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Reliability and Validity of Measurement Techniques for the Static Position of the Scapula

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Reliability and Validity of Measurement Techniques for the Static Position of the Scapula

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Abstract

This study had three objectives 1) to determine the test-retest reliability of tape measure and calipers as measurement tools for the position of the scapula, 2) to examine the concurrent validity of measurements obtained for scapula position using tape measure, calipers and three dimensional motion analysis and 3) to determine if differences in scapula position are detectable between healthy volunteers and those with shoulder pathology. The scapula position was measured at rest and in maximum elevation in 20 healthy volunteers and 20 subjects with shoulder pathology. Measurements were taken bilaterally for each subject with tape measure, calipers and three dimensional motion analysis. Statistical analysis found good test retest reliability for the use of tape measure and calipers as a measure of scapula position. ICC's indicated poor agreement between the tape measure and calipers, tape measure and three dimensional motion analysis, and calipers and three dimensional motion analysis, while Pearson r values indicated a strong positive correlation between the three measurement tools. T tests indicated that there is no statistically significant difference between scapula position within subjects. However there appears to be significant differences when comparing the scapula between healthy volunteers and subjects with shoulder pathology.

Keywords: Scapular resting position, reliability, validity, physiotherapy assessment, surface palpation, motion analysis

Dedication

"My family would be supportive if I said I wanted to be a Martian, wear only banana skins, make love to ashtrays, and eat tree bark."

Casey Affleck

Although my master's degree has been a far cry from the above, I can easily relate to this quote by the oh so eloquent Casey Affleck. Because of their tremendous support and ongoing encouragement, there is no one that I would rather dedicate this work to than my mom, dad and sister Pam. No matter what task I have decided to tackle, I can count on my own personal cheerleading squad. I appreciate all your interest and attempts to understand what I have been doing over the past 2 ½ years, driving through a snow storm to participate in my study, making it seem like the "cool thing to do" to the rest of the family. It has been very touching and somewhat amusing to watch you try and explain the details of my "shoulder study" to your coworkers and friends.

I also dedicate this work to Joe Perfetto, and although he "joined the team" near the end of the season, provided unfailing enthusiastic encouragement, patience and love which ultimately helped lead the team to victory.

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It would be a tremendous oversight on my part if I failed to acknowledge, first and foremost, my advisor Dr. Pamela Houghton. Although I do not drink coffee or beer, play golf and prefer early mornings to late nights, she decided to accept me as a student. Despite the fact that my study was not her primary area of expertise, Dr. Houghton dedicated her time to understanding the mechanics of the shoulder complex, readily adding new words like scaption to her vocabulary. It was her guidance, dedication and patience that made this journey most enjoyable. It is my hope that someday I am able to inspire someone the way that you have inspired me. I have truly enjoyed the opportunity to work with you and it is my hope that we will be able to do it again someday.

I would also like to thank my advisory committee. Although they may not have agreed with all my big ideas, they were gentle in telling me that they might not work. I can only hope that someday I will be considered in the same company as you Trevor, Lorie and Tom.

To Shawn, the WOBL lab still largely remains a mystery to me. If it wasn't for you, I wouldn't have any data or a thesis. To Anne, thank you for lending me your eyeballs and assessing what must have seemed like a never-ending line up of scapulae. I appreciate the hours that you gave up to help me.

To my friends and co-workers in the Physiotherapy Department at St. Joes, your support with my crazy changing hours and my questions regarding stats, shoulders and otherwise was amazing. I couldn't possibly ask for a more supportive (and fun) work environment.

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Term	**Description**
Scapular Movements	
Depression:	A gliding movement in which the scapula moves caudally, this movement is the reverse of elevation
Elevation	A gliding movement where the scapula moves cranially, as in "shrugging" the shoulders
Anterior tilt	Movement of the scapula around a coronal axis in which the coracoid process moves in an anterior and caudal direction while the inferior angle moves in a posterior and caudal direction
Downward rotation	Movement about a sagittal axis in which the inferior angle moves medially and the glenoid cavity moves caudally
Upward rotation	Movement about a sagittal axis in which the inferior angle moves laterally and the glenoid cavity moves caudally
Protraction	A gliding movement in which the scapula moves away from the vertebral column and following the contour of the thorax, assumes a posterolateral position in full abduction
Retraction	A gliding movement in which the scapula moves toward the vertebral column
Winging	Movement about a vertical axis where the vertebral border of the scapula moves away from the thorax while the glenoid fossa moves anteriorly (Sahrmann, 2002)
Planes of Movement	
Median Plane	An imaginary plane passing longitudinally through the body from anterior to posterior, dividing the body into right and left halves
Sagittal Plane	An imaginary plane passing through the body parallel to the median plane, this plane divides the body into right and left portions but does not pass through the median plane
Coronal Plane	An imaginary plane passing through the body at right angles to the median plane, dividing the body into anterior (front) and posterior (back) halves, also referred to as the frontal plane

Horizontal Plane	An imaginary plane passing through the body at right angles to both the median and coronal planes, dividing the body into superior (upper) and inferior (lower) portions

(Kendall et. al. 2005 and Moore, 2002)

Chapter 1

Literature Review

"Painful shoulders form an important part of orthopaedic practice but their obscurity, uncertain prognosis, and the fact that they present so few definite signs and symptoms, render their classification into types difficult on clinical grounds."

Burns and Ellis, 1937

1.1 Epidemiology of Shoulder Pathology

Individuals presenting with signs and symptoms resulting from a shoulder pathology constitute a large percentage of patients seen by physiotherapists in both the hospital and community settings. Shoulder pathologies can create significant pain, loss of mobility and strength at the shoulder joint, often resulting in significant functional limitations and time lost at work for an individual (Magermans, 2005). In their 2005 review paper on the epidemiology of persistent shoulder pain, Meislin et. al. (2005), reported that shoulder pain accounts for approximately 16% of all musculoskeletal complaints of patients presenting to a primary care physician. According to the Medical Expenditure Panel Survey conducted in the United States in 2000, the direct cost associated with the treatment of shoulder pathologies is seven billion dollars annually. The mean cost per episode of care per patient in the outpatient and inpatient setting was $1667.00 and $3011.00 US respectively (Meislin et. al. 2005). In a study that analyzed job related compensation claims in France, the number of claims for disorders in the upper extremity was four times higher in 1994 than in 1985 and upper extremity disorders accounted for 50% of all reported occupational ailments (Cassou et. al. 2002). Furthermore this authors found that the prevalence (men 7.8% and women 14.8%) and incidence (men 7.3% and women 12.5%) of chronic neck and shoulder pain increased with age and was more common in women than men in each birth cohort. In the Health 2000 survey conducted between 2000-2001 in Finland, it was found that one in every eight people living in Finland had shoulder pain. This study also found that insulin dependent diabetes increased the risk of chronic rotator cuff tendonitis almost 13 times in men (Miranda et. al. 2005). In their 2004 systematic review of 19 papers on the incidence and prevalence of shoulder pain, Luime et. al. found that prevalence figures differed from 6.9 - 26% for point prevalence, 18.6-31% for the month prevalence, 4.7 – 46.7% for the one-year prevalence and 6.7 – 66.7% for lifetime prevalence. These authors concluded that the wide variability in prevalence rates was due to differing definitions of shoulder pain and that prevalence rates decreased as the definition of shoulder pain was more restricted. It was clear that in all of the 19 articles included in the review, the older age groups experienced a higher prevalence of shoulder pain.

1.2 Scapula Kinematics

The work of Inman et. al. in 1944 was the first attempt to describe the scapula motion during glenohumeral movement. This study used radiographs and the insertion of pins directly into the bones of the living subjects to study the movement of the scapula in the coronal plane. This work concluded that during the first 30-60 degrees of glenohumeral joint elevation the scapula maintains a position of stability, serving as the base from which the humerus moves. During this range, the scapula will either fixate itself on the thoracic wall or move slightly medially or laterally until the position of stability is obtained. This phase of motion has been termed the "setting phase" and the axis of rotation of this movement is considered to be in the mid to lower aspect of the scapula (Poppen and Walker, 1976). Once approximately 60 degrees of glenohumeral joint elevation has been attained, the scapula begins to move along the thoracic wall. It is the combination of elevation and upward rotation of the scapula with the humerus that maintains the subacromial space, allowing the humerus to pass under the acromial arch without impinging on the tissues which lie in this space (Meyers, 2005). Figure 1 illustrates this point. In their study of scapula position as determined by radiographs, Poppen and Walker (1976) found that during the second phase of movement the centre of rotation moves towards the glenoid and the glenoid fossa moves medially and tilts upwardly while the inferior angle moves laterally. At this point, for every two degrees of humeral elevation, one degree of scapula rotation occurs, for example for every 15 degrees of elevation that occurs, 10 degrees occurs at the glenohumeral joint and five degrees occurs at the scapula as it upwardly rotates. This two to one ratio of movement continues until maximum elevation is reached, optimally consisting of 60 degrees of scapular rotation and 120 degrees of glenohumeral joint elevation. At the completion of elevation, the scapula should protract and sit close to the mid axillary line on the thorax and the vertebral border of the scapula should be upwardly rotated to 60 degrees. At the end of the range, the scapula will be positioned in a slightly depressed and a posteriorly tilted position (Sahrman 2002). Although this is the historical and widely accepted view of scapulohumeral rhythm, debate continues regarding its accuracy. A study conducted by McQuade and Smidt (1998) suggests that the accepted 2:1 ratio of scapula to humeral movement is somewhat simplistic and that this ratio changes when the humerus is loaded. These authors recommended further exploration of this theory.

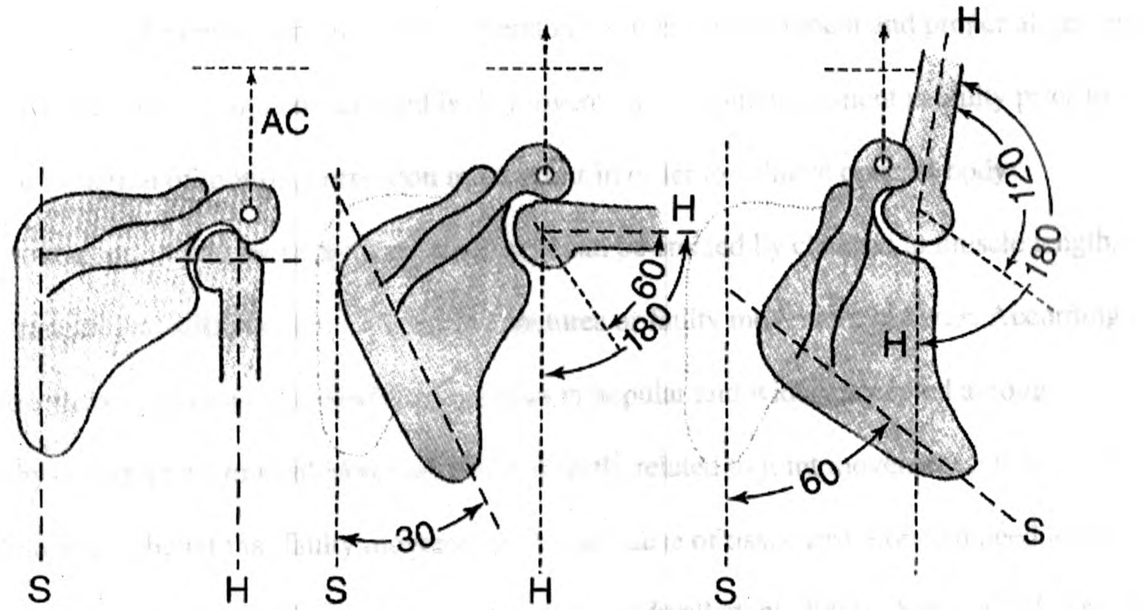

Figure 1: Scapulohumeral Rhythm (From Calliet R: Shoulder Pain, ed 2, Philadelphia, 1981, FA Davis.)

1.3 Sahrman Theory

Ideal joint alignment is the cornerstone to precise movement and proper alignment facilitates precise and coordinated body movement. If joint alignment is faulty prior to the initiation of motion, correction must occur in order to achieve optimal body movement. Changes to the joint alignment can be created by changes in muscle length, strength, and stiffness due to sustained postures or faulty movement patterns. According to a theory developed by Sahrman, one that is popular and widely accepted among physiotherapists, musculoskeletal pain is directly related to joint movement. It is Sahrman's belief that faulty movements are the cause of tissue irritation and need to be corrected in order to alleviate pain symptoms (Caldwell et. al. 2007). Sahrman likens the human body to any other mechanical system, theorizing that the longevity of the components and the efficiency of the systems performance requires maintenance of precise movements of the system. In the case of the human body, loss of the precise movement can begin a series of events causing changes in the body tissues, progressing from micro-trauma to macro-trauma.

