.3^{0} **Standard deviation=** $\pm15.0^{0}$	**Mean=** 14.9^{0} **Standard deviation=** $\pm7.0^{0}$
110^{0}OF HUMERAL ELEVATION (scapular plane)	**Mean=** 11.1^{0} **Standard deviation=** $\pm5.0^{0}$	**Mean=** 18.2^{0} **Standard deviation=** $\pm11.5^{0}$	**Mean=** 24.8^{0} **Standard deviation=** $\pm7.3^{0}$
110^{0}OF HUMERAL ELEVATION (frontal plane)	**Mean=** 12.2^{0} **Standard deviation=** $\pm6.3^{0}$	**Mean=** 14.6^{0} **Standard deviation=** $\pm10.5^{0}$	**Mean=** 28.7^{0} **Standard deviation=** $\pm7.1^{0}$

Table 4. Clavicle motions during arm elevation in the sagittal, scapular and frontal plane (*From* Ludewig PM, Behrens SA, Meyer SM, et al: Three dimensional clavicular motion during arm elevation: reliability and descriptive data. J Orthop Sports Phys Ther 34 (3), 2004, p. 144).

However, many authors reported different overall ratios in their studies (Saha, 1961; Freedman and Munro, 1966; Doody et al, 1970; Poppen and walker, 1976). Different ratios were found for different angles of arm elevation range of motion, regardless of whether flexion, abduction or scaption (elevation on the scapular plane) took place. Bagg and Forrest (1988) claimed that the scapulohumeral ratio was dynamic; therefore it cannot be considered constant and linear.

The difference between the ratio values reported in these studies might be due to observation during different arm elevation on each study (flexion, abduction or scaption) or to a high degree of variability between people (Bagg and Forest, 1998).

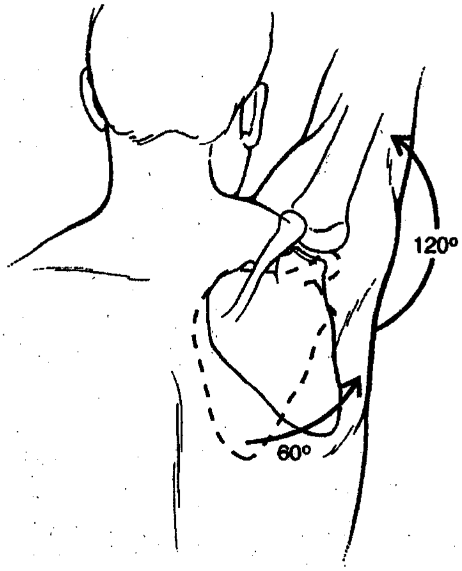


Figure 11. Scapulohumeral rhythm. For 180 degrees of flexion or abduction, approximately 120 degrees of movement occurs in the glenohumeral joint and 60 degrees of movement occurs in the scapulothoracic joint. (*From* Hamill J, Knutzen KM: Functional anatomy of the upper extremity. *In* Hamill J, Knutzen KM: Biomechanical basis of human movement, ed 2.Baltimore, Lippincott Williams & Wilkins, 2003, p. 134.)

Scapulohumeral rhythm function can include the following:

- Shared movement between the glenohumeral and scapulothoracic joints allowing larger range of motion, avoiding overload of both joints.
- Keeping the glenoid in proper position in order to support the humerus and increase congruency and decrease shearing forces.
- To optimize length-tension relation of the scapular muscles so that the muscles that insert into the scapula are better able to generate power.

In the first 30 degrees of arm abduction or 45-60 degrees of arm flexion, the scapula does not present a constant pattern (Sahrmann, 2005; Magee, 2002; Hamill and Knutzen, 2003). During this phase, the scapula could rotate upwards, rotate downwards or not move at all. This phase is called the "setting phase", where the scapula is being stabilized on the chest wall by the scapular stabilizer muscles to provide support for the humerus (Sahrmann, 2005; Hamill and Knutzen, 2003).

During the next 60 degrees of movement (second phase), the scapula rotates 30 degrees upwards, creating the 2:1 ratio (Magee, 2002).

In the third phase there is still a 2:1 ratio between the glenohumeral joint and scapulothoracic joint (Magee, 2002). The joint movements that contribute to scapular movement are 20 degrees of acromioclavicular movement, 40 degrees of sternoclavicular movement and 40 degrees of clavicular posterior rotation (Hamill and Knutzen, 2003).

Since there is still no agreement about whether the ratio is linear or dynamic, it is more important to focus on asymmetry between both shoulders than to worry about the scapulohumeral ratio in each phase (Magee, 2002).

Scapular Instant Center of Rotation

To determine the scapular rotator muscles' action, it is essential to identify the center of scapular rotation (Bagg and Forrest, 1998). It is believed that the scapular center of rotation is not static. Instead, it takes place in different locations as the arm is elevated.

The center of rotation is located near the base of the scapular spine during the initial elevation of the arm in the scapular plane. As the arm elevates further, the instantaneous center of rotation migrates towards the acromioclavicular joint (Bagg and Forrest, 1998). Bagg and Forrest (1988) also stated that the instant center of rotation starts its migratory movement between 60 and 90 degrees of scaption. The instant center of rotation moves to the acromioclavicular joint by 120 - 150 degrees of scaption.

Glenohumeral Instant Center of Rotation

The glenohumeral instant center of rotation (pivot point about which the humerus appears to rotate) throughout elevation of the arm is practically the same, if not the same, in normal individuals (Poppen, and Walker, 1976; Veeger, 2000). Poppen et al. reported the average of the instant center of rotation in the normal individual to be 6.0 millimeters from the geometric center of the humeral ball. They also reported that the abnormal glenohumeral instant center of rotation is located 10 millimeters or more from the geometric center of the humeral ball. These values are geometric estimations based on a spherical fit through the surface of the glenoid.

Veeger (2000) compared two methods of estimation of the glenohumeral instant center of rotation in an attempt to check the validity of these methods. It was concluded that both methods appear to be valid and the results achieved were similar to the ones reported by Poppen et al.

Dislocation of the glenohumeral instant center of rotation occurs due to superior-inferior translation of the humeral head, which was also reported to be very small (0.3 to 0.35mm) (Halder, et al., 2000). However, anterior-posterior translation was quite large (8.7mm). This was said to occur due to the geometrical shape of the glenoid, which is more concave in the superior-inferior direction than in the anterior-posterior direction (Halder, et al., 2000).

Force Couples

Inman et al. (1944) suggested a shared and coordinated scapular movement between the scapula muscles, the force couples. In their study, they mentioned three main force directions: upward rotation, medial contraction and an antero-lateral force over the inferior angle of the scapula. During elevation of the arm, the superior force couple muscles are the upper trapezius, levator scapulae and upper digitations of the serratus anterior; and the inferior force couple muscles are the lower trapezius and lower digitations of the serratus anterior (Halder, et al., 2000). These muscles mainly function in pairs to control the movement or position of the scapula (Figure 12). Bagg and Forrest (1988) suggested a biomechanical model for scapula rotation. They divided upward rotation of the scapula into three phases: the first phase from 20.8 - 81.8 degrees of scaption; the second phase from 81.8 – 139.1 degrees of scaption, and phase 3 from 139.1 – 160.0 of scaption, with the greatest relative amount of upward rotation of the scapula occurring between 80 – 140 degrees of scaption.

During the first phase, the scapula motion was significantly less than glenohumeral motion. Upper trapezius and lower serratus anterior is the main force couple generating upward rotation (Figure 13). They present relatively large force arms when compared to those of the middle and lower trapezius. The scapular instantaneous center of rotation is located at or near the base of the scapula.

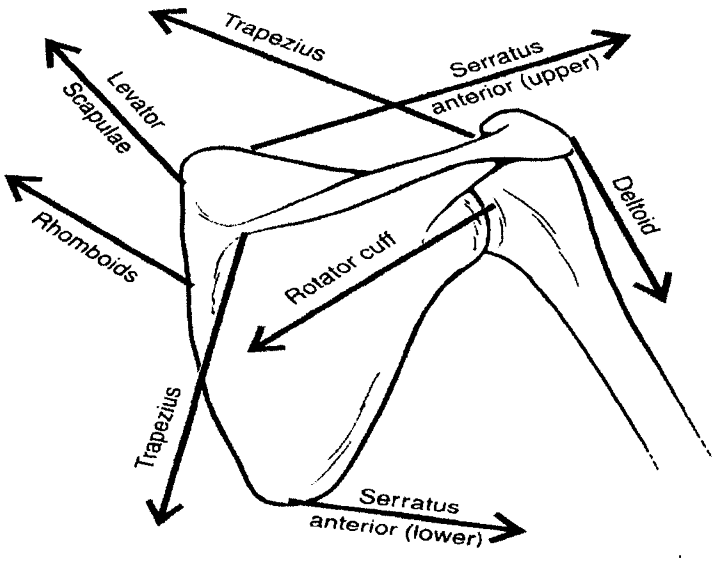


Figure 12. Different force couples acting upon the scapula. (*From* Hamill J, Knutzen KM: Functional anatomy of the upper extremity. *In* Hamill J, Knutzen KM: Biomechanical basis of human movement, ed 2.Baltimore, Lippincott Williams & Wilkins, 2003, p. 135.)

During phase two, there was a larger increase in the scapular movement in relation to glenohumeral movement. This greater contribution occurs because the upper trapezius and lower serratus anterior force arms are relatively longer than those of the deltoid and supraspinatus muscles. During this phase, the lower trapezius force arm is lengthening, contributing to an increase in the rotatory force. After 90 degrees of scaption, activity in the upper trapezius and lower serratus anterior go through a reduction in the rate of electrical activity while lower trapezius rapidly increases its activity.

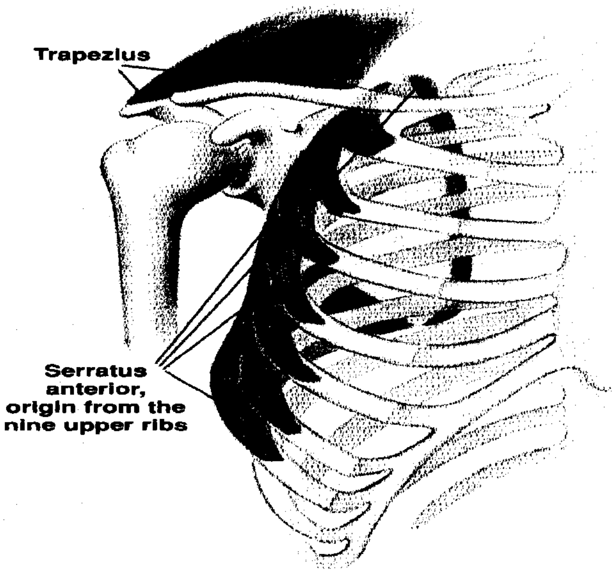


Figure 13. Serratus anterior and superior trapezius force couple. (*From* Butters KP: The scapula. *In* Rockwood CA Jr, Matsen FA III: The Shoulder, ed 2, vol 1. Philadelphia, WB Saunders, 1998, p. 392.)

In the third phase, the scapula's contribution to arm elevation in the scapular plane is reduced. The scapular instantaneous center of rotation is now located at or near the acromioclavicular joint. Because of this, the upper trapezius rotatory force arm significantly decreases its length; while the lower trapezius and serratus anterior force arm has not changed. These last two muscles will respectively act as the lower and upper components of scapula's upward rotatory force couple. Bagg and Forrest justify the decrease in scapular motion due to the middle trapezius function during this phase as a downward rotator. Decrease in upper trapezius function as an upward rotator and middle trapezius increased function as a downward rotator justifies the decrease in scapular motion. Also, levator scapulae and upper trapezius activity is increased, trying to stop scapula depression as the arm gets closer to a vertical position. Levator scapulae might also contribute to the decrease in scapula movement, due to its other function as a downward rotator since it inserts near the scapula superior angle (Figure 14). The rhomboid muscles are also considered an important element of the force couples acting on the scapula, although they were not mentioned on this model (Hamil, and Knutzen, 2003).

The model, although very explanatory about major aspects of force couples acting on the scapula, also fails on describing force couples during lowering of the arm.

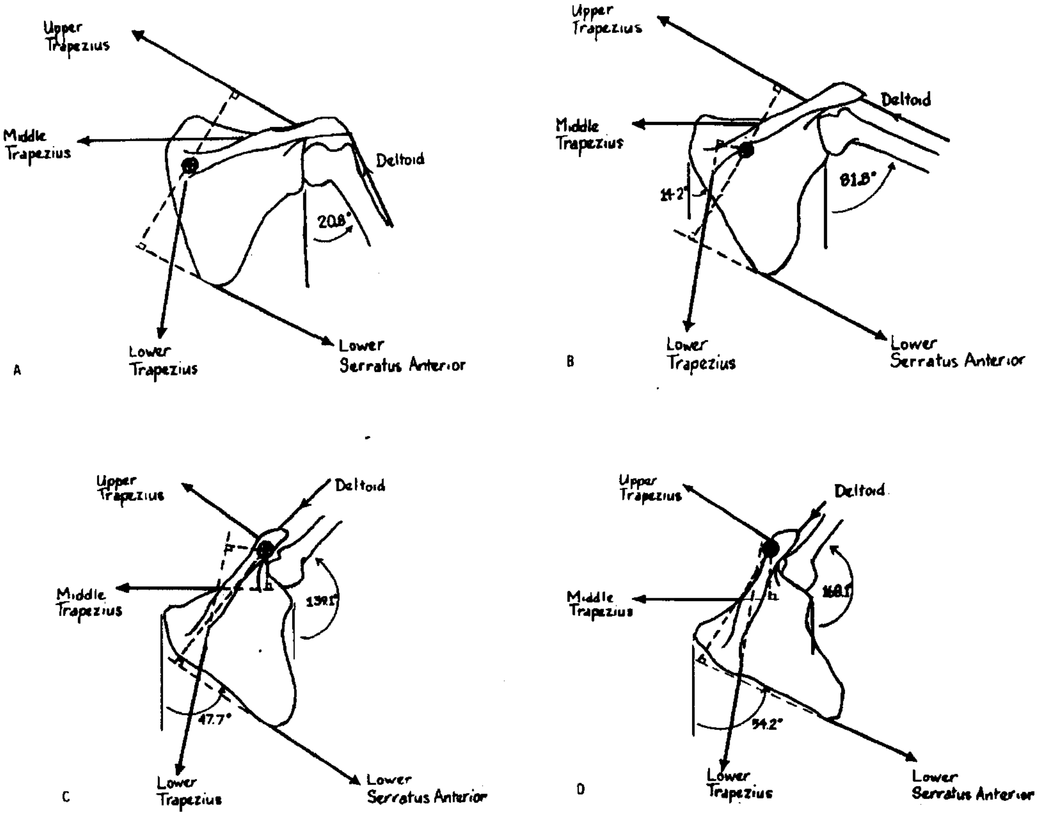


Figure 14. Biomechanical model of scapular rotation during scaption. A: beginning of first phase of scaption. B: beginning of second phase of scaption. C: beginning of third phase of scaption. D: full scaption. (*From* Bagg SD, Forrest WJ: A biomechanical analysis of scapular rotation during arm abduction in the scapular plane. Am J Phys Med Rehabil 67 (6): 238, 1988.)