1.4 Shoulder Impingement Syndrome

Definition

Shoulder impingement is a term made popular by Neer (1972) to describe the mechanical compression of the tendinous portion of the rotator cuff and subacromial bursa against the anterior undersurface of the acromion and coracoacromial ligament. Impingement syndrome can be classified as being primary or secondary. Primary impingement is defined as impingement caused by an outlet stenosis or decrease in the subacromial space in a stable shoulder. Secondary impingement is described as impingement secondary to instability of the glenohumeral joint (Cools et. al. 2003).

Regardless of the etiology, compression of the soft tissues is thought to be due to inadequate space in the subacromial space for the clearance of the rotator cuff tendons and subacromial bursa as the arm is positioned in elevation. The condition can be further exacerbated by inflammation of the rotator cuff tendons, inhibition of the rotator cuff muscles, and/or altered joint mechanics. Simply put, any postural alteration that brings the humeral head (more specifically the greater tuberosity) closer to the acromial arch initiating a series of events which can potentially lead to an impingement syndrome. These alterations include, but are not limited to, decreased amount of upward rotation and posterior tipping of the scapula on the thorax. These movements are considered to be normal movements that should occur during humeral elevation (Ludewig et. al., 2000).

Because impingement occurs during the elevation of the arm, many common activities of daily living, job related tasks and sporting pursuits can be seriously affected (Ludewig et. al., 2000). This pathology can affect an individual's quality of life by limiting his/her ability of perform normal tasks and to get an uninterrupted nights sleep (Lewis, 2005). In their study examining the relationship between health status and shoulder impingement syndrome, Chipchase et. al. (2000) found that individuals suffering from chronic shoulder impingement reported significant functional disability and a reduced quality of life. Eighty one individuals diagnosed with chronic shoulder impingement scheduled to undergo a subacromial decompression, completed the SF-36, a generic quality of life questionnaire and the Simple Shoulder Test (SST) (a shoulder-specific questionnaire), the results of which were compared to Australian normative data. The subjects who suffered from shoulder pathology were found to be lower in all health dimensions on the SF-36 than the "normal" population. The results from the SST revealed that the individuals with shoulder impingement were very limited functionally, experiencing particular difficulties working full time and being unable to life weight above their head.

The Scapula's Contribution to Impingement Syndrome

Current literature regarding the etiology of impingement syndrome reflects the differing views of health care professionals. A number of contradictory theories have been proposed to explain the cause of this condition. Numerous factors have been suggested as contributing to the alteration in the position of the scapula including: age, bony and muscular changes, and habitual postures.

Aging

A study conducted by Endo et. al. (2004) found a significant correlation between aging and scapular orientation. Working with 44 subjects aged 16 to 73, the study investigators took radiographs of each subject's scapula with the arm in the neutral position and in 90 degrees of abduction. The position of each subject's scapula was then determined by taking measurements on the radiograph and through the calculation of what the authors called the coracoid upward shift distance. This distance was defined as the distance between the scapular spine line and the upper border of the coracoid process. Based on this calculation, the results of this study indicate that with aging, the amount of posterior tilt and upward rotation of the scapula decreases during elevation. The authors of this study went on to suggest that the change in scapula orientation was likely as a result of age related muscle weakness in the shoulder girdle however, no evidence to support this theory was presented.

The results of a study conducted by Dayanidhi et. al. (2005) suggests that significant differences exist between children and adults with respect to scapula movement patterns. Using a group of 15 adults (mean age 28.8 years +/- 4.3) and 14 children (mean age 6.7 +/- 1.5 years) kinematic data using an electromagnetic tracking device was collected from the scapula during upper extremity elevation in the plane of the scapula. This study found that during elevation, the scapulohumeral rhythm was 2.4:1 for adults and 1.3:1 for children. These results suggest that as one ages changes appears with the movement of the scapula, although the mean age of the adult population was only 28.8 years. What happens to the dynamics of the scapula as we continue to age remains to be determined. It is possible that further changes in the scapula position as an individual ages could result in shoulder pathology.

Bony and Muscular Changes

Inman et. al. (1944) were the first group to look at the relationship between movement at the glenohumeral, scapulothoracic, sternoclavicular and the acromioclavicular joints. The investigators of this study used roentgenography and the direct insertion of pins into the bones of living subjects and identified that the role of the clavicle was more complicated than previously suspected. During elevation of the humerus the scapula must rotate along the thoracic wall, a movement that is made possible because of movement at the acromioclavicular and sternoclavicular joints. Consequently, any loss of motion at either the acromioclavicular or sternoclavicular joints or to the clavicle itself, the position and resulting movement will be compromised. This in turn can create a situation where an impingement syndrome can develop.

Changes to the muscular system can also result in abnormal scapula position potentially contributing to shoulder pathology. Changes in the length, tension or the coordination and activation of the muscles which attach to the scapula can lead to an abnormal resting position of the scapula. According to Sahrman's theory an abnormal scapula position at rest can manifest as a movement impairment during shoulder elevation (2002).

In their 2005 study, Ebaugh et. al. used electromagnetic sensors to determine the effects that muscle activity had on three-dimensional scapulothoracic motion. Twenty individuals with no history of shoulder pathology served as subjects and had the muscle activity of their upper and lower trapezius, serratus anterior, infraspinatus and anterior and posterior deltoid measured during both active and passive glenohumeral elevation. The results of this study suggest that decreased scapula upward rotation, potentially due to decreased range of motion at the scapulothoracic or acromioclavicular joint or altered activity in the trapezius or serratus anterior muscles, play a key role in the instability of the glenohumeral joint by altering the optimal alignment of the humeral head on the glenoid. The results of this study were similar to those found by Cools et. al. (2003). Using surface EMG the muscle activity of the upper, middle and lower fibres of trapezius along with the middle portion of the deltoid muscle were recorded while resistance was applied at various degrees of scapula elevation. Results of this study indicate that differences exist in the timing of muscle activation between subjects presenting with an impingement syndrome and healthy volunteers. In particular, subjects with impingement syndrome had a delay in muscle activation time in both the middle and upper fibres of trapezius which both play a key role in the upward rotation of the scapula during glenohumeral elevation.

Posture

Postural deviations including, but not limited to, forward head posture, increased thoracic kyphosis and rounded shoulders (scapular protraction) have been associated with the development of shoulder pain (Borstad, 2006). Sahrman (2002) theorized that postural deviations change that ability of a joints to perform precise movement which over time and with exposure to repetitive movements may cause tissue breakdown and pain. Any change in the position of the scapula resulting in a decrease in the subacromial space by failing to move the acromion away from the humeral head during arm elevation will cause an increase in the compressive loads on the tissues which lie within the subacromial space. This includes the tendons of the rotator cuff, long head of biceps and the subacromial bursa. In the presence of this increased load tissue breakdown occurs rapidly resulting in an impingement syndrome, rotator cuff tendonitis and eventually a rotator cuff tear (Borstad, 2006).

In his 2006 study, Borstad looked at the relationship between postural deviations resulting from a tight pectoralis minor muscle and scapular biomechanics, linking these results to the posture/impairment relationship. With a sample size of 50 asymptomatic subjects, a three-dimensional electromagnetic motion capture system was used to measure the resting length of the pectoralis minor muscle. Based on the measurements taken, subjects were then divided into two groups, those with normal resting length of pectoralis minor and those with abnormal resting length of pectoralis minor. The resting position of the scapula was then measured using the Scapula Index and the Thoracic Kyphosis Index. Subjects with abnormal resting pectoralis minor length had different amounts of scapula upward rotation and protraction/retraction with increased scapular internal rotation, decreased posterior tilting during arm elevation. These changes in scapula position are similar to those with impingement syndromes. (Ludewig and Cook, 2000).

Research conducted by McClure et. al. (2006) found that subjects presenting with a glenohumeral impingement syndrome had slightly greater scapula upward rotation and clavicular elevation during glenohumeral flexion and greater posterior scapula tilt and clavicular retraction during scapular plane elevation compared to healthy volunteers. The results of this study were in agreement with the results found in a similar study conducted by Rundquist (2007). A hypothesis of Rundquist's study was that individuals with shoulder pathology causing decreased glenohumeral joint range of motion would exhibit different scapula kinematics on the affected side. Rundquist found that subjects with shoulder pathology had greater amounts of scapular upward rotation when the shoulder was elevated to end range. Based on these results the author concluded that treatment of glenohumeral dysfunction should include examination of the scapulothoracic joint.

Kebaeste et. al. (1999) conducted a study to determine the effect of thoracic spine posture on scapular movement patterns, glenohumeral range of motion and muscle strength in the plane of the scapula. Using an electromagnetic digitizer, 34 healthy subjects had the position of their scapulae measured; 1) with their arm at the side, 2) in abduction to 90 degrees in the plane of the scapula and 3) maximum shoulder elevation in the plane of the scapula. These measurements were taken twice for each subject, once with the subject in erect sitting posture and then again in thoracic flexion or "slouched" sitting posture. This study found that when subjects were in "slouched" sitting posture both scapula were significantly more elevated when the arm was at rest and in 90 degrees of elevation in the plane of the scapula and less posterior tilted in the 90 degree and maximum elevated arm positions. Furthermore, this study found there was significantly less glenohumeral abduction range of motion in the slouched postures than in the erect sitting postures. Since posterior tilting is a movement that must occur at the scapula during elevation of the humerus a decrease in the scapular movement is believed to contribute to limited shoulder range of motion. The findings of this study support the suggestion that thoracic spine, scapula and glenohumeral joint movements do not function independently. Therefore, in order to effectively treat a problem that exists at the shoulder, the position of the thoracic spine and scapula need to be taken into consideration. The results of this study were similar to those found by Finley et. al. (2003) in their study looking at the effect of sitting posture on three-dimensional scapular kinematics. This study included 16 healthy young adults who had the position of their scapula measured using skin mounted electromagnetic tracking sensors. As in the previous study, scapula measurements were taken during glenohumeral elevation with the subject in upright and slouched sitting postures. The results of this study were consistent with those found by Kebaeste et. al. (1999), suggesting that increased thoracic kyphosis alters the movement of the scapula during humeral elevation. More specifically, this study found that in the slouched sitting posture the scapula exhibited less posterior tilting and lateral rotation, movements found to be necessary to maintain the subacromial space and prevent impingement.

In their 2005 study, Lewis at el investigated the effect of changing posture on the range of motion of shoulder flexion and scapular plane abduction in both asymptomatic individuals and individuals who had been diagnosed with a subacromial impingement syndrome. The investigators used surface palpation techniques, a camera, measuring tape and inclinometers to identify eight points on the axial skeleton, the scapula and the humerus for the 120 subjects included in this study. Using the above techniques investigators measured the position of the cervical spine, the scapula, glenohumeral joint range of motion and thoracic spine motion in four data collection phases. In the first phase the subject was measured in normal sitting posture then tape was applied to the scapula in order to change the posture of the scapula. Measurements were then repeated in the normal scapula position phase and lastly in the placebo tape position. Results of the study indicate that changing the posture of the subject, including the posture of the scapula and the thoracic spine increases the amount of elevation in flexion and in scaption.

Ludewig and Cook (2000) conducted a study that investigated glenohumeral and scapulothoracic kinematics along with muscle activation in individuals with symptoms of shoulder impingement. This study utilized an electromagnetic motion capture system to determine the three-dimensional position and orientation of the scapula, the humerus and the thorax. When compared to the control group, individuals with a diagnosis of shoulder impingement syndrome demonstrated decreased amounts of upward rotation during the three test phases of motion (31-60 degrees, 61-90 degrees and 91-120 degrees of motion), increased anterior tipping of the scapula during the end of the third phase of motion and increased scapular medial rotation under load conditions. The results of this study suggest that shoulder impingement syndrome can in part be due to alterations in the position of the scapula.

1.5 Scapula Assessment

It has been widely theorized that the abnormal resting position of the scapula is a potential cause of impingement syndrome, therefore, a physiotherapy assessment conducted to determine the cause of this pathology should include the scapulothoracic joint.

Over the years, a variety of methods have been developed to measure the position of the scapula. Early research examining the position and motion of the scapula relied on two dimensional measurement techniques. Doody et. al. (1970) used a two dimensional goniometric measure to study the relationship between glenohumeral and scapula movement during abduction 30 degrees anterior to the frontal plane. The results of this study were in agreement with Inman's (1944) previous discovery of a two to one ratio of glenohumeral to scapula movement during arm elevation. Results to date have limited clinical application since there is not a reliable and valid method that clinicians can use for measuring the movement of the scapula. Assessing scapular movement using a goniometer also relies on palpation skills and measuring the movement of the scapula as it moves under soft tissue. In addition, this method of measurement fails to take into consideration the three-dimensional nature of scapula movement.

Three Dimensional Measurement Devices

More recent efforts to capture the movement of the scapula have utilized various three-dimensional measurement tools including fluoroscopy, digitization and electromagnetic based methods (Price et. al. 2000,McClure et. al. 2001 and Watson et. al., 2006). This has proved to be a difficult task for researchers since the movement of the scapula actually occurs under the skin and is often obscured by the overlying muscle and subcutaneous fat. This task is challenging because three-dimensional measures often require the use of surface markers which do not move with the scapula as it moves under the skin (McClure, 2001).

Price et. al. (2000) used a sample size of ten healthy subjects to compare the movement of the scapula during active and passive humeral elevation. To capture the three-dimensional movement of scapulohumeral motion, the two channel SPACE IsotrakII system was used which utilizes technology (i.e. the Scapula Locator) previously developed and validated by Barnett et. al. (1999). This tool is a so-called palpation fixture that has a transmitter attached and is placed over the scapula with three locators ("legs") attaching to the acromion, the inferior angle and the root of the spine of the scapula. The transmitter records the three dimensional static and dynamic position of the scapula during the active and passive movement of the humerus. The authors of this study argue that this system is an adequate method for measuring the position of the scapula during movement due to its portable non-invasive nature and that it has proven high inter and intra observer reliability. However, this system is not without its faults and is subject to difficulty in palpating the bony landmarks. There is movement of the hand held scapular locator during measurement, and an artefact from skin motion, and high costs and time associated with the use and set up of this tool. Therefore it is not considered an feasible tool for the measurement of the scapula in a clinical setting.

Watson et. al. (2006) conducted a study to determine the clinical reliability of the Plurimeter-V gravity inclinometer to measure the upward rotation of the scapula in glenohumeral abduction. Twenty-six subjects presenting with a wide variety of shoulder pathologies were assessed in two repeated tests within a single test period. Each subject was asked to elevate his/her shoulder into abduction in the scapular plane while the inclinometer measured the movement of both the humerus and the scapula. Results of this test indicated good intra-rater reliability and the authors concluded that the Plurimeter-V gravity inclinometer can be used effectively and reliably for measuring upward rotation of the scapula. The results of this study were consistent with those reported by Johnson et. al. (2001) who found that the digital inclinometer is an appropriate method for measuring scapular upward rotation in the plane of the scapula. These investigators found good to excellent intra-rater reliability and concurrent validity when measuring the upward rotation of the scapula. Despite these results, this measurement tool is limited in that it looks at the position of the scapula in only one plane of movement. The scapula moves in a three-dimensional arch of movement, and an abnormality in any plane can lead to shoulder pathology. In addition, as part of the standardized test protocol used in both studies, the measures of scapula upward rotation occurred at 45, 90 and 135 degrees of humeral elevation. No measurements were taken in the resting position, which is often where abnormalities are most obvious and in most patients with shoulder pathology, 135 degrees and sometimes even 90 degrees of elevation are often not possible due to pain. As with most measures of scapula position for successful use of the "digital inclinometer" or the Plurimeter-V gravity inclinometer accurate surface palpation is required to position the device on the spine of the scapula. If the patient has considerable soft tissue in the area this makes the measurement instrument less reliable.

McClure and colleagues have used a sophisticated laboratory based three-dimensional motion analysis system to document changes in scapula position during movement of the humerus. These researchers used an electromagnetic motion analysis system to determine if patients presenting with impingement syndrome had abnormal three-dimensional scapular kinematics when compared to a control group. This study used three sensors placed on the thoracic spine, humerus and scapula and measured three scapular rotations (external rotation, upward rotation and posterior tilting) in order to determine scapula orientation. Three motions were measured, scapular plane elevation, flexion in the sagittal plane and humeral external rotation. Results of this study indicate that when compared to a control group, subjects with impingement syndrome had greater scapular upward rotation and clavicular elevation during flexion and slightly greater scapula posterior tilt and clavicular retraction during scapular plane elevation. The group of subjects with impingement syndrome also demonstrated less scapular and glenohumeral range of motion overall when compared to the control group. This work was important since it demonstrated that differences in dynamic movement of scapula might contribute to shoulder pathology. However a limitation of this study is that the electromagnetic system has not been validated for the measurement of scapular kinematics. Because the scapula moves under the skin and the electromagnetic sensors are placed over top of the skin, the sensor may not be accurately measuring the actual position of the scapula.

In 2001 the same group of researchers described three-dimensional scapular motion during dynamic shoulder movements in vivo, after inserting two pins directly into the scapula of eight healthy volunteers. A small three-dimensional motion sensor, which measured the movement of the scapula during abduction of the humerus in the scapular plane, was then fixed to the two pins. This study found that during glenohumeral elevation, the scapula rotates around three axes, the scapula upwardly rotates and posteriorly tilts around a medial/ lateral axis and externally rotates around a vertical axis. The mean ratio of scapula to glenohumeral joint movement was found to be 1:1.7 (McClure et. al. 2001). Although this study provided useful information regarding the normal movements of the scapula during movement of the humerus this technique for measuring scapula position is clearly not appropriate in a clinical setting.

Digital fluoroscopy has also been used to measure scapulohumeral rhythm during humeral elevation in the plane of the scapula (Mandalidis et. al. 1999). Thirty-eight males with no history of shoulder pathology participated in this study. Each subject was positioned in the front of a fluoroscopic table with the test shoulder 30 degrees anterior to the frontal plane. Anterioposterior images of the shoulder girdle were taken at rest, 30, 60, 90, 120,150 degrees and maximum elevation of the scapula. Results of this study concluded that fluoroscopy is a reliable method for measuring the position of the scapula relative to the humerus, with the exception of measures taken above 150 degrees of abduction. This study found that during the initial 60 degrees of glenohumeral elevation, upward rotation of the scapula was highly variable while after 60 degrees the scapula assumed a 2:1 ratio of glenohumeral to scapula rotation. The benefit of fluoroscopy over standard radiographs is that fluoroscopy allows for the scapula to be evaluated dynamically. This study also confirmed previous studies regarding the biomechanics of the scapulothoracic joint, concurring that the scapula experiences minimal movement during the initial 60 degrees of humeral elevation, beginning movement at 60 degrees and, reaching end range at approximately 120 degrees of glenohumeral elevation. Although useful in confirming previous work on scapula motion during shoulder movement, the results of this study do little to the development of a clinically useful measurement tool. The average clinician does not have access to this equipment due to costs and it requires that patients be exposed to radiation.

Clinical Measures of Scapula Position

The four most common techniques used in a clinical setting for scapular measurement are 1) surface palpation of bony landmarks, 2) the Lennie Test, 3) the Lateral Scapular Slide Test and 4) the Scapula Index.

A study conducted by Lewis et. al. (2002) used 12 embalmed cadavers to determine whether palpatory techniques were valid methods to locate bony landmarks on the scapula and thoracic spine. The first investigator of the study was instructed to palpate six points on each of 12 prone lying cadavers and then place a red topped metal pin at the anatomical site. A second investigator then removed the previously resected skin to identify where the actual anatomical site was located and place a pin at the location. The distance between the two pins was then measured. This study concluded that palpation is an acceptable method for determining scapular position in a clinical population. However, a clear description of the statistical analysis that led to this conclusion was not provided in the article. This study was also limited since it did not examine inter or intra rater reliability, it only measured resting scapular position in the frontal plane and it did not account for differences in skin texture or soft tissue between the cadaver and a typical clinical population. In addition the amount of subcutaneous tissue overlying each anatomical point was not calculated, therefore there is no way to tell whether this is a factor that could affect a clinician's ability to palpate tissue.

In an effort to develop a quantitative measure of scapula position, Sobush et. al. (1996) developed the Lennie test to assess the normal horizontal and vertical scapular resting position and providing a method to measure the amount of rotation occurring in the scapula. This test was developed with 15 healthy females ages 19-21. Each of the study's three investigators were asked to identify six anatomical landmarks bilaterally including, the superior angle, the root of the spine of the scapula, the inferior angle along with the spinous process that lay most parallel on the thoracic spine. Following this procedure, measurements were taken from each point to the thoracic spine using calipers which were then transposed to a metric ruler. These distances where then compared to those found on radiographs. Correlation coefficients between skin surface and radiographic measurements of scapular positions ranged from 0.43 to 0.82 while agreement between raters (ICC's) for surface measurements of scapular position ranged from 0.64 to 0.86. Surface landmark measurements for scapular position were within 0.56cm and 1.7 degrees of the measurements made from radiographs for linear and angular position. These values will reflect in part the distortion that occurs with radiographs. Based on these results, this study concluded that the Lennie Test could be used to objectively measure scapular position in both healthy populations and those presenting with shoulder pathology. Limitations of this test include the fact that the tool was developed with healthy young females, a population not typically seen in clinic and it has not yet been validated on individuals with shoulder pathology. In addition, this test relies largely on surface palpation and the use of radiographs, a method which has not been proven to be a gold standard for the measurement of bony landmarks. The authors also did not report whether they had accounted for any distortion of the images which may have occurred on the radiographs. The primary problem is that radiographs are a two-dimensional representation of a three-dimensional body and are subject to distortion and magnification. Also slight postural variations or rotation towards or away from the radiographic plate could influence the results and would potentially affect the reliability and validity of the measurements.

The Lateral Scapular Slide Test was developed by Kibler (1998) to assess scapular asymmetry. In each of the three test positions utilized (neutral, 45 and 90 degrees of glenohumeral elevation), tape measurements were taken from the thoracic spine to the inferior angle. A difference in the distance measured from the inferior angle to the thoracic spine greater than 1.5cm was hypothesized to indicate scapular dyskinesis or dysfunction. This test is limited in that it assumes that the scapulae are symmetrical. However it is widely accepted, but not definitively proven, that asymmetry does exist between the dominant and non-dominant upper extremity. In addition, tests conducted by Koslow et. al. (2003) and Odom et. al. (2001) failed to find this test reliable, sensitive or specific.

The Scapula Index is a measurement tool developed by Borstad (2006) to determine the resting position of the scapula. Developed with 50 subjects presenting with asymptomatic shoulders this tool uses a tape measure to take two measurements, one from the midpoint of the sternal notch (SN) to the medial aspect of the coracoid process (CP) and one from the posterolateral angle (PLA) of the acromion to the most parallel spinous process of the thoracic spine (TS). The resting position of the scapula is then determined by using the equation (SN to CP/PLA to TS) x 100. An increase in scapula protraction would result in a decreased value from SN to CP, an increased value from PLA to TS and a smaller Scapula Index. A more retracted position of the scapula would result in the opposite. Although simple and cost effective to use, this tool is theoretically based and has not undergone reliability and validity testing. In addition this measurement can easily be affected by the amount of subcutaneous tissue bulk of the test subject. This tool was also developed using a group of subjects with no known shoulder pathology, therefore, its potential for use with individuals presenting with shoulder pathology is not currently known.

A reliable and valid clinical tool for assessing static and dynamic scapular position and a tool which takes into account more than just movement in the frontal plane does not exist therefore further research needs to be conducted to develop an appropriate tool.