During return of the arm from abduction or flexion, the scapula retracts, depresses and rotates downward. The rhomboids rotate the scapula downwards and work together with teres major and latissimus dorsi as a force couple to control the movement of the arm (latissimus dorsi and teres major) and the scapula (rhomboids) during lowering of the arm. Other muscles that actively contribute to scapular movement during lowering of the arm are pectoralis minor, which is a scapula depressor and downward rotator, and middle and inferior trapezius, scapula retractors (Figure 15) (Hamil, and Knutzen, 2003).

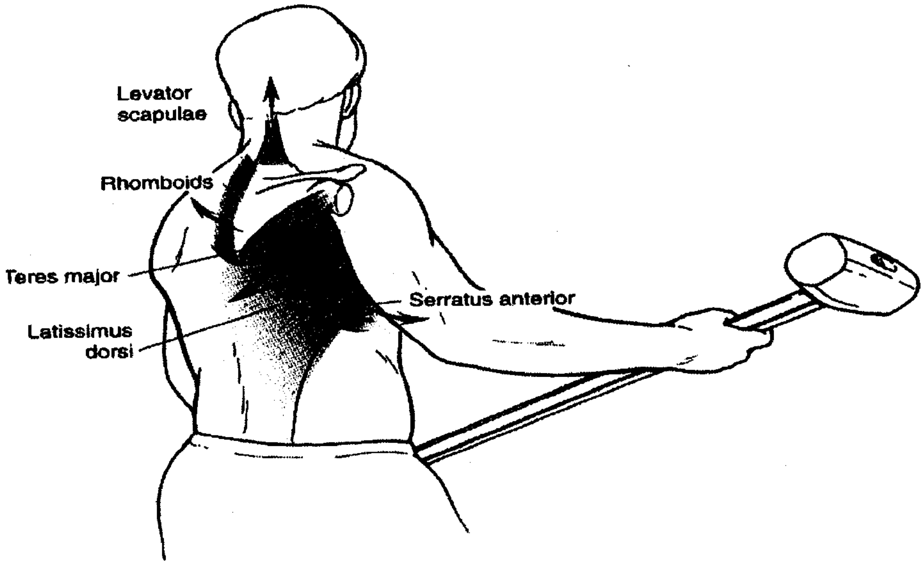


Figure 15. Latissimus dorsi and teres major working as a force couple with the rhomboids during lowering of the arm. Pectoralis major and minor, levator scapulae, and serratus anterior are other muscles that contribute to lowering of the arm. (*From* Hamill J, Knutzen KM: Functional anatomy of the upper extremity. *In* Hamill J, Knutzen KM: Biomechanical basis of human movement, ed 2.Baltimore, Lippincott Williams & Wilkins, 2003, p. 135.)

Influence of Scapular Protraction and Retraction on the Shoulder Girdle

Protraction of the scapula has a biomechanical importance for shoulder function. It increases reach by increasing the range of humerothoracic motion, it is important to help muscles keep a better muscle length-tension relationship, and it allows the glenoid to be positioned under the humerus to share the support of the arm weight (Halder, et al., 2000).

Some studies have observed the malignant effects of a malalignment of the scapula in a protracted or retracted position. It is believed that possible causes for scapular malalignment are muscle imbalance and/or deficient recruitment of the scapular muscles (Sahrmann, 2005). In general, the alteration in normal scapular positioning may lead to pathologies such as shoulder impingement syndrome, glenohumeral instability, labral tears, tendinopathies, rotator cuff tear, sub-deltoid bursitis, and musculoskeletal pain syndromes (Sahrmann, 2004; Cools, et al., 2004; Burkhart, et al. 2003). In an attempt to avoid such pathologies and consequent pain, the patient may try to compensate for altered static position during dynamic movement, which will lead to excessive muscular energy dispend (Kibler, 1998; Sahrmann, 2005) (Figure 16).

Possible causes for a protracted scapula is an overstretched trapezius and possibly rhomboids, along with shortening of the serratus anterior. Also, shortening of the scapulohumeral muscles might lead to a protracted scapula. A retracted scapula might occur due to rhomboids and trapezius shortening (Sahrmann, 2005).

Alterations of scapular position into retraction or protraction may lead to some specific problems in the shoulder. Smith et al (2002), observed the negative effects of a static protracted or retracted scapula on the length-tension relationship of the scapular elevators. Although conducted on normal participants, the investigators could observe that the capability of the scapula elevators to produce an isometric contraction was compromised in both protracted and retracted positions.

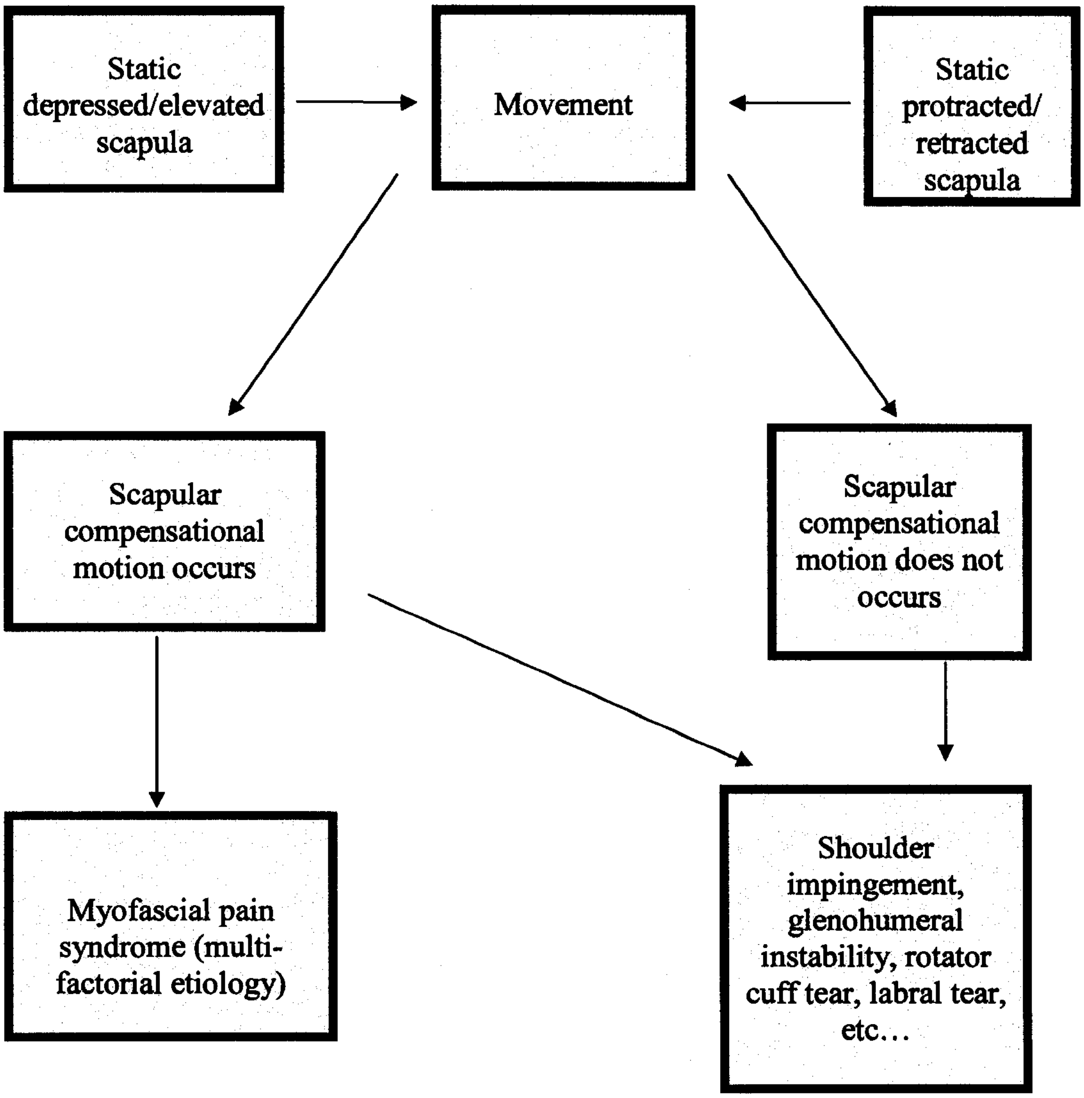


Figure 16. Possible effects of a static protracted/retracted or downward/upward rotated scapula on the shoulder.

On another study, Smith et al (2006) observed that protraction or retraction of the scapula affected shoulder isometric internal and external rotation strength. Although some may question the practical importance of observing isometric strength, many functional activities demand the scapula be a stable base for optimal performance. During daily and occupational activities such as assembly-line work, painting, and washing windows, the muscles of the shoulder girdle are usually isometrically contracting to maintain the arm position, while most of the movement occurs at the elbow, wrist, and hand. Also, when an isometric contraction is compromised, rotator cuff function as a stabilizer may be compromised.

Solem-Bertoft et al (1993) studied the influence of scapular retraction and protraction on the width and configuration of the subacromial space by the use of magnetic resonance imaging *in vivo*. They observed that the anterior opening of the subacromial space narrowed or decreased as the scapula moved from a retracted to a protracted position. Azzoni and colleagues (2004) associated the decrease in the subacromial space with the onset of shoulder pain.

Lewis and colleagues (2005) observed the negative effects of a protracted scapula. They observed that individuals with a shoulder impingement syndrome had a more protracted scapula in the resting position when compared to an otherwise healthy group. They reported an increase in shoulder function in scaption and flexion after correction of faulty scapular position.

Weiser and colleagues (1999) observed the influence of scapular protraction on shoulder stability. They observed that when positioning the scapula in a protracted position, the anterior band of the inferior glenohumeral ligament became increasingly taut. The anterior band of the inferior glenohumeral ligament is the major static restraint during 90 degrees of shoulder abduction in the frontal plane and 90 degrees of shoulder external rotation. This is how the shoulder is positioned when testing for anterior instability of the shoulder (apprehension test position). Hence, a chronic or repetitive protraction of the scapula may lead to excessive wear and, ultimately, insufficiency in this ligament and lead or contribute to anterior instability of the shoulder.

Influence of Scapular Elevation and Depression on the Shoulder Girdle

Different studies comparing norms and patient groups have reported significant differences between them related to depression/elevation of the scapula.

Warner and colleagues (1992), using Moire topographic analysis, evaluated 22 "normal" individuals and 29 individuals with shoulder pathology. Patients presented with more asymmetry between symptomatic and asymptomatic shoulders when compared to "normal" individuals. Patients with shoulder instability presented the symptomatic shoulder lower than the asymptomatic shoulder. Patients with impingement syndrome presented a higher symptomatic shoulder when compared to the asymptomatic shoulder.

Babyar (1996) investigated scapular position in 16 patients with shoulder pathology. He reported that patients had greater scapular elevation on the symptomatic side.

Lukasiewicz and associates (1999) reported that excessive elevation of the scapula was found in individuals with impingement syndrome when compared to "normal" individuals. However, there was no significant difference between symptomatic and asymptomatic shoulders in the impingement group.

Lin and colleagues (2005) studied the scapular position in individuals with shoulder dysfunctions while performing functional activities. Twenty-five patients were compared to 25 "normal" individuals. They reported a greater elevation of the scapula in individuals with shoulder dysfunction when they raised their arms to place an object at a height overhead and when they raised their arms maximally.

It is unclear whether elevation and in less frequency, depression of the scapula is secondary to shoulder pain or is one of the factors that lead to shoulder pain. (Babyar, 1996; Lukasiewicz et al, 1999; Lin et al, 2005). Lukasiewicz and associates (1999) suggested a central phenomenon such as a preferential motor pattern or a generalized capsular tightness to be the cause of scapula elevation since they found both shoulders to be elevated. Babyar (1996) reported that elevation of the scapula continued even after all pain was eliminated and range of motion was restored.

However, it was suggested by Babyar (1996) that a treatment emphasizing motor control of shoulder position could reduce scapular elevation after only one session. Lewis and colleagues (2005) suggested that scapular elevation can be decreased by 1.7cm with postural correction technique. Also, Wang and associates (1999) reported that scapula elevation can be decreased with a strengthening and stretching exercise program. Figure 16 shows scapular elevation/depression altered kinematics and its possible courses and consequences.

Sahrmann (2005) described a syndrome in which the scapula is depressed or does not elevate sufficiently during arm elevation. She reported that the main reasons for this scapular behavior were excessive lengthening of the upper trapezius and shortening of the pectoralis major and latissimus dorsi muscles. The pathologies that might occur as a consequence of this syndrome are: tendinopathy and impingement of rotator cuff tendons; rotator cuff tears, thoracic outlet syndrome; glenohumeral instability and subluxation; cervical pain (with or without irradiation to the upper extremities); myofascial pain syndrome, and pain in the acromioclavicular joint.

Scapular Measurement

Scapular positioning has been reported in 2-dimensional and 3-dimensional measurements. Two-dimensional measurements are used to observe scapular spatial orientation in a single plane. They are non-invasive, simpler to conduct, and generally cheaper than 3-dimensional measurements, thus more viable in the clinical setting. Different tools and techniques for 2-dimensional scapular measurement have been reported (Table 5). However, scapular movement is very complex, and can involve 5 different movements occurring simultaneously with arm movement (anterior/posterior tilt, internal/external rotation, upward/downward rotation, elevation/depression, and abduction/adduction of the scapula).