1.6 Rationale

The upper extremity has been described as the “origin of manual activity” (Moore, 1992). In order to allow for maximum function, the upper extremity must be freely movable, with the entire limb functioning to position the hand for grasping and manipulation tasks. Although its “stability has been sacrificed for mobility” (Sahrman, 2002), the upper limb does require a stable platform from which to move and the scapula is the bone that performs this role. It is because the shoulder girdle functions as a platform from which the upper extremity moves that any impairment at the shoulder girdle will impact the entire upper extremity (Michener, 2005). Therefore, physiotherapists agree that a patient presenting with shoulder complaints should undergo an assessment which includes the multiple joints that make up the shoulder girdle. The function of these joints should be assessed not only in the resting position but also during movement. According to a theory developed by Sahrman (2002), if an abnormality exists in the resting position of the joint, this abnormality must be corrected for during the joint movement or problems, primarily pain, will be created. Although widely accepted, this theory has not been supported by research. Because of the co-dependent relationship between the scapula and the humerus, any abnormality in the resting position of the scapula will potentially manifest itself as a movement impairment at the glenohumeral joint. It is because of this relationship that physiotherapists often consider the scapula as the key to solving shoulder pathology. The challenge to the assessing physiotherapist is that currently there are no available clinically useful and cost-effective measures to identify abnormalities in scapular position. Clinicians must rely heavily on their observation skills and palpatory techniques to identify abnormalities affecting the scapula. In addition they must rely on comparison to the contralateral shoulder girdle and personal experience to determine if an abnormality is significant enough to produce the identified pathology.

Although an optimal physiotherapy assessment of the scapula should take into account the three-dimensional position of the scapula, currently there are no clinically useful and cost-effective measures to do this. It is, however, the expectation that the assessing physiotherapist be able to identify abnormalities in the three-dimensional resting position and movement of the scapula in order to treat it appropriately. Currently physiotherapists must rely on observation and palpation skills to quantify the position of the scapula at rest and during movement, a task made all the more challenging by the fact that the scapula is a bone which moves under the skin and its position is often obstructed by the overlying soft tissues.

The purpose of this study was to investigate the test-retest and concurrent validity of a three-dimensional clinical measurement technique using a tape measure and calipers to assess scapular position at rest and at the end of elevation in the scapular plane. The measurements taken using the tape measure and calipers were compared to three-dimensional imaging which served as the gold standard. Although there is limited research on the use of three-dimensional motion analysis in the upper extremity, this tool is the best available for determining the three- dimensional position of bony landmarks. In addition, this study attempted to document normal variation in scapula position and determined if greater asymmetries in scapula position were related to greater symptomology.

This study had the following three objectives:

1. To determine the test-retest reliability when using the tape measure and calipers to measure four distances from the scapula to the thoracic spine on two separate occasions in subjects presenting with and without shoulder pain.
2. To determine the amount of agreement between tape measure and calipers, calipers and motion analysis and tape measure and motion analysis when used to measure four distances from the scapula to the thoracic spine in both rest and elevation arm positions.
3. To determine whether greater asymmetry between scapulae is related to greater pathology when comparing the affected versus unaffected side and in comparing the DASH (Disabilities of the Arm, Shoulder and Hand) and Numerical Pain Rating Scores between healthy volunteers to those with shoulder pathology.

4. To determine whether differences in scapular position could be detected using clinical measures between individuals with shoulder pathology compared to healthy volunteers.

Chapter Two

Methods

2.1 Study Population

Forty subjects participated in this study. Twenty subjects with shoulder pathology were recruited using a convenience sample of patients referred for physiotherapy treatment by one of five orthopaedic surgeons at the outpatient physiotherapy department at St. Joseph's Health Care. The control group was made up of 20 subjects who had no history of shoulder pathology and was composed of volunteers recruited by the study investigators.

To be included in the shoulder pathology group subjects had to be; 18 years of age or older, have unilateral shoulder pathology diagnosed by an orthopaedic surgeon or physiotherapist, and have no history of shoulder pain/pathology in his/her contralateral shoulder. Subjects were excluded from the shoulder pathology group if they had signs of neurological compromise in their upper extremities, or thoracic spine pain or pathology, including a thoracic scoliosis.

Prior to testing, information regarding age, hand dominance and a brief pain history including type, location and duration of pathology was collected for each subject. An assessment of pain and functional ability was also conducted. This information was recorded on an initial assessment form which was developed for this study. (Appendix A)

The University of Western Ontario's ethics review board approved this study and all participants read the Letter of Information and provided written consent prior to participation. The study Letter of Information and Ethics approval notice are provided in the Appendices C and D, respectively.

2.2 Study Design

The study design was cross sectional and observational with repeated measures. Initial testing occurred in the Wolf Orthopaedic Biomechanics Lab (WOBL) located in the 3M Centre at the University of Western Ontario. The WOBL lab is equipped with a three-dimensional motion analysis system (Eagle, Motion Analysis Corporation, Santa Rosa, California), including eight high-resolution digital video cameras and accompanying accessories including computer software. The second session of testing occurred 48-72 hours later at a location convenient for each subject but also which had the equipment necessary to replicate the initial assessment (i.e. a pole and appropriate stool). The time period between the first and second test period allowed for any skin markings which may have occurred as a result of the stylus used in the three-dimensional analysis to fade. This time period also allowed for any increase in pain symptoms which were the result of the testing procedure to resolve. This time period was not considered long enough to introduce a maturation effect due to the natural process of healing.

2.3 Rater

The rater of this study was an experienced physical therapist with specialized training in manual therapy. The rater had been actively involved in clinical work in the orthopaedic setting for five years.

2.4 Testing Procedure: Day One

Once subjects arrived at the WOBL lab they were required to complete a DASH (Disabilities of the Arm, Shoulder and Hand) (Appendix E), a functional outcome measure previously determined to have excellent test-retest reliability, known groups and convergent validity (Beaton et. al. 2001, Navsarikar et. al. 2006). This outcome measure was designed to be used for single or multiple disorders in the upper limb, providing a single questionnaire for measuring disability in the entire upper extremity. (Navsarikar et. al. 2006). The questionnaire contained 30 items which were scored by the subject on a zero to four point scale with greater scores representing greater disability (Beaton et. al., 2001). The questionnaire was scored by adding up the sum of the responses and subtracting 30, then dividing by 1.2 to get a score out of 100. This outcome measure was chosen because it is short, self-administered and easy to use to measure shoulder symptoms and the functional status of the subject.

Each subject was also asked to complete a Numerical Pain Rating Scale (NPRS) for the current level of pain he or she was experiencing in the affected shoulder. This single item pain rating scale has been previously found to be reliable and valid and is the most sensitive scale compared to the Visual Analogue Scale and the Verbal Rating Scale (Williamson and Hoggart, 2005). The NPRS consists of a 10 centimetre line with marks placed one centimetre apart, numbered from zero to ten. The subject was asked to mark on the line where they considered his/her pain to be, with zero being no pain while ten is the worst pain imaginable. The NPRS can be found in Appendix F.

Prior to commencement of testing, each subject received instruction regarding the testing procedure and was informed that he/she could discontinue the testing procedure at any time. Subjects were then asked to either change into a standard hospital gown or to wear a tank top which would allow exposure of both the subjects' scapulae. Each subject was then asked to sit on a backless stool placed in the center of the lab to allow equal exposure to the eight digital video cameras mounted on the ceiling of the lab. The order of the arm (left versus right) to be tested was determined randomly by the assessor in a concealed manner. Measurements were always taken first in the resting position and repeated with the arm in elevation. This order was applied consistently for all three measurements and was repeated on day two of testing.

Three Dimensional Motion Analysis

Each subject then had three-dimensional images taken of his/her scapula using the digital motion analysis system. Before testing each subject had a three prong reflective marker attached to his/her manubrium using two-sided tape. The marker consisted of three spheres (eight millimeter) covered with reflective tape attached to a cylindrical base. This marker provided an reference point that created a relationship between the reflective marker and the landmarks described below. A 260 millimeter long styloid pointer with three equidistant reflective balls attached beginning at the distal end, ending with a point (similar to a pencil) on the opposite end was used to identify each point. Each point was first identified through palpation and then the styloid pointer was placed on the bony landmark. With the measure, the bony landmark had to be relocated through palpation, then the end of the stylus was placed at the identified point. Similar to a previous study conducted by Lewis et. al. (2005) that found that palpation of the scapula has good inter rater reliability, each subject had the following 11 points digitized by the same experienced assessor.

1) The midpoint of the sternal notch
2) The xyphoid process
3) The center of spinous process of the 7th cervical vertebrae
4) The center of the spinous process of the 12th thoracic vertebrae
5) The tip of the inferior angle of the scapula
6) The center of the spinous process of the thoracic spine most parallel to the inferior angle

7) The midpoint of the medial aspect of the spine of the scapula

8) The center of the spinous process of the thoracic spine most parallel to the spine of the scapula

9) The posterior aspect of the acromial tubercle

10) The center of the spinous process of the12th thoracic vertebrae

11) The inferior aspect of the coracoid process

Figures 2 and 3 illustrate the above points.

Each subject remained in the sitting position assumed during the measurement portion of the testing procedure. At the beginning of the three-dimensional motion analysis testing each subject had his/her sternal notch, xyphoid process, seventh cervical spinous process, and spinous process of the twelfth thoracic vertebrae identified by palpation and then digitized using the stylus. Then the position of the inferior angle, spine of the scapula, acromion and coracoid were palpated and digitized in order. At each point the proximal or "pointed end" of the stylus was applied to the anatomical landmark and using eight motion capture cameras, the motion analysis system software recorded the three dimensional components of each point. This order of palpation and digitization was completed three consecutive times. The above steps were then completed on the contralateral upper extremity in the resting position.

Once all points were digitized on both scapulae in the resting position, the testing procedure was repeated with the same arm in the elevated position. The inferior angle, spine of the scapula, coracoid and acromion of the test scapula were digitized using the three-dimensional motion capture system. Each subject placed the test arm in maximum elevation in the scapular plane by abducting the arm to 90 degrees. Then using a goniometer the arm was positioned thirty degrees anterior to the frontal plane, using the acromioclavicular joint as the axis of rotation.

Each subject was asked to elevated his/her arm in the maximum amount of pain-free elevation in the scapular plane with the arm in external rotation. A pole was then positioned in that plane to allow the subject to rest the arm. This is a similar test position as used by Ebaugh (2005) and Dayanidhi et. al. (2005). In the elevated position the same four points were digitized bilaterally, three times in succession.

Tape Measurements

With the subject seated on the backless stool, and the subject's shoulder in the resting position, the above four distances were measured by the same assessor using a standard tape measure with millimetre increment markings. Starting with the distance from the inferior angle to the spinous process of the most parallel thoracic vertebrae, each of the four distances was measured three times using a flexible tape measure (Sammons Preston, Mississauga, Ontario). Once the measurements were completed on each extremity in the resting position, they were then repeated with the arm in the maximum elevation in the plane of the scapula. The entire process was then repeated on the contralateral side.

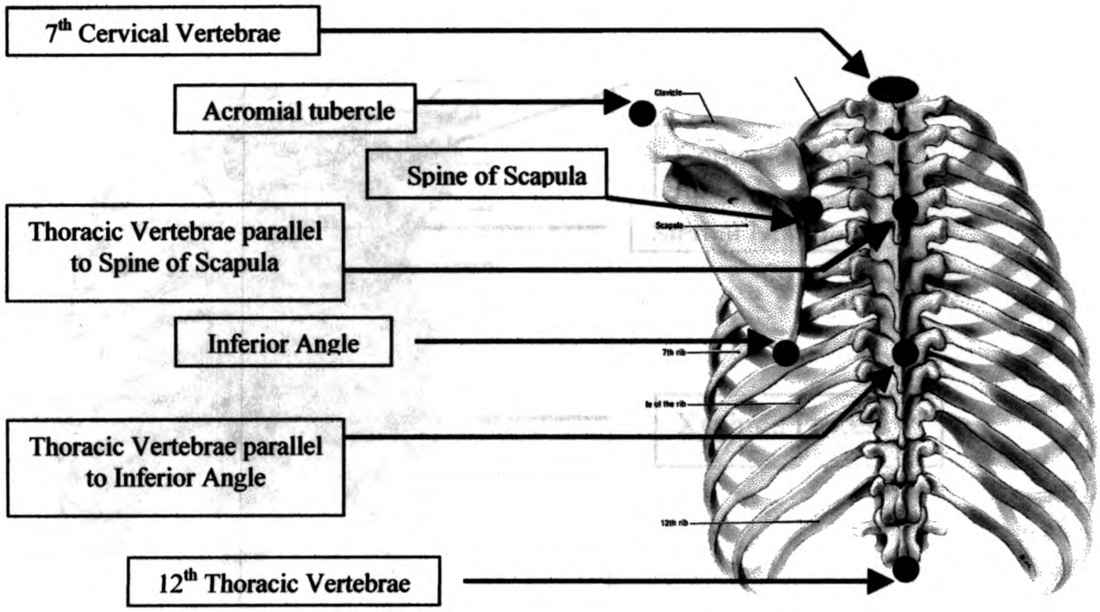

Figure 2: Three-dimensional motion analysis points on the posterior thorax and scapula (modified from Netter FH: Atlas of Human Anatomy, 3rd Edition, Teterboro, New Jersey, 2004, Icon Learning Systems)

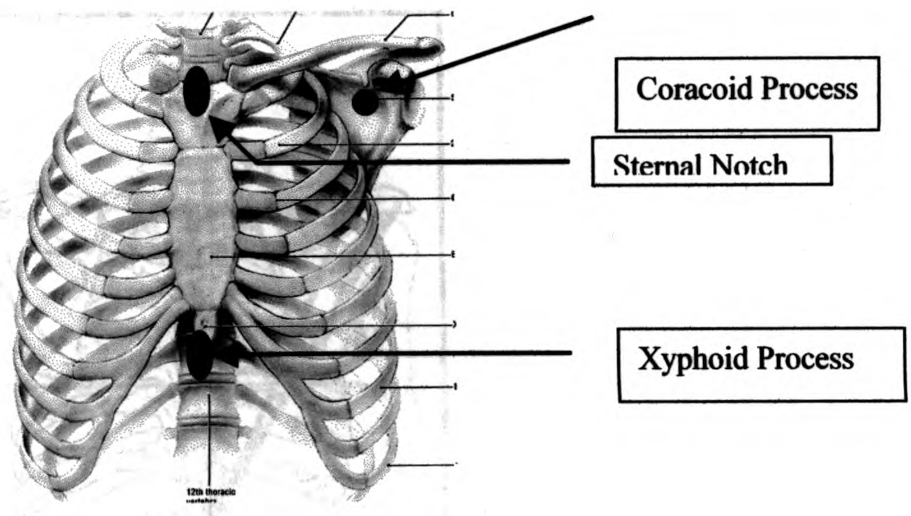

Figure 3: Three-dimensional motion analysis points on the anterior thorax and scapula (modified from Netter FH: Atlas of Human Anatomy, 3rd Edition, Teterboro, New Jersey, 2004, Icon Learning Systems)

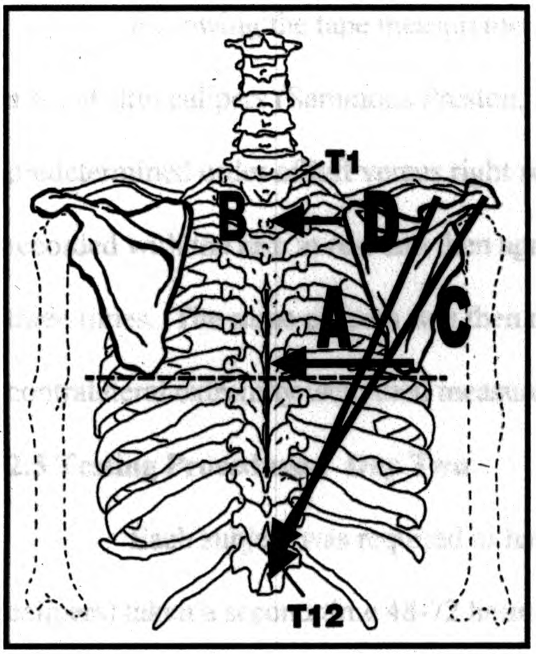

Figure 4: Distances measured from the scapula to the thoracic spine with tape measure and calipers. (adapted from: Lewis J, Green A, Reichard Z, Wright C. Scapular position: the validity of skin surface palpation. *Manual Therapy,* 7(1): 2002)

Calipers

Following the tape measurements, the same four distances were measured using a set of skin calipers (Sammons Preston, Mississauga, Ontario). Using the same predetermined order of left versus right scapula, the four distances measured were then recorded with the arm at rest and then again in elevation. Each distance was measured three times. The same process was then repeated and the four distances on the contralateral extremity were then measured.

2.5 Testing Procedures: Day Two

Each subject was required to have the manual measures (tape measure and calipers) taken a second time 48-72 hours later. A location that was convenient for each subject was chosen, based on accessibility to the appropriate equipment necessary for testing. A backless stool and a pole were needed to position the patient appropriately to replicate the measures taken with the tape measure and calipers. On day two of testing, each subject had the four distance measurements repeated using the tape measure and calipers. The same order of testing used on day one was repeated.

2.6 Data Analysis

The information obtained through the motion analysis system was captured and reduced with EvaRT software (Motion Analysis Corporation, Santa Rosa, CA). The information was then entered into a custom MATLAB software program which then calculated the distance between the four measured points that were identified with the stylus.

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc. Version 14.0, 1997, Chicago, Il, USA) data analysis software.

Objective One: Reliability of Manual Measures

To determine the test-retest reliability of using a tape measure and calipers to measure scapular position at rest and at end of available range, the mean of the three measures for each of the four distances taken on day one and repeated on day two were calculated. The means were then compared using an Intraclass correlation coefficient type 2,1(ICC 2,1). An ANOVA table provided the values necessary to calculate the Standard Error of Measure (SEM) and Minimally Detectable Change (MDC_{90}) scores. The SEM was calculated by taking the square root of the mean square residual and the MDC_{90} was calculated by multiplying the SEM by the square root of two, multiplied by 1.64 (the z value for 90% confidence interval). All of the above calculations were conducted using the dominant extremity for the healthy volunteers or the affected extremity for those subjects presenting with shoulder pathology.

Objective Two: Concurrent Validity between Manual Measures and Motion Analysis

The amount of agreement between distances obtained using tape measure and three dimensional motion analysis, was determined by calculating ICC (2,1). ICC(2,1)s were also calculated for measurements obtained using calipers versus three dimensional motion analysis and calipers versus tape measure. The two way random model of ICC with absolute agreement was used for this calculation. The mean of the three measures for each of the four distances taken using the tape measure was compared to the same values calculated for the three-dimensional motion analysis. This series of calculations was completed for values obtained with the scapula in both the resting and elevated positions. For each subject with no history of shoulder pathology the values used in the calculation were those from the dominant arm. For those subjects with shoulder pathology, the values obtained were from the affected extremity. Using the SPSS software, a 95 % confidence interval was calculated along with the SEM and MDC_{90} for each ICC.

Objective Three: The Relationship between shoulder pathology, scapula asymmetry, the DASH and NPRS

A paired t test was used to compare asymmetry between the scapular position of healthy volunteers and those with shoulder pathology. For this statistical test, mean values were calculated for each distance for the left and right scapulae for the same individual. To determine if scapula position is different between healthy volunteers and those with shoulder pathology the mean for each of the four distances measured in the dominant arm of the healthy volunteers were compared to the mean of the same measures taken on the affected arm of subjects in the shoulder pathology group. These mean values were obtained for the 20 subjects in each of the healthy volunteer group and shoulder pathology group and were compared using independent student t tests ($p < 0.05$).

To determine whether the mean values for each distance measured on the left and right scapula of the same individual were asymmetrical paired samples t tests was conducted using SPSS software. This process was repeated on the bilateral scapula using both the tape measure and calipers in the elevated and rest position. This statistical analysis was similar to that conducted in the study performed by Rundquist (2007).

Pearson r correlation coefficients were calculated to examine the relationship between distances measured using each of the three measurement tools and values obtained from the NPRS and the total DASH score. These relationships were examined using only the data obtained from the 20 subjects who had shoulder pathology. This data provided information about the relationship between scapular position and severity of pain and upper extremity dysfunction.

Chapter Three

Results

3.1 Patient Population

A total of 40 subjects between the ages of 22 and 77 were recruited into this study. Demographic information and other characteristics of the study population are presented in Table 1. The mean age of the twenty healthy volunteers was 28.6 years with a standard deviation of 5.7, while the group of subjects presenting with shoulder pathology were generally older (47.01 +/- 18.6 years). The majority of subjects were female (n=33) with equal distribution of female and male subjects in each of the healthy volunteer and shoulder pathology group. Of the 40 study participants, 39 were right hand dominant, 19 in the healthy volunteer group and 20 in the shoulder pathology group. Only one subject, who was included in the healthy volunteer group, reported being left hand dominant. The healthy volunteer group had a mean DASH score of 0.13 +/- 0.4 while the shoulder pathology group had a mean score of 20.2 +/- 24.0. The healthy volunteer group had a mean NPRS score of 0.15 +/- 0.4 and the shoulder pathology group had a mean score and standard deviation of 3.3 +/- 3.2, respectively.

Table 1: Demographic Information for study population (n = 40), Healthy Volunteers (n= 20) and subjects with shoulder pathology (n = 20)

	Age (Mean +/-SD)	Gender	Hand Dominance	DASH Score (Mean +/-SD)	NPRS (Mean +/-SD)
Study Population (n=40)	37.8 +/- 16.5 (range:22 - 77)	F= 43 M= 7	R = 39 L = 1	11.2 +/- 20.1 (range:0 - 72.5)	1.7 +/- 2.8 (range:0 - 10)
Healthy Volunteers (n=20)	28.6 +/- 5.7 (range:22 – 47)	F = 16 M = 4	R = 19 L = 1	0.13 +/- 0.4 (range:0 - 1.7)	0.15 +/- 0.4 (range:0 - 1)
Shoulder Pathology (n=20)	47.01 +/- 18.6 (range:24 - 77)	F =17 M =3	R = 20 L = 0	22.2 +/- 24.0 (range:0 - 7.25)	3.3 +/- 3.2 (range:0 - 10)

Legend: F = female, M = male , R = right, L = left
DASH = Disability of the Arm, Shoulder and Hand
NPRS = Numerical Pain Rating Scale

3.2 Objective One: Reliability of Clinical Measures

The means and standard deviations of the four distances measured from the scapula to the thoracic spine using the tape measure and calipers in the resting and elevated position on two separate occasions are presented in Table 2. The mean distances were calculated by taking three measures on the dominant/affected side on day one and on day two.

The distances measured from the coracoid and the acromion to the thoracic spine were greater than the distances measured from the spine of the scapula and the inferior angle to thoracic spine. Distances measured using the calipers were consistently shorter than those taken with the tape measure in both the resting and elevated positions. In particular, the mean values for the coracoid and the thoracic spine were shorter when using calipers as compared to the tape measure. The mean distance between the inferior angle and the thoracic spine measured using either the tape measure or calipers was greater when the arm was elevated than it was at rest. Other distances measured were no different when the arm was elevated as compared to the resting position. Mean distances for all four measurements were similar on Day 1 versus Day 2 of testing.

ICC (2,1)'s calculated to determine the amount of absolute agreement between measures taken on Day 1 versus Day 2 of testing for the four distances measured using the tape measure and calipers from the scapula (inferior angle, spine of the scapula, acromion and coracoid) to the thoracic spine are shown in Table 2. The ICC (2,1)'s for the distance measured from the inferior angle, spine of the scapula and acromion to the thoracic spine ranged from 0.82 (CI 95% 0.69 – 0.9) to 0.98 (CI 95% 0.97 – 0.99) using the tape measure and calipers in both the resting and maximally elevated position. The ICC (2,1)'s calculated for the distances measured between the coracoid to 12^{th} thoracic vertebrae were lower when using tape measure in both the resting and maximally elevated position and when using the calipers in the resting position. The lowest ICC (2,1) was calculated for the distance between the coracoid and the thoracic spine using the tape measure in the rest position at 0.65 (CI 95% 0.43 – 0.8). With the exception of 0.65 which was calculated for the distance measured from the coracoid to the thoracic spine in the resting position, all ICC's were above 0.80, which indicates excellent agreement (Shrout and Fleiss, 1973).

The Standard Error of Measurement (SEM) scores were calculated to determine the amount of response stability or the standard error in the set of repeated scores (Portney and Watkins, 2002). In other words, the SEM is the standard deviation of the difference between the measured or estimated values and the true values. The SEM values for the distance between the thoracic spine and inferior angle and spine of the scapula were lower than the SEM's calculated for the thoracic spine to the coracoid and acromion using both the calipers and tape measure in the rest position. In general, relatively low (<1.0 cm) SEM's were produced for three of the four distances measured. Higher SEM's were found for the distance measured between the coracoid and the thoracic spine when using either tape measure or caliper. This was consistent with that arm at rest and when maximally elevated. The distance between the coracoid to the thoracic spine measured using the tape measure when the arm was elevated was much higher at 2.9cm.