A. **2-DIMENSIONAL SCAPULAR MEASUREMENT TOOLS**	**B.** **SCAPULAR MEASUREMENT TECHNIQUES**
String (DeVita et al, 1990) Moire Topographic Analysis (Warner et al, 1992) Scoliometer (Sobush et al, 1996) Tape Measure (Peterson et al, 1997) Baylor Square (Peterson et al, 1997) Double Square (Peterson et al, 1997) The Perry Tool (Plafcan et al, 1997) Digital Inclinometer (Borsa et al, 2003) Plurimeter-V gravity inclinometer (Watson, et al, 2005)	Normalized Scapular Protraction Test (DeVita et al, 1990) Lennie Test (Sobush et al, 1996) Posterior Scapular Displacement (Plafcan et al, 1997) Lateral Scapular Slide Test (Kibler, 1998) Pectoralis Minor Shortening test (Nijs et al, 2005) Scapula Index Measurement (Borstad, 2006)

Table 5. Scapular measurement tools (A) and measurement techniques (B).

Three-dimensional measurement is a more complete technique in providing clinicians and researchers with information about scapular position and movement. It not only can enable one to observe all scapular movements simultaneously, but can also enable observation of glenohumeral movement at the same time. This is an important feature for clinicians and researchers when trying to treat a patient and understand more about pathokinematics of the scapula.

Conversely, it is considerably more expensive and a more time-consuming technique when compared to most 2-dimensional techniques, which makes it less feasible in the clinical setting. There are basically three options that are well reported in the literature to directly or indirectly record scapular motions 3-dimensionally: quasi-static measurements, regression equations, and direct measurement of scapular kinematics (Veeger et al, 2003). Quasi-static measurements observe scapular, arm, and trunk orientation in static positions. This measurement is usually performed with the help of a scapular locator, a triangular device with adjustable pins that is placed over the anatomical landmarks of the scapula (Veeger et al, 2003). The disadvantage of this method is that it needs to be performed in static positions, therefore it has a lower clinical importance than the other 3-dimensional measurements (Illyes and Kiss, 2006). Regression equations can be used to estimate the orientation of the scapula from measurements of trunk and arm motion. These equations rely on the relatively stable relationship between the scapula and the humerus. The disadvantage of this method is that it depends on its own indirect measurement of scapular orientation to be executed. That is, in order to define scapular orientation, the center of the head of the humerus is the most appropriate landmark. However, the orientation of the scapula, which was not directly measured, is required for the definition of this landmark (Veeger et al, 2003). Direct measurement of scapular kinematics can be accomplished by using an electromagnetic sensor, in combination with calibration measurements to define the sensor's relationship with anatomical landmarks. The most important aspect of this procedure is the calibration, which is based on a rigid-body assumption (Veeger et al, 2003). Karduna et al (2001) has validated two non-invasive methods of 3-dimensional measurements: the acromial method, in which the sensors are directly attached to the posterior-lateral acromion with double-sided tape; and the tracker method, which uses a custom designed scapular tracker that is attached to the skin with adhesive-backed Velcro strips. To independently assess the concurrent validity of the two skin based methods, the authors rigidly fixed an additional sensor to the scapula with pins (Figure 17). A disadvantage of this method is that its accuracy past 120 degrees of humeral elevation is still uncertain (Karduna et al, 2001; Veeger et al, 2003).

A common disadvantage of all electromagnetic-based systems is that the accuracy of measurements can be affected by an electromagnetic field of the building itself (Illyes and Kiss, 2006).

Illyes and Kiss (2006) have recently developed and validated an ultrasound-based method to record and process shoulder kinematic data. They reported that even if a completely inexperienced person performs the measurements, standard deviation stays below 3mm. They believe that the accuracy of an ultrasound-based motion system is higher than that of an electromagnetic-based system, because the electromagnetic field of the building does not interfere with measurements of an ultrasound-based system.

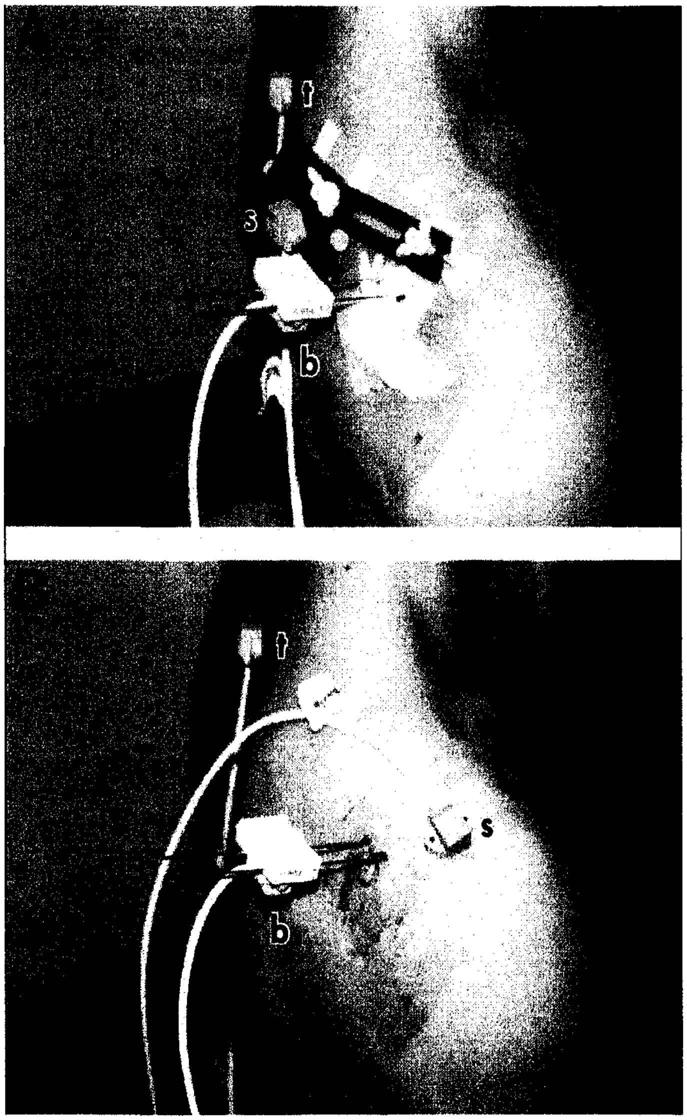


Figure 17. Photographs of bone and skin sensors locations. A: tracker method. B: acromial method. (*From:* Karduna, AR, et al: Dynamic measurements of three-dimensional scapular kinematics: a validation study. J Biomech Eng 123, 2001, p. 185).

Measurement and Available Data for the Horizontal Distance of the Scapula from the Vertebral Column and Scapular Elevation/Depression

A few studies have reported on the horizontal distance of the scapula from the vertebral column. Sobush et al (1996) described a procedure for measuring scapular positioning in the resting position, the Lennie test. This test uses a scoliometer to measure the horizontal distance of the scapula from the vertebral column. They reported an average of 8.8cm from the vertebral column to the root of the spine of the scapula, and 8.7cm from the vertebral column to the inferior angle of the scapula. They found the test to have a moderate to high intertester reliability and to be valid based on X-ray readings. However, their sample consisted of only 15 females, between 19 and 21 years old, which limits generalizability of their results.

Peterson et al (1997) investigated the reliability and validity of measuring the horizontal distance from the vertebral column (T3 spinous process) to the medial border of the scapula using a tape measure, with the scapula in its resting position. The average measurements were 7.2 cm. Their sample consisted of 49 participants with no complaint of shoulder pain (24 women and 25 men), aged 20-48 years. They reported high intratester reliability (ICC = 0.91). However, validity based on X-ray readings was not established.

DiVeta et al (1990) developed a measurement of horizontal distance between the scapula and the vertebral column that accounted for scapular size: the *normalized scapular protraction*. This measurement consisted of the distance between the inferior angle of the acromion and the spinous process of the T3 vertebra with the arm at rest in neutral, divided by the linear distance from the root of the scapular spine to the inferior angle of the acromion. They reported an intraclass correlation coefficient for intratester reliability of 0.78. Greenfield et al (1995) replicated the study of DiVeta et al (1990) and found an intraclass correlation coefficient of 0.97 for intratester reliability and 0.96 for intertester reliability. They also compared their measurements to X-ray measurements that supported the validity of the method. The *normalized scapular protraction* on Greenfield et al study was of 2 cm.

Kibler (1998) developed a method called the lateral slide test to measure quantitatively the scapular stabilizers' strength. The test involves three positions. The first position is with the arms relaxed at the side, the second position is with the hands on the hips (thumbs pointing posteriorly), and the third position is with the arms at 90 degrees of abduction with maximal internal rotation at the glenohumeral joint (Figure 18). The distance from the inferior angle of the scapula to the vertebral column reference point is measured in each position. The vertebral column reference point is the nearest spinous process. Kibler reported an intraclass correlation coefficient between 0.84 and 0.88 for intratester reliability and between 0.77 and 0.85 for intertester reliability, depending on the test position. He also reported validation of the method by X-ray readings. However, Odom et al (2001) have reported that reliability, sensitivity and specificity of the test are poor, and that the test should not be used to identify people with and without shoulder dysfunction.

Different authors have reported the distance between the scapula and the vertebral column using Kibler's lateral scapular slide test (Gibson et al, 1995; Crotty et al, 2000; Wang and Cochrane, 2001; Odom et al, 2001; Nijs et al, 2005). Reported values in "normal" participants ranged from 8.66cm to 10.09cm in position 1, 9.23cm to 10.81cm in position 2, and 9.25cm to 12.94 in position 3.

Scapular elevation/depression can be measured directly or indirectly using 2 dimensional methods. Warner and colleagues (1992) used Moire topographic analysis to evaluate asymmetry between shoulder heights. Eleven out of 29 patients presented height asymmetry between symptomatic and asymptomatic shoulders. However, neither reliability nor validity was reported.

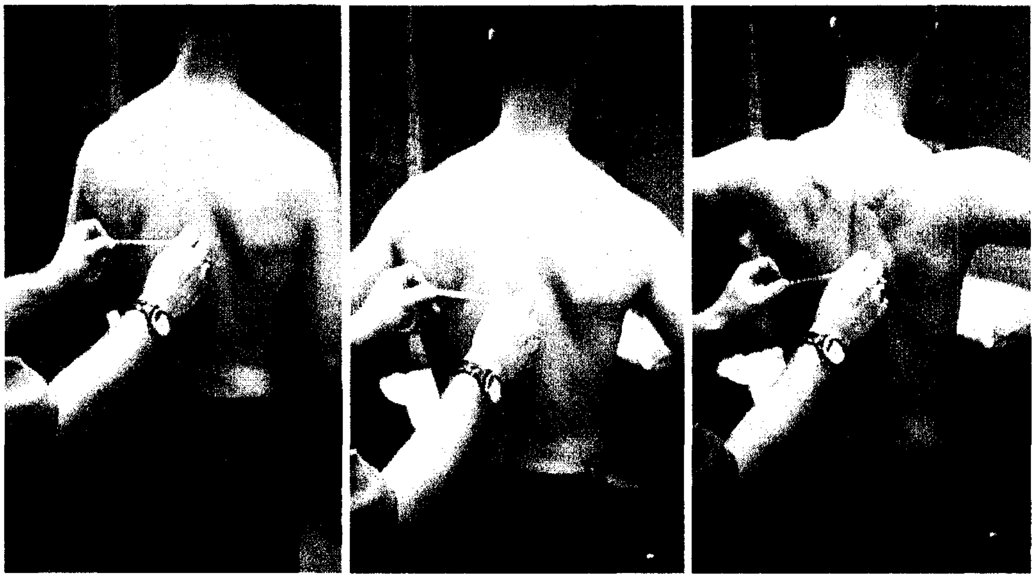


Figure 18. First position (A), second position (B), and third position (C). (*From* Kibler WB: The role of the scapula in athletic shoulder function. Am J Sports Med 26 (2), 1998, p. 332).

Lewis and associates (2005) used an indirect measurement to determine elevation or depression of scapula. They used Pythagoras' theorem to calculate vertical displacement of the scapula. For these calculations, they palpated the necessary landmarks and measured the distance between them. Although they did not report an absolute value of scapular elevation/depression in relation to a landmark, they reported that postural correction decreased elevation in the resting position in an average of 1.7cm. They reported a high intrarater reliability of 0.91 and 0.96 depending on the landmark. Neither interrater reliability nor validity was reported.

CHAPTER 3

MATERIAL AND METHODS

PARTICIPANTS

A convenience sample of 30 participants (15 females and 15 males) was recruited through posters at the University of Alberta. Sample size was estimated based on a table that estimates sample size for studies using ICC (intraclass correlation coefficients) values (Walter et al, 1998).

Both genders were recruited because if the procedure was shown to be reliable, it would be used for data collection in a large epidemiological study including males and females. Participants were continually recruited until the pre-defined number of participants was reached. Potential participants were asked to contact the researcher by telephone, and at that time they received orientation about time commitment, risks, and general information about the procedure and it was determined if they met the inclusion criteria or were excluded because of the exclusion criteria. The use of a convenience sample of normal participants can restrict the range of scores and therefore yield lower reliability coefficients than if patients were used in the study. However, this population of participants was chosen for this reliability study since a future study using this procedure to observe reference values in "normals" will be conducted.

INCLUSION CRITERIA

To be included in this study, participants had to:

1. Be between 18 and 40 years of age to ensure full musculoskeletal development and to avoid joint degenerative changes associated with aging (both may affect

normal biomechanics) (Nicholson et al., 1996; Rockwood et al., 1998; Borstad, 2006).

2. Present pain-free full range of motion in both shoulders.

EXCLUSION CRITERIA

Participants were excluded if they presented with or had a history of:

1. Shoulder girdle pain or pathology;
2. Cervical radiculopathy with radiated pain to the shoulder;
3. Thoracic outlet syndrome;
4. Surgery or trauma to the thoracic spine, rib cage, shoulder girdle, or cervical spine;
5. Scoliosis or hyperkyphosis;
6. Musculoskeletal disease such as myofascial pain syndrome or fibromyalgia syndrome;
7. Any congenital defect of the scapula (e.g. Sprengel's deformity);
8. Any neuromuscular disorder such as palsy of the shoulder muscles due to nerve injuries (e.g. long thoracic nerve, suprascapular nerve, axillary nerve);
9. Leg length discrepancy;
10. Body Mass Index (BMI - Kg/m^2) >25 if female and >27 if male;
11. Currently pregnant;
12. Cardiovascular disease

Further posture deviations were not considered for exclusion criteria. The reason for this is because most people have some kind of posture deviation. Controlling for many posture deviations will significantly decrease the generalizability of this study, decreasing its usefulness in both research and clinical settings.