The Minimum Detectable Change score (MDC_{90}) represents the smallest difference or change that would be statistically significant when comparing different samples (Portney and Watkins, 2002). The largest calculated MDC_{90} was 10.9cm found for the distance measured from the coracoid to thoracic spine using the tape measure in elevation. There would need to be at least an 11cm change in the position of the coracoid to report a clinically important difference. The lowest calculated MDC_{90} was 0.8cm which occurred for both the distance measured from the inferior angle to thoracic spine measured using the tape measure at rest and the spine of the scapula to thoracic spine using the tape measure in elevation. In other words a change of less than 1 cm would need to occur to be considered clinically relevant. All MDC_{90} values were below 2cm with exception of the distance from the coracoid to the thoracic spine measured using the tape measure in the elevated position. The highest MDC_{90} value was found with the resting position of the scapula.

Table 2: Means, Standard Deviations (SD), Intraclass Correlation Coefficients (ICC (2,1)), Standard Error of Measurement (SEM) and Minimal Detectable Change (MDC_{90}) comparing measures taken on Day 1 and Day 2 on the dominant or affected upper extremity using a tape measure and calipers for all subjects (n = 40) (unit of measurement = centimetre)

	Day 1*	Day 2*			
	Mean +/- (SD) (cm)	Mean +/- (SD) (cm)	ICC (2,1) (95% CI)	+/- SEM	+/-MDC_{90}
Tape Measure: Rest					
1. Inferior Angle	11.7 +/- 2.8	10.8 +/- 2.8	0.98 (0.97 - 0.99)	0.3	0.8
2. Spine of Scapula	8.6 +/- 2.4	8.7 +/- 2.2	0.93 (0.88 – 0.96)	0.6	1.3
3. Acromion	31.9 +/- 6.4	32.7 +/- 5.2	0.82 (0.69 – 0.9)	2.4	5.6
4. Coracoid	35.8 +/- 9.0	37.0 +/- 6.9	0.65 (0.43 – 0.8)	4.7	10.9
Caliper: Rest					
1. Inferior Angle	8.6 +/- 2.4	8.5 +/- 2.3	0.96 (0.92 – 0.98)	0.4	1.1
2. Spine of Scapula	7.0 +/- 2.0	7.2 +/- 1.9	0.93 (0.88 – 0.97)	0.4	1.1
3. Acromion	26.2 +/- 4.1	26.1 +/- 4.1	0.94 (0.89 – 0.97)	1.0	2.3
4. Coracoid	24.9 +/- 5.2	18.4 +/-12.4	0.84 (0.74 – 0.92)	1.9	4.4
Tape Measure: Elevation					
1. Inferior Angle	17.2 +/- 2.7	17.1+/- 2.8	0.93 (0.87 – 0.96)	0.7	1.6
2. Spine of Scapula	6.9 +/- 1.7	7.0 +/- 1.7	0.95 (0.91 – 0.97)	0.3	0.8
3. Acromion	27.0 +/- 5.9	27.4 +/- 5.5	0.99 (0.97 – 0.99)	0.6	1.5
4. Coracoid	34.0 +/- 8.3	35.5 +/- 6.5	0.83 (0.69 –0.91)	2.9	6.7
Caliper: Elevation					
1. Inferior Angle	14.3 +/- 2.2	15.4 +/-5.3	0.90 (0.82 – 0.95)	0.7	1.8
2. Spine of Scapula	5.6 +/- 1.2	5.7 +/-1.2	0.89 (0.80 – 0.94)	0.4	1.0
3. Acromion	24.0 +/- 4.8	24.3 +/- 4.7	0.99 (0.98 – 0.99)	0.3	0.9
4. Coracoid	24.1 +/- 5.2	24.5 +/- 5.2	0.98 (0.95 – 0.99)	0.7	1.7

3.3 Objective Two: Concurrent Validity between Clinical Measures and Motion Analysis

The means, standard deviations, ICC's(2,1) of the distance from the inferior angle, to the thoracic spine, spine of the scapula to the thoracic spine, acromion and coracoid to the 12th thoracic vertebrae taken using the tape measure and calipers are found in Tables 3 and 4. Pearson r values comparing measures of the four distances between the tape measure and calipers, tape measure and three dimensional motion analysis and calipers and motion analysis are shown in Tables 3, 4 and 5 respectively. The measurements used in the calculations were taken on Day 1 using the dominant shoulder for the healthy subjects and the affected shoulder for subjects with shoulder pathology.

Tape Measure and Calipers

Distances measured using the tape measure were similar to those measured using the calipers. The mean value for each distance was consistently shorter for calipers as compared to that with the tape measure.

The calculated ICC(2,1)'s ranged from 0.23 to 0.73 for the distances measured in the resting position. In the elevated position ICC (2,1)'s ranged from 0.39 to 0.76. With measurements taken with the arm in both the resting and elevated positions, the lowest ICC (2,1) was calculated for the comparison of the tape measure and calipers when measuring the distance from the coracoid to the thoracic spine. Pearson r-values calculated for the distances measured between the calipers and the tape measure were greater than 0.7 except when measuring the coracoid to the thoracic spine in the rest position (0.6). All r-values were statistically significant at the 0.01 level.

Tape Measure and Motion Analysis

The means calculated for the four distances measured from the scapula to the thoracic spine using the tape measure were similar to those calculated using motion analysis. This was consistent for measurements taken with the arm at rest and in the maximally elevated position. The differences between the coracoid and the thoracic spine were greatest when measured using the tape measure as compared to three-dimensional motion analysis.

The ICC (2,1)'s calculated for the distances measured from the inferior angle and spine of the scapula to the thoracic spine were in the moderate range (0.48 to 0.54) with the arm at rest and in the maximally elevated position (Shrout and Fleiss, 1973). The ICC (2,1)'s produced from measurements taken from the distances between the acromion and coracoid to the thoracic spine were considered to be in the low range (Shrout and Fleiss, 1973). When the arm was elevated the ICC(2,1) for the distance from the acromion to the thoracic spine was –0.15. This negative value indicates that the results of the comparison of the tape measure and motion analysis are worse than would have been expected to have occurred by chance (Portney and Watkins, 2000).

Pearson r-values were between 0.3 and 0.5 for the three distances measured between the thoracic spine and the inferior angle, spine of the scapula and the coracoid using the tape measure and motion analysis and were statistically significant ($p<0.01$) with the arm both in the resting and in the elevated position. Values obtained from the acromion to the thoracic spine using the tape measure and three dimensional motion analysis did not correlate well with the arm at rest ($r=0.2$) or in elevation ($r= 0.2$).

Calipers and Motion Analysis

Similar values were calculated for all four distances measured between the thoracic spine and the scapula using motion analysis and calipers. However, larger means were calculated for distances measured from the acromion to thoracic spine and coracoid to thoracic spine using the calipers compared to three dimensional motion analysis. This result was present whether the arm was at rest or in elevation. The difference between the means of distances measured using the calipers and motion analysis were minimal. The distance between the acromion to thoracic spine, when the arm was at rest was only 0.1cm different between the two measures.

Similar agreement and correlation coefficients were produced for values obtained using the calipers compared to three dimensional motion analysis (Table 5). ICC (2,1) values were low to moderate. Pearson r coefficients were moderate and statistically significant for three of the four distances and quite poor for the distance measured between the thoracic spine and the acromion. These results were similar regardless of arm position.

Table 3: Means, Standard Deviations (SD), and Intraclass Correlation Coefficients (ICC 2,1) and Pearson r values of Tape Measure and Calipers at rest and in elevation: measurements taken using the dominant or affected upper extremity on Day 1 (unit of measurement = centimetres)

Position	Tape Measure Mean +/- SD	Calipers Mean +/- SD	ICC 2,1 (95% CI)	Pearson r
Rest				
1. Inferior Angle	11.1 +/- 2.8	8.6 +/- 2.4	0.63 (-0.08 – 0.89)	0.9**
2. Spine of Scapula	8.6 +/- 2.4	7.0 +/- 2.0	0.73 (-0.07 – 0.92)	0.9**
1. Acromion	31.9 +/- 6.4	26.2 +/- 4.1	0.46 (-0.1 – 0.77)	0.8**
4. Coracoid	35.8 +/- 9.0	24.8 +/- 5.2	0.23 (-0.1 - 0.55)	0.6**
Elevation				
1. Inferior Angle	17.2 +/- 2.7	14.3 +/- 2.2	0.43 (-0.1 – 0.76)	0.7**
2. Spine of Scapula	6.9 +/- 1.7	5.6 +/- 1.2	0.6 (-0.9 – 0.86)	0.9**
3. Acromion	27.0 +/- 5.9	24.0 +/- 4.8	0.76 (0.1 – 0.92)	0.9**
4. Coracoid	34.0 +/- 8.3	24.1 +/- 5.2	0.39 (-0.08 – 0.74)	0.9**

** correlation significant to the 0.01 level

Table 4: Means, Standard Deviations (SD), and Intraclass Correlation Coefficients (ICC 2,1) and Pearson r values of Tape Measure and Three Dimensional Motion Analysis at rest and in elevation: measurements taken using the dominant or affected upper extremity on Day 1 (unit of measurement = centimetres)

Position	Tape Measure Mean +/-SD	Motion Analysis Mean +/- SD	ICC 2,1 (95% CI)	Pearson r
Rest				
1. Inferior Angle	11.1 +/- 2.8	10.7 +/- 2.6	0.49 (0.22 – 0.69)	0.5**
2. Spine of Scapula	8.6 +/- 2.4	8.3 +/- 2.5	0.54 (0.28 – 0.73)	0.6**
3. Acromion	31.9 +/- 6.4	26.1 +/- 3.6	0.09 (-0.11 – 0.32)	0.2
4. Coracoid	35.8 +/- 9.0	23.7 +/- 2.4	0.06 (-0.07 – 0.24)	0.3*
Elevation				
1. Inferior Angle	17.2 +/- 2.7	16.0 +/- 2.7	0.5 (0.2 – 0.71)	0.6**
2. Spine of Scapula	6.9 +/- 1.7	6.6 +/- 2.1	0.48 (0.21 – 0.69)	0.5**
3. Acromion	27.0 +/- 5.9	23.2 +/- 4.9	-0.15 (-0.39 – 0.13)	-0.2
4. Coracoid	34.0 +/- 8.3	22.0 +/- 2.3	0.09 (-0.07 - 0.29)	0.5**

** correlation significant at the 0.01 level

* correlation significant at the 0.05 level

Table 5: Means, Standard Deviations (SD) and Intraclass Correlation Coefficients (ICC 2,1) of Calipers and Three Dimensional Motion Analysis at rest and in elevation: measurements taken using the dominant or affected upper extremity on Day 1 (unit of measurement = centimetres)

Position	Caliper Mean +/- (SD)	Motion Analysis Mean +/- (SD)	$ICC_{2,1}$ (95% CI)	Pearson r
Rest				
1. Inferior Angle	8.6 +/- 2.4	10.7 +/- 2.6	0.33 (-0.01 – 0.6)	0.4**
2. Spine of Scapula	7.0 +/-2.0	8.3 +/- 2.5	0.47 (0.15 – 0.69)	0.5**
3. Acromion	26.2 +/- 4.1	26.1 +/- 3.6	0.04 (-0.29 – 0.34)	0.0
4. Coracoid	24.8 +/- 5.2	23.7 +/- 2.4	0.25 (-0.05 – 0.52)	0.3*
Elevation				
1. Inferior Angle	14.3 +/- 2.2	16.0 +/- 2.7	0.38 (-0.06 – 0.62)	0.5**
2. Spine of Scapula	5.6 +/- 1.2	6.6 +/- 2.1	0.36 (0.07 – 0.6)	0.5**
4. Acromion	24.0 +/- 4.8	23.2 +/- 4.9	-0.13 (-0.43 – 0.19)	-0.1
4. Coracoid	24.1 +/- 5.2	22.0 +/- 2.3	0.32 (0.03 – 0.56)	0.5**

** correlation significant to the 0.01 level
* correlation significant to the 0.05 level

3.4 Objective Three: The Relationship between shoulder pathology, scapula asymmetry, the DASH and NPRS

Distances measured on the left and right side of healthy volunteers and those with shoulder pathology were similar whether measured using the tape measure or calipers (Tables 6 and 7). Furthermore scapular asymmetry was not evident when the arm was placed at rest or in the maximally elevated position.