PARTICIPANT'S RIGHTS

All information will be kept confidential under lock and key where only the research team members will have access. Any published material involving this data will not reveal participant's identity. Each participant was free to withdraw from the study at any time. Contact information was provided in case participants had questions or doubts about the study.

STUDY DESIGN

This was a cross-sectional study using a repeated measures design to estimate the reliability of the proposed procedure. To investigate intra-rater reliability, 3 investigators each measured 30 participants in 2 sessions 1 week apart. To determine intra-reliability, measurements were compared within investigators and not between them. The time allowed between sessions was used to prevent the inflation of reliability estimates by recall. To investigate inter-rater reliability, 3 investigators measured 30 participants in 1 session. The measurements taken in session 2 were used to determine inter-reliability (Rankin and Stokes, 1998).

The study used a partially standardized approach to investigate intra- and interrater reliability. A study that uses a partially standardized approach, investigates reliability using moderate control of the sources of variability (Domholdt, 2005). In contrast, a highly standardized procedure will probably be unrealistic to reproduce in the clinical setting. Also, a nonstandardized approach probably would not yield a satisfactory reliability coefficient. Therefore, a standardization used in a partially standardized approach is more likely to be achieved in clinical settings and to yield satisfactory reliability coefficient.

The partially standardized approach of the present study involved complete standardization of measurement technique. Raters were trained to accurately perform a standardized measurement. However, factors that were not likely to be controlled in the clinical setting (e.g.: temperature, humidity), were not controlled for in this study. This was done to enable replication of the measurement procedure in the clinical setting.

METHODS

ORIENTATION

Prior to the measurement procedure, an orientation and information sheet (See Appendix A) was given to the participants outlining the study background information, objectives of the study, duration of each session, how measurements would be taken, possible risks and benefits, how confidentiality of the data collected would be ensured, information that subjects would be free to withdraw from the study at any time without consequence, and information about additional contacts in case they had questions or concerns about the study. Participants were asked to read the informed consent and sign it to ensure they understood and agreed to all terms of the study.

COLLECTION OF DEMOGRAPHIC DATA

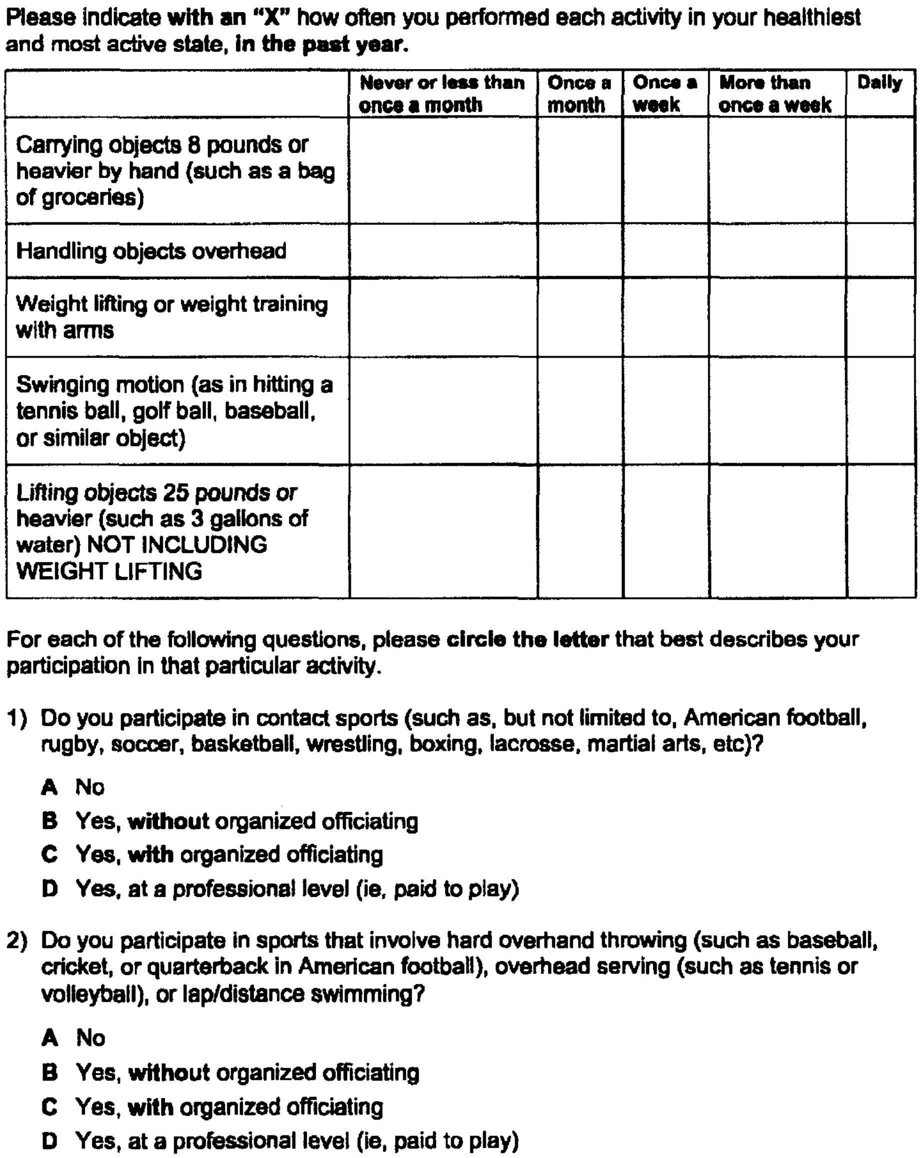
On arrival at the laboratory, demographic data was collected (i.e. age, gender, height, weight, arm dominance, and activity level according to the Shoulder Activity Scale developed by Brophy et al. (2005) - Figure 19). Demographic data was collected in order to better describe the population that participated in the study.

The purpose of the Shoulder Activity Scale is not to measure level of activity at a particular moment in time. Instead, level of activity is considered throughout the entire previous year (Brophy et al, 2005). The reported interpretation of the numeric activity score is: high ≥ 16; average 7-15; and low ≤ 6 (Brophy et al, 2005). This scale has shown excellent repeated measures reliability and construct validity (Brophy et al, 2005).

CLINICAL INVESTIGATION OF INCLUSION/EXCLUSION CRITERIA

In addition to the inclusion/exclusion criteria, a thorough clinical assessment was conducted by a physical therapist to screen participants. First, the physical therapist assessed whether participants presented pain-free full scaption ROM bilaterally. Participants had to present pain-free full scaption ROM bilaterally since side of testing was randomized.

Secondly, Adam's forward bending test was performed to identify participants with thoracic or lumbar scoliosis (Cote et al., 1998). This test was selected to screen for scoliotic participants for being cost-free and easily conducted. Adam's forward bending test has been shown to have a sensitivity of 92% and 73% when identifying participants with thoracic and lumbar scoliosis, respectively (Cote et al., 1998). Participants were asked to stand with feet shoulder-width apart, hands placed together and then bend forward letting their arms dangle (Cote et al., 1998). The test was positive if trunk asymmetry was present.



Please indicate with an "X" how often you performed each activity in your healthiest and most active state, in the past year.

	Never or less than once a month	**Once a month**	**Once a week**	**More than once a week**	**Daily**
Carrying objects 8 pounds or heavier by hand (such as a bag of groceries)					
Handling objects overhead					
Weight lifting or weight training with arms					
Swinging motion (as in hitting a tennis ball, golf ball, baseball, or similar object)					
Lifting objects 25 pounds or heavier (such as 3 gallons of water) NOT INCLUDING WEIGHT LIFTING					

For each of the following questions, please **circle the letter** that best describes your participation in that particular activity.

1) Do you participate in contact sports (such as, but not limited to, American football, rugby, soccer, basketball, wrestling, boxing, lacrosse, martial arts, etc)?

   A No
   B Yes, **without** organized officiating
   C Yes, **with** organized officiating
   D Yes, at a professional level (ie, paid to play)

2) Do you participate in sports that involve hard overhand throwing (such as baseball, cricket, or quarterback in American football), overhead serving (such as tennis or volleyball), or lap/distance swimming?

   A No
   B Yes, **without** organized officiating
   C Yes, **with** organized officiating
   D Yes, at a professional level (ie, paid to play)

Figure 19. Shoulder Activity Scale. (*From* Brophy, R, et al: Measurement of shoulder activity level, Clin Orthop Rel Res, 439: 101, 2005.)

Next, participants were examined for leg length discrepancy. Comparison between the height of the pelvic crests were used as an indirect measurement of leg length discrepancy (Petrone et al., 2003). The PALM has been shown to be a valid and reliable instrument to measure pelvic crest height difference (Petrone et al., 2003). Participants were asked to walk in place for 10 steps. They were then asked to stand in a fully erect posture with no bending of the ankles, knees, hips, or spine, and to fold their arms across their chest (Petrone et al., 2003). The investigator palpated the most superior aspect of the iliac crests with the PALM calipers and recorded caliper and inclinometer values. These values were used with a slide ruler (PALM calculator) to calculate the pelvic crest height difference. Participants were excluded if they presented a pelvic crest height difference similar to symptomatic individuals' value, which was above 5mm. (Petrone et al., 2003).

Finally, participant BMI was calculated. Participants were excluded if they exceeded Canadian normative values of BMI according to their age range and gender (Payne et al., 2000). For our sample, these values were of 25Kg/m^2 for females and 27Kg/m^2 for males. Exclusion of individuals above Canadian normative values may limit generalizability of the findings of this study. However, the difficulty of landmark palpation imposed by significant amount of fat tissue could result in clinically unacceptable reliability coefficients.

RANDOM SELECTION

There were three examiners for this study. All three examiners participated in sessions 1 and 2. Randomization using a random-number table was used to decide the sequence of examiners measuring each subject during data collection. Randomization using a random-number table was also used to decide which side (right or left) was measured for each subject. Once a side was randomly selected for a particular participant, only that side was measured on that participant. For example, if the right side was randomly selected, then all raters measured only the right side of that participant on both sessions.

The order of arm position (resting scapular position, 90 degrees of scaption, and full scaption) was not randomized. The reason for this is that the proposed procedure was meant to be used in this sequence in both research and clinical settings. The logical rationale is that patients would start from the easiest position which requires least ROM to the most challenging one which requires the greatest ROM.

PREPARATION OF PARTICIPANTS

Prior to the measurement procedure, participants were asked to either wear a sports bra if female, or take off their shirt if male to expose the upper thoracic region. They were also asked to remove their shoes to eliminate potential discrepancies in posture caused by the shoes. Participants were then asked to assume a natural and relaxed position while standing on a piece of paper on which their foot positions were marked. This piece of paper was used in the next session to position the participants' feet in the same position as previous session and also, if participants moved, they could return to their original position. Then, the following instructions were verbalized to them:

1. "Stand facing straight ahead."
2. "Allow your hands, shoulders, arms and lower extremities to assume the positions they normally would while you stand in a relaxed way."

No further attempt was made to place the participants in a single standardized position during measurements in the scapular resting position. This is because normal posture differs from person to person and any attempt to standardize their posture while standing might compromise the participants' capability to assume a natural relaxed position. If the participants do not assume their normal position while standing, it could lead to alterations in their normal scapular resting position and the subsequent pattern of movement, thereby compromising external validity of the study. Sobush et al. (1996) used this same rationale and presented a moderate to high intertester reliability (ICC: 0.66 to 0.86 depending on scapular surface landmark).

For measurements at 90 degrees and complete scaption, participants stood in the same piece of paper used during measurements in the scapular resting position. Additionally, participants were instructed about not moving their trunk during arm elevation. Raters observed participants' trunk during arm elevation and reinforced instructions to avoid trunk movement if trunk movement was noticed.

SCAPULAR MEASUREMENTS

(A) Instrument

Reliability estimates were conducted using a Palpation Meter (PALM) (Performance Attainment Associates, St. Paul, MN). The palpation meter is a caliper with an inclinometer attached to it (Figure 20). By having an inclinometer attached to a caliper, the horizontal and vertical distance between body parts can be measured.

No studies that reported on the reliability of the PALM for measuring scapular position were found. However, Sobush et al (1996) reported a moderate to high intertester reliability when measuring the scapular distance from the spine with a caliper (ICC: 0.66 to 0.86 depending on scapular surface landmark). They also reported validation of the caliper based on X-ray verification to measure the anatomical location of the scapula using surface landmarks. Petrone et al (2003) tested the PALM validity and reliability to measure pelvic discrepancy and concluded that the instrument was valid and reliable for that purpose.

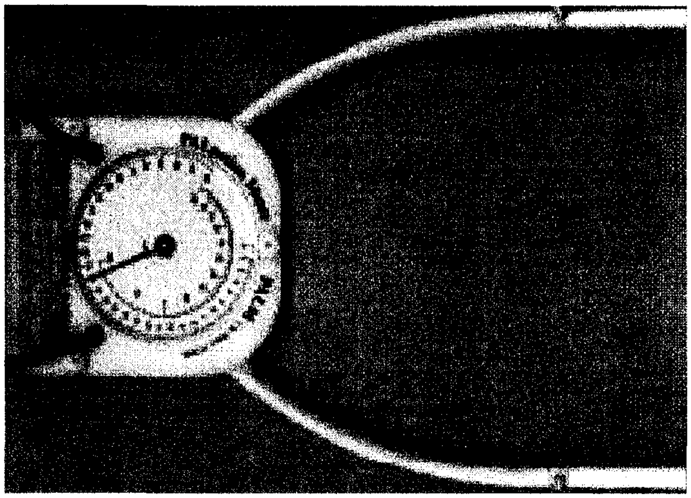


Figure 20. The Palpation Meter (PALM)

(B) Description of the measured dimensions

The following scapular positions were measured:

1. Lateral scapular displacement,
2. Scapular vertical distance from C_7,
3. Normalized lateral displacement of the scapula.

To quantify the previously mentioned scapular positions, the following measurements were taken:

1. Horizontal distance of the scapula from the spine,
2. Vertical distance between the postero-inferior angle of the acromion and the spinous process of C_7,
3. Distance between the root of the spine of the scapula and the postero-inferior angle of the acromion.

1. To measure the **horizontal distance of the scapula from the spine**, the horizontal distance of the inferior angle of the scapula to the thoracic spine (line C-D in Figure

21) and from the root of the spine of the scapula to the thoracic spine (line A-B in Figure 21) were measured in three different positions (resting position of the scapula, 90 degrees of scaption, and complete scaption.

2. To measure the **vertical distance of the postero-inferior angle of the acromion to C_7** (line E-F in Figure 21), the distance measured by the caliper and the inclination displayed by the inclinometer were used to calculate the vertical distance between these two landmarks. The PALM calculator was used to calculate this dimension. This distance was measured only in the resting position. Participants were asked to perform flexion/extension of the cervical spine so that C_7 was identified. The spinous process of C_7 was identified by identifying C_6. During flexion/extension, movement is felt in the spinous process of C_6 but not in the spinous process of C_7 (Magee, 2002).

3. The third measurement corresponded to line B-E in Figure 21. This measurement was used to determine the **normalized lateral displacement of the scapula**, which was determined by the following formula:

$$\text{Normalized lateral displacement of the scapula} = \frac{BE}{CD}$$

This measurement was conducted only in the resting position.

(C) Data Collection Procedure

Participants were prepared from the beginning of the section as explained in "Preparation of Participants Section".

Measurements were taken in the following arm positions:

1. Resting position of the scapula (with arms relaxed beside the trunk),
2. Ninety degrees of arm elevation in the scapular plane
3. Complete arm elevation in the scapular plane

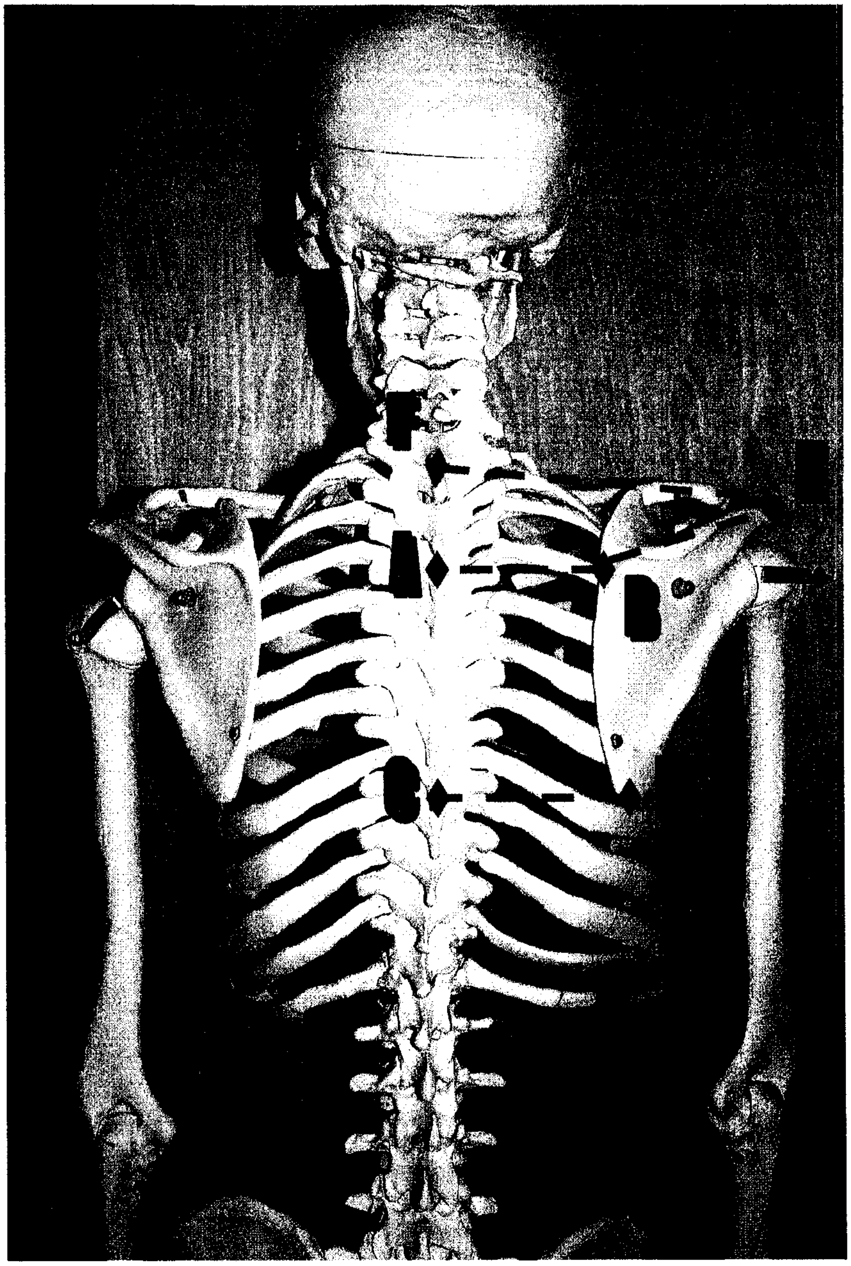


Figure 21: Diagram of anatomical landmarks used for the measurement of scapular protraction and depression. Root of the spine of the scapula (B), corresponding mark on the vertebral column (A), inferior angle of the scapula (D), corresponding mark on the vertebral column (C), postero-inferior angle of the acromion (E), and seventh cervical vertebrae (F).

The scapular plane was considered 40 degrees anteriorly from the frontal plane (Lukasiewics, et al 1999; Ludewig and Cook, 2000; Ebaugh et al 2005). A structure built of plastic pipes was used to stabilize participants' trunk during arm elevation and to guide participants' movement through the scapular plane (Figure to be added). A goniometer was used to determine 90 degrees, for measurements at 90 degrees of scaption. For measurements at the end of the scaption range of motion, the following instructions were read to participants: "Elevate your arm along the plastic pipes as high as you can with your thumb up trying not to move your spine". Participants were asked to keep their thumbs up during arm elevation to control for glenohumeral rotation.

To identify landmarks, the examiner palpated and marked anatomic structures in the upper back. First, the examiner drew a vertical line over the spinous processes of the thoracic spine, which was used to measure the horizontal distance between the scapula and the spine. The line began superior to the scapula and ended inferiorly. Each participant was positioned in 1 of the 3 positions always in the same order (resting position of the scapula, 90 degrees of scaption, or complete scaption range of motion). The examiner then palpated and identified the inferior angle and the root of the spine of the scapula, the spinous process of C_7, and the postero-inferior angle of the acromion. This procedure was repeated for each position (except for palpation of postero-inferior angle of the acromion and spinous process of C_7 which was only identified in the resting position). A line-point grease pencil was used to mark the identified structures. Lewis et al. (2002) studied the validity of skin surface palpation to determine the scapular position on cadavers. They suggested that it is a useful and valid method to use skin surface landmarks as reference points to determine the location of the inferior angle of the scapula, the root of the spine of the scapula, the postero-inferior angle of the acromion, and spinous processes of the thoracic spine.

Although this was a cadaveric study, no study to date has been found that studied the validity of skin surface palpation to determine the scapular position *in vivo*.

The examiner then used the PALM to measure the previously mentioned distances. The end of one arm of the caliper was positioned over one of the landmarks, and the end of the other arm was positioned over another landmark. The inclinometer on the PALM had to be level for the measurements of the horizontal distance between the scapula and the thoracic spine. The inclinometer value was used to calculate the vertical distance between the scapula and $C_{7.}$ The inclinometer value was ignored for measurement 3. The observed data was read aloud to a recorder. The recorded data was later transcribed and saved in a computer.

The positions measured during arm elevation (90 degrees and full scaption) were chosen due to their clinical importance. According to Kibler (1998), 90 degrees of shoulder elevation presents a challenge to the muscles in the position of most common function. Complete arm elevation is needed during many sports and activities of daily living (ADL). Patients with impingement of subacromial structures might complain of pain between 60-120 degrees of arm elevation or 170-180 degrees of arm elevation, which is called a "painful arc" (Magee, 2002). During arm elevation, a scapula that is considered retracted may be an attempt by the patient to decrease pain by increasing the subacromial space (Magee, 2002).

STATISTICAL ANALYSIS

Descriptive statistics were used to describe the population. Mean and standard deviation were reported for demographic information, body mass index, and scapular measurements.

Intraclass correlation coefficient (ICC) was used to generate reliability coefficients for intra-rater and inter-rater scapular measurements. SPSS 15.0 for Windows was used for data analysis. ICC was calculated using a two-way mixed effects model single measure reliability (ICC (3, 1)) with absolute agreement and alpha level set at 0.05. A two-way mixed effects model single measure reliability was chosen since raters were not randomly selected (Yaffe, 2003). Moreover, raters' measurements were not averaged for ICC calculation since it is expected that clinicians will use only 1 measurement and not an average of measurements in the clinic (Garson, 2007). Finally, absolute agreement was investigated for ICC calculation since systematic variability due to raters was relevant (Garson, 2007).

A rigid criterion was not used to assess reliability coefficients. Domholdt (2005) questions the use of a rigid criterion for acceptable reliability. She argues that the component of reliability (e.g.: instrument reliability, intra- or interrater reliability, or intrasubject reliability) being studied affects the interpretation of the reliability coefficient. Instead, she suggests that researchers should supplement relative information with absolute information. Therefore, the standard error of measurement was calculated in order to report not only relative reliability but also absolute reliability.

CHAPTER 4

RESULTS

SAMPLE CHARACTERISTICS

Out of 35 screened participants, 30 were recruited for the study (15 males and 15 females). Five subjects were dropped from the study for the following reasons: 3 participants reported history of shoulder pain and/or instability, and 2 participants presented trunk asymmetry during Adam's forward bending test. The study sample consisted mostly of students from the University of Alberta. Measurements of the dominant shoulder were taken in 15 participants and of the non-dominant shoulder in 15 participants. Measurements were taken from both dominant and non-dominant shoulders and combined so that study results could be generalized to measurement of both dominant and non-dominant shoulders.

Table 6 and 7 depicts the characteristics of the participants involved in this study.

Demographics	Mean ±S.D.	Range
Age	26.5 ±3.79	21 - 36
Height (m)	1.72 ±0.08	1.55 - 1.94
Weight	68.8 ±11.17	47.5 – 102.0
BMI (Kg/m2)	23.3 ±2.76	17.9 - 27.0

Table 6. Mean, standard deviation (±S.D.), and range of participants demographic data.

MEASUREMENTS DESCRIPTIVE INFORMATION, INTRA- AND INTER RATER ICC AND SEM VALUES

The mean values of the measurements were similar between raters. The distance from the inferior angle of the scapula to the spine constantly increased with arm elevation, whereas the distance between the root of the spine of the scapula and the spine remained similar between different arm positions.

Table 8 depicts the mean value of each measurement taken by each rater, intra and inter-rater ICC values of measurements and their respective SEM.

Activity Level	N
never perform shoulder activity	3
almost never perform shoulder activity	14
usually performs shoulder activity	6
almost always perform shoulder activity	6
always perform shoulder activity	1

Table 7. Participants' shoulder activity level distribution.

Position	Measurement	Mean rater scores (±S.D.; range)	Intra-rater ICC	Inter-rater ICC	Intra-rater SEM (cm.)	Inter-rater SEM (cm.)
Neutral	Inferior angle	1 = 8.5 (±1.7; 5.2-13.3) 2 = 8.5 (±1.7; 4.3-12.4) 3 = 8.6 (±1.7; 5.0-12.4)	1 = 0.83 2 = 0.89 3 = 0.83	0.89	1 = 0.69 2 = 0.56 3 = 0.70	0.59
	Root of the spine of the scapula	1 = 8.0 (±1.4; 5.1-11.2) 2 = 7.9 (±1.4; 5.2-11.8) 3 = 8.0 (±1.4; 5.4-11.0)	1 = 0.77 2 = 0.78 3 = 0.81	0.77	1 = 0.69 2 = 0.68 3 = 0.63	0.69
	Normalized distance	1 = 1.6 (±0.3; 1.1-2.4) 2 = 1.7 (±0.4; 1.1-3.2) 3 = 1.6 (±0.3; 1.0-2.7)	1 = 0.75 2 = 0.85 3 = 0.69	0.75	1 = 0.15 2 = 0.15 3 = 0.18	0.19
	Vertical distance	1 = 7.3 (±1.5; 3.8-10.8) 2 = 6.9 (±1.4; 3.7-10.8) 3 = 6.9 (±1.3; 4.2-9.2)	1 = 0.72 2 = 0.78 3 = 0.74	0.76	1 = 0.79 2 = 0.66 3 = 0.67	0.64
Ninety degrees of Scaption	Inferior angle	1 = 11.1 (±2.1; 7.2-15.6) 2 = 11.4 (±1.8; 8.0-15.6) 3 = 12.0 (±1.7; 8.6-15.4)	1 = 0.69 2 = 0.70 3 = 0.89	0.74	1 = 1.17 2 = 0.99 3 = 0.56	0.98
	Root of the spine of the scapula	1 = 7.6 (±1.6; 4.1-11.5) 2 = 7.9 (±1.6; 5.0-11.2) 3 = 8.0 (±1.7; 5.0-12.0)	1 = 0.86 2 = 0.86 3 = 0.78	0.74	1 = 0.61 2 = 0.60 3 = 0.79	0.84
Full scaption	Inferior angle	1 = 16.5 (±1.9; 13.4-21.5) 2 = 16.7 (±1.8; 12.0-21.2) 3 = 16.5 (±1.8; 13.0-22.4)	1 = 0.88 2 = 0.71 3 = 0.86	0.85	1 = 0.68 2 = 0.98 3 = 0.70	0.74
	Root of the spine of the scapula	1 = 8.4 (±1.3; 5.3-11.0) 2 = 8.1 (±1.5; 5.4-12.0) 3 = 8.0 (±1.7; 5.2-12.4)	1 = 0.73 2 = 0.73 3 = 0.85	0.67	1 = 0.70 2 = 0.79 3 = 0.68	0.87

Table 8. Mean, standard deviation (±S.D.), ICC and SEM of all measurements.