Healthy Volunteers versus Subjects with Shoulder Pathology

The mean distance for all four measurements taken between the scapula and the thoracic spine were longer for the group of subjects presenting with shoulder pathology in the resting position (Table 8). This difference was found using both the calipers and tape measure as the measurement tool. For distances measured using both the tape measure and calipers the greatest differences between healthy volunteers compared to the subjects with shoulder pathology were found when measuring the position of the acromion and the coracoid. For measures taken between the thoracic spine and inferior angle and the spine of the scapula, the mean difference between the healthy volunteers and subjects with shoulder pathology was small (<2cm) while the mean difference between the thoracic spine and the coracoid and acromion was much larger (>5cm). All the measurements except the distance from the inferior angle to the thoracic spine when using the calipers were found to be significantly ($p < 0.05$) different between healthy volunteers and subjects with shoulder pathology.

Similar results were noted with taking the same measurements with the arm in the maximally elevated position. The mean of the distances measured between the scapula and the thoracic spine were greater in those individuals with shoulder pathology compared to healthy volunteers when the shoulder was elevated (Table 9). In particular, 5 to 10 cm differences were found between the healthy volunteers and subjects with shoulder pathology in distances measured between the thoracic spine and the coracoid and acromion. The mean differences were all statistically significant ($p<0.05$) with the exception of the distance measured between the inferior angle and thoracic spine using the calipers.

Relationship between Scapula Position, DASH and Pain Score

The relationship between the scores obtained on the NPRS and the DASH and the four distances measured between the scapula and thoracic spine position were compared in subjects with shoulder pathology when the arm was at rest (Table 10) and in elevation (Table 11). The correlation coefficients were 0.5 or greater for the relationship between the scapula position and DASH score for only one of the four distances measured. Similarly, there was a good relationship between NPRS score and the distance measured from the spine of the scapula to the thoracic spine. When the arm was held at rest there was a good and statistically significant relationship between the DASH and NPRS and the distance from the spine of the scapula to the thoracic spine was measured in all three ways. Correlations were low and not statistically significant for the other three distances obtained using any of the measurement tools when the arm was at rest. These results suggest that in people with shoulder pathology there is more pain and less arm function when their affected scapula is positioned further away from the thoracic spine in a protracted position.

When that arm was placed in an elevated position (Table 11), the relationship between the scapular position and DASH and NPRS was generally poorer. As in the rest position, there was a good relationship only for the distances measured between the spine of the scapula to the thoracic spine and this relationship was only significant when calipers were used to measure the position of the scapula. None of the other three distances had a strong relationship between the position of the scapula and reported pain levels (NPRS) or loss of function (DASH).

Table 6: Means, Standard Deviations (SD), Mean Difference and p values for measurements (in centimeters) taken using the tape measure: A comparison of bilateral scapula for Healthy Volunteers (n=20) and subjects with Shoulder Pathology (n=20)

	Mean +/- SD		Mean Difference	p value
Tape Measure	**Dominant/Affected**	**Non Dominant/Unaffected**		
Healthy Volunteers at Rest				
1. Inferior Angle	10.2 +/- 2.0	9.1 +/-1.5	1.1	0.53
2. Spine of the Scapula	7.9 +/- 1.5	7.6 +/-1.0	0.3	0.44
3. Acromion	28.5 +/- 5.8	27.0 +/- 5.5	1.4	0.43
4. Coracoid	30.4 +/- 8.8	31.1 +/- 7.0	0.8	0.68
Healthy Volunteers in Elevation				
1. Inferior Angle	16.3 +/- 2.1	15.8 +/- 2.0	0.5	0.45
2. Spine of the Scapula	6.2 +/- 1.1	5.7 +/- 1.3	0.7	0.15
3. Acromion	24.2 +/- 4.6	23.6 +/- 0.65	0.7	0.64
4. Coracoid	28.7 +/- 7.4	29.3 +/- 6.1	0.6	0.77
Shoulder Pathology at Rest				
1. Inferior Angle	12.4 +/- 3.3	10.8 +/- 3.2	1.5	0.15
2. Spine of the Scapula	9.6 +/- 2.7	9.1 +/- 2.4	0.4	0.62
3. Acromion	35.9 +/- 4.9	33.7 +/- 4.4	2.2	0.14
4. Coracoid	41.3 +/- 4.7	39.5 +/- 5.2	1.8	0.26
Shoulder Pathology in Elevation				
1. Inferior Angle	19.3 +/- 2.8	17.5 +/- 2.3	0.8	0.31
2. Spine of the Scapula	7.6 +/- 1.9	7.0 +/- 2.2	0.7	0.32
3. Acromion	30.3 +/- 5.3	29.2 +/- 5.2	1.0	0.54
4. Coracoid	39.6 +/- 6.1	38.1 +/- 4.5	1.4	0.40

Table 7: Means, Standard Deviations (SD), Mean Difference and p values for measurements (in centimeters) taken using the calipers: A comparison of bilateral scapula for Healthy Volunteers (n=20) and subjects with Shoulder Pathology (n=20)

	Mean +/- SD		Mean Difference	p value
Calipers	**Dominant/Affected**	**Non Dominant/Unaffected**		
Healthy Volunteers at Rest				
1. Inferior Angle	8.2 +/- 1.7	8.1 +/- 1.7	0.9	0.04
2. Spine of the Scapula	6.2 +/- 1.5	6.6 +/- 1.3	0.3	0.46
3. Acromion	23.3 +/- 2.7	24.3 +/- 3.6	1.0	0.34
4. Coracoid	22.6 +/- 4.4	23.1 +/- 4.3	0.5	0.72
Healthy Volunteers in Elevation	13.8 +/- 2.2	13.4 +/- 2.5	0.4	0.58
1. Inferior Angle	5.2 +/- 0.9	5.1 +/- 1.1	0.6	0.86
2. Spine of the Scapula	21.1 +/- 3.9	21.8 +/- 4.3	0.7	0.62
3. Acromion	31.0 +/- 3.7	22.1 +/- 4.8	1.1	0.43
4. Coracoid				
Shoulder Pathology at Rest				
1. Inferior Angle	9.1 +/- 2.9	9.0 +/- 2.7	0.9	0.15
2. Spine of the Scapula	7.8 +/- 2.2	7.5 +/- 2.2	0.4	0.63
3. Acromion	28.9 +/- 3.3	29.2 +/- 4.0	0.3	0.78
4. Coracoid	27.5 +/- 4.4	27.9 +/- 4.5	0.5	0.73
Shoulder Pathology in Elevation	14.9 +/- 2.4	14.7 +/- 2.4	0.2	0.78
1. Inferior Angle	6.2 +/- 1.6	5.7 +/- 1.6	0.4	0.39
2. Spine of the Scapula	27.4 +/- 3.4	26.8 +/- 4.7	0.6	0.64
3. Acromion	27.4 +/- 4.7	27.3 +/- 3.9	0.1	0.95
4. Coracoid				

Table 8: Means, Standard Deviations (SD), Mean Difference and p values for measurements (in centimeters) taken using the tape measure and calipers in the rest position: A comparison of the dominant or affected scapula between healthy volunteers (n=20) and subjects with shoulder pathology (n=20).

	Mean +/- SD		Mean Difference	p value
	Healthy Volunteers	Shoulder Pathology		
Tape Measure: Rest				
1. Inferior Angle	10.1 +/- 1.7	12.0 +/- 3.4	1.9	0.04
2. Spine of Scapula	7.8 +/- 1.5	9.4 +/- 2.8	1.6	0.02
3. Acromion	28.4 +/- 5.7	35.5 +/- 5.0	7.1	0.00
4. Coracoid	33.4 +/- 8.8	41.3 +/- 5.1	10.9	0.00
Calipers: Rest				
1. Inferior Angle	8.2 +/- 1.7	9.1 +/- 2.9	0.9	0.18
2. Spine of Scapula	6.3 +/- 1.5	7.8 +/- 2.2	1.6	0.01
3. Acromion	23.6 +/- 2.6	28.8 +/- 3.5	5.3	0.00
4. Coracoid	22.5 +/- 4.4	27.2 +/- 5.0	4.7	0.00

Table 9: Means, Standard Deviations (SD), Mean Difference and p values for measurements (in centimeters) taken using the tape measure and calipers in elevation: A comparison of the dominant or affected scapula between healthy volunteers (n=20) and subjects with shoulder pathology (n=20).

	Mean +/- SD		Mean Difference	p value
	Healthy Volunteers	**Shoulder Pathology**		
Tape Measure: Elevation				
1. Inferior Angle	16.1 +/- 2.1	18.3 +/- 2.8	2.7	0.03
2. Spine of Scapula	6.1 +/- 1.1	7.6 +/- 1.8	1.5	0.00
3. Acromion	24.5 +/- 4.8	29.6 +/- 6.0	5.1	0.00
4. Coracoid	28.8 +/- 7.4	39.2 +/- 5.6	10.4	0.00
Calipers: Elevation				
1. Inferior Angle	13.8 +/- 2.1	14.9 +/- 2.2	1.1	0.20
2. Spine of Scapula	5.1 +/- 0.9	6.0 +/- 1.4	0.9	0.00
3. Acromion	21.2 +/- 3.9	26.8 +/- 4.0	5.6	0.00
4. Coracoid	20.9 +/- 3.7	27.2 +/- 4.5	6.3	0.00

Table 10: Pearson r values for the Numerical Pain Resting Scale (NRPS) and the Disabilities of Arm, Shoulder and Hand (DASH) compared to resting scapula position as measured by Tape Measure, Calipers and Motion Analysis

Numerical Pain Rating Score

	Tape Measure	Calipers	Motion Analysis
Inferior Angle	0.3	0.3	0.1
Spine of Scapula	0.5*	0.6**	0.6**
Acromion	0.2	0.1	0.3
Coracoid	0.0	0.1	0.2

Disabilities of Arm, Shoulder and Hand (DASH) Score

	Tape Measure	Calipers	Motion Analysis
Inferior Angle	0.3	0.3	0.1
Spine of Scapula	0.5*	0.6*	0.6**
Acromion	0.2	0.1	0.3
Coracoid	0.2	0.1	0.3

** Correlation is significant to the 0.01 level
* Correlation is significant to the 0.05 level

Table 11: Pearson r values for the Numerical Pain Resting Scale (NRPS) and the Disabilities of Arm, Shoulder and Hand (DASH) compared to scapula position in elevation as measured by Tape Measure, Calipers and Motion Analysis

Numerical Pain Rating Score

	Tape Measure	Calipers	Motion Analysis
Inferior Angle	0.2	0.2	-0.1
Spine of the Scapula	0.3	0.5*	0.2
Acromion	0.0	0.0	0.2
Coracoid	0.1	0.3	0.1

Disabilities of Arm, Shoulder and Hand (DASH) Score

	Tape Measure	Calipers	Motion Analysis
Inferior Angle	-0.0	0.1	-0.2
Spine of the Scapula	0.4	0.6**	0.3
Acromion	0.2	0.2	0.1
Coracoid	0.2	0.4	0.2

** Correlation is significant to the 0.01 level
* Correlation is significant to the 0.05 level

Chapter 4

Discussion

4.1 Study Population

The study population was predominantly female and right hand dominant. The average age of the healthy volunteer group was significantly lower than the shoulder pathology group.

It has been reported that approximately 8 to 15% of the population is left-handed (Hardyck & Petrinovich, 1977). The number of right versus left hand dominant subjects in the present study was approximately equal between the healthy volunteer and shoulder pathology groups. All subjects were right hand dominant with the exception of one subject in the healthy volunteer group. To have been truly representative of the larger population and increase the generalizability of the results, the study population should have included 3 to 6 left hand dominant subjects. However a study conducted by Milgrom et. al. (1995) found that there was no statistical difference in the incidence of impingement syndrome occurring in the dominant vs. non dominant arms.

The study population had similar numbers of females and males in each of the subject groups, however there were more females in each of the two subject groups. A statistically significant difference has not been found in the incidence of impingement syndromes between genders (Milgrom et. al., 1995). Studies indicate that gender plays a role in the quality of life and amount of disability an individual experiences as a result of shoulder pathology, however, the incidence is not affected by gender (Razmjou et. al., 2006, Bonsell et. al., 2000). In order to have controlled for between group differences due to gender, a gender matched sampling strategy could have been utilized where equal numbers of males versus females were included in each of the subject groups. This would have increased the external validity of the results of the study.