Position	Measurement	Intra-rater ICC 95% Confidence Interval	F value	Intra-rater ICC 95% Confidence Interval	F value
Neutral	Inferior angle	1 = 0.72; 0.90 2 = 0.79; 0.95 3 = 0.69; 0.91	1 = 0.55 2 = 0.17 3 = 2.49	0.81; 0.94	0.26
	Root of the spine of the scapula	1 = 0.59; 0.85 2 = 0.65; 0.80 3 = 0.66; 0.91	1 = 0.01 2 = 2.40 3 = 0.80	0.68; 0.81	0.85
	Normalized distance	1 = 0.62; 0.85 2 = 0.71; 0.92 3 = 0.58; 0.82	1 = 0.29 2 = 0.06 3 = 3.43	0.62; 0.87	8.55
	Vertical distance	1 = 0.65; 0.86 2 = 0.69; 0.88 3 = 0.65; 0.87	1 = 0.01 2 = 1.30 3 = 1.13	0.65; 0.82	***5.33**
Ninety degrees of Scaption	Inferior angle	1 = 0.49; 0.84 2 = 0.48; 0.79 3 = 0.79; 0.95	1 = 0.71 2 = 0.03 3 = 2.25	0.66; 0.86	8.43
	Root of the spine of the scapula	1 = 0.74; 0.92 2 = 0.66; 0.90 3 = 0.61; 0.82	1 = 1.14 2 = 9.99 3 = 0.90	0.67; 0.86	2.51
Full scaption	Inferior angle	1 = 0.76; 0.92 2 = 0.60; 0.83 3 = 0.72; 0.93	1 = 1.05 2 = 0.01 3 = 2.05	0.75; 0.92	1.84
	Root of the spine of the scapula	1 = 0.61; 0.85 2 = 0.52; 0.82 3 = 0.71; 0.92	1 = 0.82 2 = 3.42 3 = 2.80	0.61; 0.81	0.78

Table 9. ICC confidence interval and F values. * Significant at $p \leq 0.05$

CHAPTER 5

DISCUSSION

MEAN VALUES

For the arm rest position, the mean values for the distance between the scapula and the spine reported in this study were similar to the mean values reported in previous studies. Previous studies reported this mean value to have a range of 8.4 to 10.1 cm (Gibson et al., 1995; Sobush et al., 1996; T'Jonck et al., 1996; Crotty and Smith, 2000; Plafcan et al., 2000; Odom et al., 2001; McKenna et al., 2004; Nijs et al., 2005). The mean value of 8.5 cm for the distance between the inferior angle of the scapula and the spine found in this study falls within this range of values. As for the distance between the root of the spine of the scapula and the spine, previous studies reported a mean value within the range of 7.2 – 8.6 cm (Sobush et al., 1996; T'Jonck et al., 1996; Peterson et al., 1997; Plafcan et al., 2000; McKenna et al., 2004). Again, the mean value of 8.0 cm for the distance between the root of the spine of the scapula and the spine found in this study falls within the range found in the literature. Possible explanations for the different scapular positioning values observed across studies are the differences in procedures and sample characteristics between studies. Procedures differed in measurement tools, the plane of arm elevation, the amount of training of the raters, the amount of raters experience with palpation of structures of the shoulder girdle, and the amount of time between test and re-test. Sample characteristics differed across studies in participants' age, number of participants, gender, and shoulder condition (pain or no pain in the shoulder girdle).

The mean values for distances from the inferior angle of the scapula or root of the spine of the scapula to the spine during scaption were not found for comparison. However, a few studies investigated scapular positioning during Kibler's lateral scapular slide test (Page 45). For 90 degrees of elevation, previous studies reported a mean value in the range of 9.3 to 12.9 cm for the distance between the inferior angle of the scapula and the spine (Gibson et al., 1995; Odom et al., 2001; McKenna et al., 2004; Nijs et al., 2005). In the present study, a mean value of 11.5 cm was found for the same distance at 90 degrees of elevation in the scaption position. At 90 degrees of elevation, the distance between the root of the spine of the scapula and the spine found in the literature was between 4.5 and 5.6 cm (McKenna et al., 2004). In the present study, a mean value of 7.8 cm was found for the same distance at 90 degrees of scaption.

For full arm elevation reported in the literature, the mean value for the distance between the inferior angle of the scapula and the spine fell within the range of 15.7 and 17.09 cm and for the distance between the root of the spine of the scapula and the spine, the mean value fell between 6.85 and 8.05 cm (McKenna et al., 2004). During full arm elevation in the present study, a mean value of 16.6 cm was found for the distance between the inferior angle of the scapula and the spine, and a mean value of 8.2 cm was found for the distance between the root of the spine of the scapula and the spine. Except for the distance between the root of the spine of the scapula and the spine, values of scapular positioning during arm elevation reported in this study are similar to values found in the literature. The values reported by these studies were measured at 90 degrees of shoulder abduction with maximal internal rotation or full arm elevation with maximal internal rotation. In the present study, measurements during arm elevation were taken at 90 degrees of scaption with neutral rotation of the shoulder, and full arm elevation with neutral rotation. In spite of the observed similarity, rotation of the shoulder has been reported to influence scapular position during arm elevation (Sagano et al., 2006).

The DiVeta procedure is commonly used to report normalized values of this distance (DiVeta et al., 1990; Neiers and Worrell, 1993; Gibson et al., 1995; T'Jonck et al., 1996; Crotty and Smith, 2000). However, it was decided not to use this procedure since it involved identification of the third thoracic vertebra through palpation and this could have added an extra source of error to the procedure. Identification of the third thoracic vertebrae through palpation involves identifying other vertebrae through palpation, therefore more mistakes could happen due to extra palpation. Thus a different procedure was used in the present study to overcome this problem and reach a normalized value. The DiVeta procedure involves dividing the distance between the third thoracic vertebra and the acromion by the distance between the root of the spine of the scapula and the acromion. In the present study, the third thoracic vertebra was not identified for this measurement. Instead, the distance between the root of the spine of the scapula and the acromion was divided by the horizontal distance between the inferior angle of the scapula and the spine. By measuring the horizontal distance between the scapula and the spine, the need to identify the third thoracic vertebrae was eliminated, which, as mentioned earlier, could be an extra source of measurement error. Other studies that used a similar procedure to the present one were not found, which limits comparisons. The mean value of the normalized distance was found in this study to be 1.6 cm.

The vertical distance from the seventh cervical vertebrae to the acromion was also measured in this study. No previous study reporting this value for scapular depression was found in the literature search. In the present study, the mean value for the distance between the seventh cervical vertebrae and the acromion was 7.0 cm. Scapular depression was measured in this study because a depressed scapula has been associated with shoulder pain and pathology (Sahrmann, 2005). Accordingly, it was decided to measure scapular depression using the spinous process of C_7 and the posterior angle of the acromion due to the simplicity of identifying these structures through palpation.

INTRACLASS CORRELATION COEFFICIENT AND STANDARD ERROR OF MEASUREMENT

The results of this study were compared only with other studies that reported ICC and SEM values of measurement procedures available for the clinical setting. Measurement procedures available for the clinical setting were considered to be procedures that did not require expensive and complex equipment and that were not time consuming such as three-dimensional procedures (Nijs et al., 2007). Both ICC and SEM are reported for reliability evaluation. ICC is commonly used for reliability report. However, its clinical usefulness is questioned when reported alone (Keating and Matyas, 1998). The reliability coefficient indicates the utility of a measurement procedure to differentiate between subjects in the sample under investigation. In other words, if a procedure shows a good ICC value, it means that individual measurements within a group of measurements kept their position in the group on repeated measurements. ICC does not provide enough information about procedure reliability when a clinician wants to know whether a patient differs from normative data or if an intervention resulted in a significant change between pre- and post-test for the variable of interest (Keating and Matyas, 1998). Additional information about the magnitude of score fluctuation in the units of measurement is needed for a clinician to confidently interpret the results obtained from a certain procedure. Clinicians who measure a difference that falls within the range of SEM need to be aware that there is a chance that nothing but measurement error is being observed. This is a problem when measuring scapular positioning since there are very small differences if any between healthy and shoulder patient populations (Greenfield et al., 1995; Odom et al., 2001). However, Lewis et al. (2005) reported that, when treating patients with shoulder impingement syndrome, a change of 1.4 cm in scapular lateral displacement and of 1.7 cm in scapula elevation in the resting position was observed. All of the SEM values observed in the present study are less than 1.2 cm. Thus, the procedure reported in the present study reports enough accuracy to identify potential differences between pre- and post-intervention.

Furthermore, one must be careful when comparing measurement reliability between studies based solely in ICC since ICC is greatly influenced by the variability of the studied population. A study with large variability between subjects compared to a study with small variability between subjects may yield a larger ICC even if measurement error is larger in the first population (Keating and Matyas, 1998; Domholdt, 2005). Again, a statistic of absolute reliability such as SEM is crucial to draw conclusions about a measurement's reliability.

INTRA- AND INTER-RATER RELIABILITY

To assess intra-rater reliability, two sessions were conducted one week apart to avoid recall, a potential common source of bias when assessing intra-rater reliability. Recall might occur simply by remembering the value measured on a previous session, the area of landmark palpation in the previous session, or even visualization of landmarks by redness left in skin by previous palpation. However, this was not the case in previous studies. All of the 7 studies found for comparison conducted intra-rater re-test within minutes from the first test (Gibson et al., 1995; T'Jonck et al., 1996; Crotty and Smith, 2000; Plafcan et al., 2000; Odom et al., 2001; McKenna et al., 2004; Lewis et al., 2005).This could have resulted in high values of reliability with limited clinical utility since it is not common for a clinician to conduct measurements of scapular positioning within minutes of a previous measurement in the clinical setting. Therefore, memory effect may be one of the factors responsible for differences in ICC and SEM between the present and previous studies.

Inter-rater ICC and SEM in the present study was calculated using measurements from the re-test session. This is done because of a possible learning effect that might occur throughout the study, leading to higher values of reliability. Therefore, a clinician who whishes to use this technique to measure scapular position interchangeably with other clinicians' measurements should be aware that the inter-rater ICC values resulting from our procedure can only be achieved after some training in the procedure, to be more exact, after measuring 30 participants as was the case in the present study.

Good reliability values were observed for the measurements in general. Only one of the measurements (vertical distance from C_7 to acromion inter-rater ICC) had a significant F value. Since this was the only significance found, it is believed that it might have occurred as a result of alpha inflation due to multiple comparisons.

Only studies that reported both ICC and SEM were used for comparison since both values are needed to compare the reliability of different procedures (Keating and Matyas, 1998). Seven studies that used clinical instruments to measure scapular position were found for comparison of ICC and SEM values (Gibson et al., 1995; T'Jonck et al., 1996; Crotty and Smith, 2000; Plafcan et al., 2000; Odom et al., 2001; McKenna et al., 2004; Lewis et al., 2005).

Gibson et al. (1995) reported that for the resting position of the arm, intra-rater ICC ranged from 0.91 to 0.94 (distance from the inferior angle of the scapula to the spine, and the SEM from 0.44 to 0.54 cm (distance from the inferior angle of the scapula to the spine). In the same study, they reported that at 90 degrees of shoulder abduction with internal rotation (Kibler's test position 3), an intra-rater ICC of 0.81 to 0.91 and a SEM of 0.56 to 0.79 cm (distance from the inferior angle of the scapula to the spine). Inter-rater ICC for the resting position of the scapula was from 0.67 to 0.69 (distance from the inferior angle of the scapula to the spine) and a SEM of 1.17 to 1.20. For 90 degrees of abduction with internal rotation, inter-rater ICC was from 0.18 to 0.28 (distance from the inferior angle of the scapula to the spine) and the SEM was from 1.59 to 1.65 cm (distance from the inferior angle of the scapula to the spine). To avoid rater-bias, these authors used a string to measure the distance and then used a tape measure to measure the length of the string that corresponded to this distance. The clinical experience or the amount of training for the study's procedure was not mentioned.

T'Jonck et al. (1996) reported, for the resting position of the arm that an intra-rater ICC of 0.83 to 0.93 (distance from the inferior angle of the scapula to the spine), and 0.91 to 0.99 (distance from the root of the spine of the scapula to the spine), and a SEM of 0.18 to 0.32 cm (distance from the inferior angle of the scapula to the spine), and 0.12 to 0.38 cm (distance from the root of the spine of the scapula to the spine). In the same study, they reported, for 90 degrees of shoulder abduction with internal rotation (Kibler's test position 3), an ICC of 0.93 to 0.96 (distance from the inferior angle of the scapula to the spine), 0.57 to 0.68 (distance from the root of the spine of the scapula to the spine), and a SEM of 0.45 to 0.60 cm (distance from the inferior angle of the scapula to the spine), and 0.54 to 0.55 (distance from the root of the spine of the scapula to the spine). Inter-rater ICC for the resting position of the scapula was to range from 0.72 to 0.78 (distance from the inferior angle of the scapula to the spine), and from 0.66 to 0.79 (distance from the root of the spine of the scapula to the spine), and a SEM of 0.57 to 0.60 cm (distance from the inferior angle of the scapula to the spine), and 0.57 to 0.77 cm (distance from the root of the spine of the scapula to the spine). For 90 degrees of abduction with internal rotation, inter-rater ICC ranged from 0.89 to 0.90 (distance from the inferior angle of the scapula to the spine), and 0.52 to 0.57 (distance from the root of the spine of the scapula to the spine), and a SEM of 0.71 to 0.72 cm (distance from the inferior angle of the scapula to the spine), and 0.54 to 0.66 cm (distance from the root of the spine of the scapula to the spine). A tape measure was used for measurements in this study. Two raters were involved in this study, both physical therapists. One of the raters had had over a year of experience with the procedures in the study, whereas the other had no experience with the procedures.

Crotty and Smith (2000) reported that for the resting position of the arm, intra-rater ICC ranged from 0.93 to 0.98 (distance between the inferior angle of the scapula and the spine), and SEM ranged from 0.27 to 0.61 cm (distance between the inferior angle of the scapula and the spine). Inter-rater ICC for the resting position of the scapula was 0.87 (distance from the inferior angle of the scapula to the spine), and a SEM of 0.75 cm (distance from the inferior angle of the scapula to the spine). To avoid rater-bias, they used an inelastic fabric to measure this distance and then used a tape measure to measure the size of the inelastic fabric that corresponded to this distance. Three raters participated in this study. It was reported that all raters were physicians specializing in physical medicine and rehabilitation. One was a consultant in sports and spine rehabilitation and two were completing fellowships in sports medicine or musculoskeletal rehabilitation. Moreover, all three were familiar with spine and shoulder surface anatomy, were aware of the purpose of the study, and were familiar with the measurement techniques.

Plafcan et al. (2000) reported that for the resting position of the arm, intra-rater ICC ranged from 0.85 to 0.88 (distance between the inferior angle of the scapula and the spine), and from 0.80 to 0.86 (distance from the root of the spine of the scapula to the spine), and a SEM of 0.44 to 0.48 cm (distance between the inferior angle of the scapula and the spine), and 0.43 to 0.51 cm (distance from the root of the spine of the scapula to the spine). Inter-rater ICC for the resting position of the scapula was 0.80 (distance from the inferior angle of the scapula to the spine), and 0.61 (distance from the root of the spine of the scapula to the spine), while the SEM was 0.56 cm (distance from the inferior angle of the scapula to the spine), and 0.72 cm (distance from the root of the spine of the scapula to the spine).The tool used in this study was called the Scapular Measurement Instrument. Neither raters' experience nor training for the study's procedure was mentioned.

Odom et al. (2001) reported that for the resting position of the arm, an intra-rater ICC of 0.75 was found for the distance between the inferior angle of the scapula and the spine, and an SEM of 0.61 cm was found for the distance between the inferior angle of the scapula and the spine. In the same study, they reported that for 90 degrees of shoulder abduction with internal rotation (Kibler's test position 3), there was an ICC of 0.80 for the distance between the inferior angle of the scapula and the spine and a SEM of 0.80 cm for the distance between the inferior angle of the scapula and the spine. They found an inter-rater ICC for the resting position of the scapula of 0.67 (distance from the inferior angle of the scapula to the spine), and an SEM of 0.79 cm (distance from the inferior angle of the scapula to the spine). For 90 degrees of abduction with internal rotation, they found an inter-rater ICC of 0.74 (distance from the inferior angle of the scapula to the spine), and a SEM of 1.20 cm (distance from the inferior angle of the scapula to the spine). To avoid rater-bias, they used a string to measure this distance and then used a tape measure to measure the length of the string that corresponded to this distance. The raters were 6 physical therapists with an average of 5.8 years of clinical experience in orthopedics.

McKenna et al. (2004) reported that for the resting position of the arm, the inter-rater ICC of 0.79 to 0.87 (distance from the inferior angle of the scapula to the spine), and 0.65 to 0.74 (distance from the root of the spine of the scapula to the spine) and a SEM of 0.53 to 0.57 cm (distance from the inferior angle of the scapula to the spine), and 0.59 to 0.60 cm (distance from the root of the spine of the scapula to the spine). In the same study, they reported that for 90 degrees of shoulder abduction with internal rotation (Kibler's test position 3), inter-rater ICC was 0.55 to 0.72 (distance from the inferior angle of the scapula to the spine), and 0.65 to 0.74 (distance from the root of the spine of the scapula to the spine), with a SEM of 0.62 to 0.63 cm (distance from the inferior angle of the scapula to the spine), and 1.16 to 1.19 (distance from the root of the spine of the scapula to the spine). Moreover, they reported that for complete elevation of the arm with thumbs touching (internal rotation) in the frontal plane, the inter-rater ICC was 0.56 to 0.73 (distance from the inferior angle of the scapula to the spine), and 0.57 to 0.71 (distance from the root of the spine of the scapula to the spine), with a SEM of 8.0 to 8.7 cm (distance from the inferior angle of the scapula to the spine), and 9.2 to 11.6 (distance from the root of the spine of the scapula to the spine). A thin tape measure was used to measure scapular position. They reported that all three raters were qualified physical therapists with at least 10 years experience in musculoskeletal rehabilitation. Furthermore, all raters undertook familiarization and practice trials of the techniques on 6 subjects for approximately 4.5 hours.

Lewis (2005) reported that for the resting position of the arm, the intra-rater ICC was 0.98 (distance from the inferior angle of the scapula to the spine), and 0.96 (distance from the root of the spine of the scapula to the spine), with a SEM of 0.3 cm (distance from the inferior angle of the scapula to the spine), and 0.3 cm (distance from the root of the spine of the scapula to the spine). A tape measure was used to measure scapular position. Neither raters' experience nor training for the study's procedure was mentioned

Since the present study used a different method for calculating the normalized values of the distance between the scapula and spine and of scapular depression, no studies were found to compare the ICC and SEM values reported in the present study.

Probable reasons for different reliability for scapular positioning measurements between these studies and the present study are memory effect, learning effect, different rater expertise among studies, and different ICC calculation, which will be discussed below.

Memory effect was a frequent problem observed in previous studies looking at scapular positioning. Even though the PALM was considered to be a more reliable instrument, conducting intra-rater measurements with only a few minutes between test and re-test might have resulted in high ICC values and low SEM values in these studies (Garson, 2007). The appropriate length of time between tests depends on how stable the variable of interest is since what is being measured is stability of a measurement procedure over time (Garson, 2007). If measurements are taken too far apart, subjects might go through postural changes that could affect the measurement. If measurements are taken too close in time, it is likely that the rater will recall the previous assessment and consequently influence the new assessment values (Laenen et al., 2007). This memory effect could compromise the clinical utility of these studies. Time between measurements is important to avoid rater's recall, although the time cannot be too long so that change in the variable of interest does not occur (Laenen et al., 2007). In this study, a week was chosen to be the time between tests. This time between sessions was chosen based on experience during the training sessions for this study's procedure. One week seemed long enough to avoid a memory effect and at the same time avoid significant changes in the participant's shoulder posture.

Also, there was a significant learning effect among the raters of the present study. Inter-rater ICC values of the first test were markedly lower compared to inter-rater ICC values of the re-test. A possible difference between the first test measurements and the re-test measurements due to learning effect may have been responsible for lower intra-rater ICC values and higher SEM values. Moreover, the better inter-rater reliability of this study compared to most other studies reported may also have occurred due to a learning effect. This is because most of these studies compared first session measurements between raters. Although all raters in the present study received about 10 hours of training about the methods of this study and were physical therapists with special training in musculoskeletal rehabilitation, a learning effect is likely to have occurred since none of them had significant clinical experience with the shoulder joint.

Furthermore, the expertise of the raters involved in this study was limited compared to the expertise reported in most of the other studies. It is expected that palpation of the landmarks used for scapular position measurement such as the inferior angle and root of the spine of the scapula during arm elevation requires considerable training and expertise for optimal identification, which was not the case in the present study. It is expected that ICC values decrease and SEM values increase with elevation of the arm due to this difficulty in palpation through muscles. However, this expected trend was not reported in some previous studies (Gibson et al., 1995; Odom et al., 2001). In the present study, a decrease in ICC and increase in SEM with arm elevation was observed. The most significant decreases in reliability that occurred with arm elevation were the inferior angle of the scapula at 90 degrees of elevation, and the root of the spine of the scapula at complete arm elevation. These structures were particularly difficult to palpate in these positions. Plafcan et al. (2000) also reported that in their study, raters stated that they were having difficulty locating scapular landmarks during arm elevation and that they believed this issue was related with lower reliability of their procedure. Thus, limited palpation expertise of the raters for the shoulder joint may have also significantly influenced the ICC and SEM values reported in the present study in a negative way.

Moreover, there are at least 6 different ways to calculate ICC. Due to the present study design (raters as a fixed effect, measurements were not averaged, and absolute agreement was desired), the most conservative way of calculating ICC was used. This could have resulted in a more trustworthy but lower ICC and larger SEM values. The studies used here for comparison had similar study designs, thus should also have used the most conservative approach to calculate ICC. However, none of the studies reported in full detail how ICC was calculated. This limits comparisons between the results of the present study and the other studies.

CHAPTER 6

CONCLUSION

The PALM is a reliable instrument to measure scapular position in a population with similar demographic characteristics as the one of this study. As hypothesized, a significant and good intra- and inter-rater ICC and SEM for this tool were observed for measuring scapular position with arm elevation in the scapular plane. Intra-rater reliability was not significantly different between the PALM and other tools for measuring the distance from the scapula to the spine. Also, the PALM had a slight better inter-rater reliability for measuring the distance from the scapula to the spine than the other tools, although comparison across studies found in the literature was limited by the studies limitations (memory effect due to short period of time between test and re-test) and measurements taken in different planes of arm elevation. Moreover, the PALM was shown to be a reliable instrument for measuring the distance between the scapula and the seventh cervical vertebrae.

Therefore, three major conclusions about the PALM's clinical utility can be drawn from the present study: (1) it yielded stable measurements taken on different days by the same and different clinicians; (2) it had a higher clinical utility than the tools used in other studies reported here because the design used in this study provided a smaller chance of memory effect occurrence; (3) it could be used not only to measure the medial/lateral displacement of the scapula but also to directly measure depression/elevation of the scapula, while previous studies have only reported procedures that indirectly measured scapular position.

Recommendations for future research

The amount of time between tests in a reliability study would depend on what is being tested (Garson, 2007). To avoid a memory effect on raters values, measurement sessions should not be taken on the same day. This was not the case in the reported studies which conducted the second session test within minutes of the preceding test. The present study was designed to observe a procedure's stability over a period of time, which is the purpose of a reliability study.

Although the PALM can theoretically offer a more precise measurement of the scapula positioning in the scapular plane compared to other available tools, reliability studies of scapular positioning measurements in the scapular plane with better designs using other tools is needed to draw more sound conclusions. Thus, future studies should focus on testing intra- and inter-rater reliability not in the same day so that more valid conclusions about a procedure's reliability can be reached and used for comparison across studies. Moreover, studies that investigate the validity of the PALM to measure scapular position are also needed. Furthermore, studies with sample sizes that are large enough to report more precisely whether there is a difference between patients with shoulder pain and normals are needed. This facilitates a better judgment about whether a procedure's SEM is small enough to have clinical utility.

References

Andrews, A.W., Thomas, M.W. & Bohannon, R.W. (1996). Normative values for isometric muscle force measurements obtained with hand-held dynamometers. *Physical Therapy,* 76, 248-259.

Anetzberger, H. & Putz, R (1996). The scapula, principles of construction and stress. *Acta Anatomica,* 156, 70-80.

Azzoni, R., Cabitza, P. & Parrini, M. (2004). Sonographic evaluation of subacromial space. *Ultrasonics*, 42, 683-687.

Bagg, S.D. & Forrest, W.J. (1998). A biomechanical analysis of scapular rotation during arm abduction in the scapular plane. *American Journal of Physical Medicine and Rehabilitation,* 67, 238-245.

Bongers, PM (2001). The cost of shoulder pain at work. *BMJ,* 322, 64-65.

Borsa, P.A., Timmons, M.K. & Sauers, E.L. (2003). Scapular-positioning patterns during humeral elevation in unimpaired shoulders. *Journal of Athletic Training,* 38, 12-17.

Borstad, J.D. (2006). Resting position variables at the shoulder: evidence to support a posture-impairment association. *Physical Therapy,* 86, 549-547.

Brophy, R.H., Beauvais, R.L., Jones, E.C., Cordasco, F.A. & Marx, R.G. (2005). Measurement of shoulder activity level. *Clinical Orthopaedics and Related Research*, 439, 101-108.

Burkhart, S.S., Morgan C.D. & Kibler, W.B. (2003). The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthoroscopy,* 19, 641-661

Cools, A.M., Witvrouw, E.E., Declercq, G.A., Vanderstraeten, G.G. & Cambier, D.C. (2004). Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *British Journal of Sports Medicine,* 38, 64-68.

Cote, P., Kreitz, B.G., Cassidy, J.D., Dzus, A.K. & Martel, J. (1998). A study of the diagnostic accuracy and reliability of the Scoliometer and Adam's forward bend test. *Spine*, 23, 796-802.

Crotty, N.M.N. & Smith, J (2000). Alterations in scapular position with fatigue: a study in swimmers. *Clinical Journal of Sport Medicine*, 10, 251-258.

Culham, E. & Peat, M. (1993). Functional anatomy of the shoulder complex. *The Journal of Orthopedics and Sports Physical Therapy,* 18, 342-350.

Dayanidhi, S., Orlin, M., Kozin, S., Duff, S. & Karduna, A. (2005). Scapular kinematics during humeral elevation in adults and children. *Clinical Biomechanics,* 20, 600-606.

DiVeta, J., Walker, M.L. & Skibinski, B. (1990). Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Physical Therapy*, 70, 470-476.

Domholdt, E. (2005). *Rehabilitation research: principle and applications* (3rd ed.). Saint Louis, MO. Elsevier Sauders.

Donatelli, R.A. (2004). *Physical therapy of the shoulder.* (4th ed.). Saint Louis, MO: Churchill Livingstone.

Ebaugh, D.D., McClure, P.W. & Karduna, A.R. (2005). Three-dimensional scapulothoracic motion during active and passive arm elevation. *Clinical Biomechanics,* 20, 700-709.

Endo, K., Yukata, K. & Yasui, N. (2004). Influence of age on scapulo-thoracic orientation. *Clinical Biomechanics,* 19, 1009-1013.

Garson, D. (2007). *Reliability Analysis.* Retrieved September, 24th, 2007 from http://www2.chass.ncsu.edu/garson/pa765/reliab.htm.

Gibson, M.H., Goebel, G.V., Jordan, T.M., Kegerreis, S. & Worrell, T.W. (1995). A reliability study of measurement techniques to determine static scapular position. *Journal of Orthopedic and Sports Physical Therapy*, 21, 100-106.

Greenfield, B., Catlin, P.A., Coats, P.W., Green, E., MacDonald, J.J. & North, C. (1995). Posture in patients with shoulder overuse injuries and healthy individuals. *Journal of Orthopedics and Sports Physical Therapy*, 21, 287-295.

Halder, A.M., Itoi, E. & An, K.N. (2000) Anatomy and biomechanics of the shoulder. *The Orthopedic Clinics of North America,* 31, 159-175.

Hamill, J. & Knutzen, K.M. (2003) *Biomechanical Basis of Human Movement.* Philadelphia, PA: Lippincott Williams & Wilkins.

Hawkins, R.J. & Misamore, G.W. (1996). *Shoulder injuries in the athlete: surgical repair and rehabilitation.* (1st ed.). New York, NY: Churchill Livingstone.

Hoppenfeld, S. (1976). *Physical examination of the spine and extremities.* New York, NY: Appleton-Century-Crofts.

Illyes, A. & Kiss, R.M. (2006). Method for determining the spatial position of the shoulder with ultrasound-based motion analyzer. *Journal of electromyography and kinesiology*, 16, 79-88.

Inmann, V.T., Saunders, J.B.D.C.M. & Abbot, L.C. (1944). Observations on the function of the shoulder joint. *The Journal of Bone and Joint Surgery,* 26, 1-30.

Johnson, M.P., McClure, P.W. & Karduna, A.R. (2001). New method to assess scapular upward rotation in subjects with shoulder pathology. *Journal of Orthopedics and Sports Physical Therapy*, 31, 81-89.

Johnston, T.B. (1937). The movement of the shoulder joint – A plea for the use of the 'plane of the scapula' as the plane of reference for movements occurring at the humero-scapular joint. *The British Journal of Surgery*, 25, 252-260.

Karduna, A.R., McClure, P.W., Michener, L.A. & Sennett, B. (2001). Dynamic measurements of three-dimensional scapular kinematics: a validation study. *Journal of Biomechanical Engineering*, 123, 184-190.

Keating, J. & Matyas, T. (1998). Unreliable inferences from reliable measurements. *The Australian Journal of Physiotherapy*, 44, 5-10.

Kendall, F.P., McCreary, E.K. & Provance, P.G. (1993). *Muscles, testing and function: with posture and pain.* (4th ed.). Baltimore, MD: Williams & Wilkins.

Kibler WB. The role of the scapula in athletic shoulder function (1998). *The American Journal of Sports Medicine,* 26, 325-336.

Krishnan, S.G., Hawkins, R.J., Warren, R.F. (2004). *The shoulder and the overhead athlete.* (1st ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Kuijpers, T., van der Windt, D.A.W.M., van der Heijden, G.J.M.G. & Bouter, L.M. (2004). Systematic review of prognostic cohort studies on shoulder disorders. *Pain*, 109, 420-431.

Laenen A., Alonso A., Molenberghs G., and T. Vangeneugden. *Accounting for the rater's memory effect in reliability estimation.* Retrieved September, 24th, 2007 from http://www.stat.ucl.ac.be/ISpub/tr/2006/TR0656.pdf.

Lewis, J., Green, A., Reichard, Z. & Wright, C. (2002). Scapular position: the validity of skin surface palpation. *Manual Therapy*, 7, 26-30.

Lewis, J., Wright, C., & Green, A. (2005). Subacromial impingement syndrome: the effect of changing posture on shoulder range of motion. *Journal of Orthopedics and Sports Physical Therapy*, 35, 72-87.

Lin, J.J., Hanten, W.P., Olson, S.L., Roddey, T.S., Soto-quijano, D.A., Lim, H.K., et al. (2005). Functional activity characteristics of individuals with shoulder dysfunctions. *Journal of electromyography and kinesiology,* 15, 576-586.

Ludewig, P.M., Behrens, S.A., Meyer, S.M., Spoden, S.M. & Wilson LA. (2004) Three-dimensional clavicular motion during arm elevation: reliability and descriptive data. *Journal of Orthopedics and Sports Physical Therapy,* 34, 140-149.

Ludewig, P.M., Cook, T.M. & Nawoczenski, D.A. (1996). Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. *Journal of Orthopedics and Sports Physical Therapy,* 24, 57-65.

Ludewig, P.M. & Cook, T.M. (2000). Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Physical Therapy,* 80, 276-291.

Lukasiewicz. A,C., McClure, P., Michener, L., Pratt, N. & Sennet, B. (1999). Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *Journal of Orthopedics and Sports Physical Therapy,* 29, 574-583.

Macfarlane, G.J., Hunt, I.M. & Silman, A.J. (1998). Predictors of chronic shoulder pain: a population based prospective study. *The Journal of Rheumatology,* 25, 1612-1615.

McKenna, L., Cunningham, J. & Straker, L. (2004). Inter-tester reliability of scapular position in junior elite swimmers. *Physical Therapy in Sport*, 5, 146-155.

Magee, D.J.: Shoulder Rehabilitation *In* Zachazewski, J.E., Magee, D.J. & Quillen, W.S. (1996). *Athletic Injuries and Rehabilitation.* Philadelphia, PA: WB Saunders.

Magee D.J (2002). *Orthopedic Physical Assessment.* (4th ed.). Philadelphia, PA: WB SAUNDERS.

Michiels, I. & Grevenstein, J. (1994) Kinematics of shoulder abduction in the scapular plane. *Clinical Biomechanics,* 10, 137-143.

Miranda, H., Viikari-Juntura, E., Heistaro, S., Heliovaara, M. & Riihimaki, H. (2005). A population study on differences in the determinants of specific shoulder disorder versus nonspecific shoulder pain without clinical findings. *American Journal of Epidemiology*, 161, 847-855.

Neiers, L. & Worrell, T.W. (1993). Assessment of scapular position. *Journal of Sport Rehabilitation*, 2, 20-25.

Nicholson, G.P., Goodman, D.A., Flatow, E.L. & Bigliani, L.U. (1996). The acromion: morphologic condition and age-related changes. A study of 420 scapulas. *Journal of Shoulder and Elbow Surgery*, 5, 1-11.

Nijs, J., Roussel, N., Vermeulen, K. & Souvereyns, G. (2005). Scapular positioning in patients with shoulder pain: a study examining the reliability and clinical importance of 3 clinical tests. *Archives of physical medicine and rehabilitation,* 86, 1349-1355.

Odom, C.J., Taylor, A.B., Hurd, C.E. & Denegar, C.R. (2001). Measurement of scapular asymmetry and assessment of shoulder dysfunction using the Lateral Scapular Slide Test: a reliability and validity study. *Physical Therapy*, 81, 799-809.

Ostor, A. J. K., Richards, C.A., Prevost, A.T., Speed, C.A. & Hazleman, B.L. (2005). Diagnosis and relation to general health of shoulder disorders presenting to primary care. *Rheumatology*, 44, 800-805.

Payne, N., Gledhill, N., Katzmarzyk, P.T., Jamnik, V.K. & Keir, P.J. (2000). Canadian musculoskeletal fitness norms. *Canadian Journal of Applied Physiology*, 25, 430-442.

Peterson, D.E., Blankenship, K.R., Robb, J.B., Walker, M.J., Bryan, J.M., Stetts, D.M., et al. (1997). Investigation of the validity and reliability of four objectives techniques for measuring forward shoulder posture. *Journal of Orthopedics and Sports Physical Therapy,* 25, 34-42.

Petrone, M.R., Guinn, J., Reddin, A., Sutlive, T.G., Flynn, T.W., Garber, M.P. (2003). The accuracy of the Palpation Meter (PALM) for measuring pelvic crest height difference and leg length discrepancy. *Journal of Orthopedics and Sports Physical Therapy,* 33, 319-325.

Picavet, H.S.J. & Schouten, J.S.A.G. (2003). Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC_3-study. *Pain,* 102, 167-178.

Picavet, H.S.J. & van den Bos, G.A.M. (1997). The contribution of six chronic conditions to the total burden of mobility disability in the Dutch population. *American Journal of Public Health*, 87, 1680-1682.

Plafcan, D.M., Turczany, P.J., Guenin, B.A., Kegerreis, S. & Worrell, T.W. (1997). An objective measurement technique for posterior scapular displacement. *Journal of Orthopedics and Sports Physical Therapy,* 25, 336-341.

Plafcan, D.M., Canavan, P.K., Sebastianelli, W.J. &Swope, K.M. (2000). Reliability of a new instrument to measure scapular position. *The Journal of Manual &*

Manipulative Therapy, 8, 183-192.

Poppen, N.K. & Walker, P.S. (1976). Normal and abnormal motion of the shoulder. *The Journal of Bone and Joint Surgery,* 58-A, 195-201.

Rankin G. & Stokes M. (1998). Reliability of assessment tools in rehabilitation: an illustration of appropriate statistical analyses. *Clinical Rehabilitation*, 12, 187-199.

Rockwood, C.A. & Matsen, F.A. (1998). *The shoulder: volume 2.* (2nd ed.). Philadelphia, PA: W.B. SAUNDERS COMPANY.

Sagano, J., Magee, D. & Katayose, M. (2006). The effect of glenohumeral rotation on scapular upward rotation in different positions of scapular plane elevation. *Journal of Sport Rehabilitation*, 15, 144-155.

Sahrmann, S.A.(2005). *Diagnosis and Treatment of Movement Impairment Syndromes.* Sao Paulo, SP: Santos Editora.

Shah, N.N., Bayliss, N.C. & Malcom, A. (2001). Shape of the acromion: Congenital or acquired – a macroscopic, radiographic, and microscopic study of acromion. *Journal of Shoulder and Elbow Surgery*, 10, 309-316.

Sobush, D.C., Simoneau, G.G., Dietz, K.E., Levene, J.A., Grossman, R.E. & Smith, W.B. (1996). The Lennie test for measuring scapular position in healthy young adult females: a reliability and validity study. *The Journal of Orthopedics and Sports Physical Therapy,* 23, 39-50.

Solem-Bertoft, E., Thuomas, K., Westerberg, C. (1993). The influence of scapular retraction and protraction on the width of the subacromial space. *Clinical Orthopedics and Related Research,* 296, 99-103.

Smith, J., Dietrich, C.T., Kotajarvi, B.R. & Kaufman, K.R. (2006). *Journal of Shoulder* *and Elbow Surgery,* 15, 339-343.

Smith, J., Kotajarvi, B.R., Padgett, D.J. & Eischen, J.J. (2002). Effect of scapular protraction and retraction on isometric shoulder elevation strength. *Archives of Physical Medicine and Rehabilitation,* 83, 367-370.

Su, K.P.E., Johnson, M.P., Gracely, E.J. & Karduna, A.R. (2004). Scapular rotation in swimmers with and without impingement syndrome: practice effects. *Medicine and Science in Sports and Exercise,* 36, 1117-1123.

T'Jonck, L., Lysens, R. & Grasse, G. (1996). Measurements of scapular position and rotation: a reliability study. *Physiotherapy Research International*, 1, 148-158.

Urwin, M, Symmons, D, Allison, T, Brammah, T, Busby, H, Roxby, M, et al. (1998) Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Annals of the Rheumatic Diseases*, 57, 649-655.

Veeger, H.E. (2000). The position of the rotation center of the glenohumeral joint. *Journal of Biomechanics,* 33, 1711-1715.

Veeger, H.E., van der Helm, F.C., Chadwick, E.K. & Magermans, D. (2003). Toward standardized procedures for recording and describing 3-D shoulder movements. *Behavior research methods, instruments, & computers,* 35, 440-446.

von Schroeder, H.P., Kuiper, S.D. & Botte, M.J. (2001). Osseous anatomy of the scapula. *Clinical Orthopaedics and Related Research,* 383, 131-139.

Walter, S.D., Eliasziw, M. Donner, A. (1998). Sample size and optimal designs for reliability studies. *Statistics in Medicine*, 17, 101-110.

Wang, H.K. & Cochrane, T. (2001). Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes. *The Journal of sports medicine and physical fitness*, 41, 403-10.

Warner, J.J.P., Micheli, L.J., Arslanian, L.E., Kennedy, J. & Kennedy, R. (1992) Scapulothoracic motion in normal shoulders and shoulder with glenohumeral instability and impingement syndrome. *Clinical Orthopaedics and Related Research,* 285, 191-199.

Watson, L., Balster, S.M., Finch, C. & Dalziel, R. (2005). Measurement of scapula upward rotation: a reliable clinical procedure. *British Journal of Sports Medicine,* 39, 599-603.

Weiser, W.M., Lee, T.Q., McMaster, W.C. & McMahon, P.J. (1999). Effects of simulated scapular protraction on anterior glenohumeral stability. *The American Journal of Sports Medicine,* 27, 801-805.

Yaffee, R.A. (2003). *Enhancement of Reliability Analysis: Application of Intraclass Correlations with SPSS/Windows v.8.* Retrieved September, 24th, 2007 from http://www.nyu.edu/its/statistics/Docs/intracls.html.

APENDIX A: PARTICIPANT IDENTIFICATION

Date: / /

Name: ____

Age: _________

Gender: **Male ( )** **Female ( )**

Height: ________ **Weight:** ________

Shoulder activity scale score: ________

Side of dominance: **Right ( )** **Left ( )**

Investigator sequence: ________________________________

Side of measurement: **Right ( )** **Left ( )**

APENDIX B: DATA COLLECTION SHEET

Date: / /

Participant's Name: ____

Participant's #: ___________

Investigator: ___________

Resting position:

Inferior angle: ___________ **Superior angle: ___________**

Scapula Size: ___________ **Distance from C_7 to RS: ___________**

PALM Inclination (C_7 to RS): ___________

90° of scaption:

Inferior angle: ___________ **Superior angle: ___________**

Full Scaption:

Inferior angle: ___________ **Superior angle: ___________**

APENDIX C: INCLUSION/EXCLUSION FORM

Inclusion Criteria

1. Aged between 18-40 years old .... Yes/No

2. Pain free full range of motion on both shoulders .... Yes/No

Any "No" results in participant exclusion

Exclusion Criteria

1. Shoulder girdle pain or pathology .... Yes/No

2. Cervical radiculopathy with irradiated pain to the shoulder .... Yes/No

3. Thoracic outlet syndrome .... Yes/No

4. Surgery or trauma to the thoracic spine, rib cage, shoulder girdle or cervical spine .... Yes/No

5. Scoliosis or hyperkyphosis .... Yes/No

6. Musculoskeletal disease .... Yes/No

7. Any congenital defect of the scapula (e.g., Sprengel's deformity) ...... Yes/No

8. Any neuromuscular disorder .... Yes/No

9. Currently pregnant .... Yes/No

10. Cardiovascular disease .... Yes/No

11. Leg length discrepancy over 5mm .... Yes/No

Any "Yes" results in participant exclusion

Participant inclusion .... Yes/No