A difference existed between the healthy volunteer group and the shoulder pathology group with respect to age. The mean age of the healthy volunteer group was 28.6 years, while the mean age of the shoulder pathology group was 47.1 years. The difference in age could be a potential confounding factor since the two study groups were not equal on this variable. This potential confounding factor could have been controlled for my using an age-matched sample where an subjects of similar ages were included in each of the study groups. (Portney and Watkins, 2000). This difference could be explained by the fact that shoulder pathology tends to increase with age, making it difficult to recruit a sample that was equal in age to the healthy volunteer group (Endo et. al., 2004). The prevalence of rotator cuff tears has been reported to increase markedly over the age of 50. A linear increase in shoulder pathology has been found after the fifth decade of life (Milgrom et. al., 1995).

It is essential in clinical research to ensure that the selection of study subjects controls for any intersubject differences which may influence the results of the study (Portney and Watkins, 2000). One of the easiest ways to control for intersubject differences is by using the random assignment of subjects to either the experimental or control group. Due to the nature of this study and because subjects with a certain characteristic, (i.e. shoulder pathology) were required, true random assignment was not possible. This study used a common form of non-probability sampling called convenience sampling where subjects were chosen on the basis of availability instead of using a true random sample. The most practical type of convenience sampling is consecutive sampling which involves recruiting subjects who meet the inclusion and exclusion criteria of the study as they become available (Portney and Watkins, 2000). In this study, subjects were chosen for the shoulder pathology group as they presented to the physiotherapy department at St. Joseph's Health Care. These subjects may not be truly representative of the larger population of individuals with shoulder pathology since the 20 subjects presenting with shoulder pathology were all referred to the physiotherapy department by an orthopaedic surgeon at the Hand and Upper Limb Centre at St. Joseph's Health Care. It is often those individuals who have more severe pain who seek medical attention for their shoulder pain, excluding those who have more minor symptoms or who do not have a family doctor.

Subjects in the healthy volunteer group were accepted into the study as they presented to the primary investigator, which is another commonly used type of convenience sampling. A potential flaw of using volunteers in this study was the potential bias of self-selection, where individuals willing to participate may have certain characteristics which predispose them to volunteer for studies, which would make the subject atypical of the larger population. Another method to eliminate bias is to select a homogeneous group of subjects who are similar in all aspects other than the dependent variable (Portney and Watkins, 2000). In this case the variable of interest was shoulder pathology, therefore, the subjects should be similar in all other respects.

Hand dominance and gender do not appear to have an appreciable affect on the incidence of shoulder pathology. (Milgrom et. al., 1995)Age appears to play a role in shoulder pathology with increasing age related to an increase in the incidence of shoulder pathology. The difference in age between the healthy volunteer group and the shoulder pathology group is one limitation of the present study.

4.2 Objective One: Reliability of Clinical Measures

The results of this study indicate that the tape measure and calipers have good test-retest reliability when measuring the position of the scapula. This was true with measurements taken with the scapula at rest and in elevation. Most of the ICC's (2,1) calculated for the four distances measured between the thoracic spine and scapula were larger than 0.8. This was true for measurements taken using both the tape measure and calipers. ICC's larger than 0.75 represent good reliability, while those below represent moderate to poor reliability (Portney and Watkins, 2000). The ICC produced for the measurements taken using the tape measure from the coracoid to the 12th thoracic vertebrae with the scapula in the rest position was 0.65, which represents moderate to poor test retest reliability (Portney and Watkins, 2000). One explanation for the poor reliability with this measurement is inherent difficulty in palpating the coracoid process. The coracoid serves as an attachment site for three muscles and is often obscured by soft tissue (Moore, 2002). The distance from the coracoid to the 12^{th} thoracic vertebrae was also awkward to measure, since one point was on the posterior aspect of the thorax, while the other was on the anterior thorax.

Few studies have looked at the test-retest reliability of using calipers or a tape measure to determine scapular position. No research has examined the ability to reliably measure the distance between the acromion, coracoid or spine of the scapula to the thoracic spine. A limited number of studies have looked at the measurement of the inferior angle to the thoracic spine. This distance is a component of the Lateral Scapula Slide Test (LSST) developed by Kibler (1998). The results of the present study contrast with results found by Odom et. al. (2001), when testing the reliability of the LSST found poor intrarater reliability for measurements taken from the inferior angle to the thoracic spine. Gibson et. al. (1995) also examined the reliability of measuring the distance from the inferior angle to the thoracic spine. The author of this study marked the distance from the inferior angle to the thoracic spine on a string then transferred the string to a metric ruler. This distance was measured bilaterally with the arm in three different positions. ICC's calculated to determine intrarater reliability for the three positions ranged from 0.81 to 0.95, indicating good intrarater reliability of the measurement from the inferior angle to the thoracic spine. Thus, there is limited and conflicting research that exists regarding the reliability of manual measures of scapular position.

4.3 Objective Two: Validity of Clinical Measures and Motion Analysis

Tape Measure and Calipers

The results of this study indicate poor to moderate agreement between the tape measure and calipers when measuring all four distances from the thoracic spine to the scapula. This result could be explained by the fact that these measurement tools do not measure the same thing. Calipers measure the shortest distance between two points while the tape measure takes into account the contours of the body. It was expected that the distances measured with the tape measure would be consistently higher than those found with the calipers.

In general better agreement between tape measure and calipers was found for the distance measured between the inferior angle and thoracic spine and the spine of the scapula and the thoracic spine. Because the inferior angle, spine of the scapula and the thoracic spine all lie in the frontal plane, the two dimensional distances should be minimally affected by bony contour or soft tissue. This study suggests that the values obtained using the tape measure and calipers are more similar when measuring two-dimensional distances than when they are used to measure longer distances over contoured anatomical planes.

Pearson r correlations were also calculated to determine if a relationship exists between measurements taken using the tape measure and calipers. Pearson correlation coefficients were all $r>0.5$ and statistically significant ($p<0.01$) for the four distances measured between the thoracic spine and the scapula. The Pearson r-values indicate a strong positive relationship between the two measurement tools (Portney and Watkins, 2000).

The concurrent validity of measures of scapular position was examined previously by Johnson et. al. (2001). These authors looked at the concurrent validity of the inclinometer and magnetic tracking device as measurements of scapular position. The results indicated that the inclinometer had good to excellent validity as a measure of static scapular position during elevation in the plane of the scapula.

Agreement with Motion Analysis

Results of this study indicate poor agreement between the tape measure and three dimensional motion analysis as measures of scapula position. Similar results were found when comparing the distance measured using calipers and three dimensional motion analyses. These values indicate poor agreement between these two measures and the "gold standard"(Portney and Watkins, 2000).

In particular, agreement was very low for the distances measured from both the acromion and the coracoid to the thoracic spine. These low ICC values were seen when examining agreement between measures taken using three dimensional motion analysis with both the tape measures and the calipers. Using the tape measure to measure the distance between the acromion and the twelfth thoracic vertebrae requires that the end of the tape be held on the spinous process while the tape passes superiorly over the scapula to the acromion. If the scapula sits in an abnormal position, this distance will be larger than the distance found using three dimensional motion analysis. The same issue would result with the distance measured from the coracoid to thoracic spine. For measurements taken between the acromion and the thoracic spine, the ICC was a negative value, which indicates that the results are worse than would have been expected to occur by chance (Portney and Watkins, 2000). This value often indicates that an intrinsic variable is affecting the results to the point where the values are distorted (Cook, 2003).

Pearson r correlation coefficients calculated for the distances measured using the tape measure and three-dimensional motion analysis were higher than the ICC's. Pearson r-values ranged from 0.17 to 0.55 and were significant for three of the four distances measured from the thoracic spine to the scapula. These results suggest that the relationship between the distances measured using tape measure and the three-dimensional motion analysis are fair. Similarly, a fair relationship was found for the values obtained using the calipers when compared to three-dimensional motion analysis. These values were consistent whether measurements were taken with the arm at rest or in the elevated position. Pearson r-values for distances measured between the acromion and the thoracic spine were poorly correlated and not statistically significant. This was likely due to difficulty in landmarking the acromion with the caliper.

When using a tape measure to measure the distance between two bony points, the soft tissue contours of the body will be reflected in the resulting measurement. In contrast, the calipers and three-dimensional motion analysis measure the shortest distance between two points. This is less of an issue when measuring distances that are in the same plane or are two dimensional in nature. The measurement of the distance between two points that lie in different planes will take into account the amount of soft tissue that lies between those points, causing measurements to be longer. Therefore, we expected the calipers and three-dimensional motion analysis to yield higher ICC's than the comparison of the tape measure versus three-dimensional motion analysis. It was anticipated that the measurements obtained when using the calipers and three dimensional motion analysis would have good agreement since they both measure the direct distance between the two landmarks.

Three dimensional motion analysis uses motion capture cameras and computer software to provide precise three-dimensional coordinates of the points identified by the stylus. The stylus uses a sharp, precise point when identifying bony landmarks which allows for accurate measures, taken to the nearest thousandth of a millimetre, thus small scale movements, including postural sway and respiration may have influenced the measurements taken. Using computer software, the shortest distance between the identified points is calculated. A computer system then determines the three-dimensional coordinates of the position of the bony landmark. The stylus only requires one point to be identified at a time, which differs from both the tape measure and calipers. The differing amount of accuracy of the measurement tools is a possible explanation for the low ICC's. When measuring the distance between two points using a tape measure, two hands are required, one to position the end of the tape on the thoracic spine and the other to position the tape on scapular landmark. Calipers also have the potential for decreased accuracy because they require two hands, one to hold the caliper on the first point and the second to palpate and hold the end of the caliper on the second point. A subject's posture may have been influenced when the rater placed her hands on his/her thorax while taking measurements. This may have contributed to the relatively poor agreement seen between three dimensional motion analysis and both manual measurement tools. Other reasons for these results include the distances measured with the calipers were rounded off the nearest centimetre and tape measurements were rounded to the nearest 0.1 centimetres. The markings on the caliper are somewhat difficult to see therefore environmental factors like lighting, shadows and the angle from which the number was read will affect the accuracy of these measurements. The end of the caliper also has a four-centimetre wide ball at the tip, which may produce a larger margin of error when using this measurement tool.

When the arm is in the elevated position the acromion becomes more difficult to accurately palpate due to soft tissue bulk. The deltoid musculature is an elevator of the glenohumeral joint therefore once contracted it can obscure the location of the acromion making it difficult to landmark (Moore, 1992). This difficulty in palpation combined with potential for rater error when using the tape measure could explain the negative ICC for the distance measured between the acromion and thoracic spine in elevation.

Although the three-dimensional motion capture system allowed for the analysis of the scapular movement in three planes, there were some disadvantages to using this system. It was not possible to obtain true three-dimensional angles using surface markers (like the stylus), since the stylus is more superficial than the actual joint angle. Furthermore, the computer created lines that connect the joint angles did not pass through the centre of rotation of the joint and the true joint angle was not identified. The inability to accurately locate the actual joint angle makes the three-dimensional system a good estimation at best (Turner-Stokes et. al. 1999).

Due to the differences in how the same distance was measured between the two-dimensional and the three-dimensional motion analysis, the low values for the ICC's were understandable. However, this does not explain why values obtained with the tape measure and calipers were poorly correlated with the three-dimensional motion analysis. No articles demonstrating the reliability of scapula or shoulder measurements using three dimensional motion analysis were found by the author. Unfortunately, there has been limited research looking at the validity of the clinical measurements with respect to the scapula. Whether the three-dimensional motion analysis system is the best "gold standard" has yet to be determined.

4.4 Objective Three: The Relationship between shoulder pathology, scapula asymmetry, the DASH and NPRS

The results of this study suggest that a significant difference does not exist between the scapular position of the dominant and non-dominant scapulae of healthy volunteers or in subjects with shoulder pathology. These findings are consistent with results found by Gibson et. al. (1995) and Odom et. al. (2001). Odom et. al. (2001) did not find any differences in scapular position between the involved and uninvolved scapula in subjects with shoulder pathology. They concluded that side-by-side comparisons of the scapula are not appropriate clinically. Gibson et. al. (1995) looked at the reliability of four tools developed to measure the static position of the scapula. These authors attributed the inability to detect scapula asymmetry due to disagreement between the two raters on the position of the scapula. The results of this study contrast with the work by Rundquist (2007) who completed a side-by-side comparison of the scapula in individuals presenting with shoulder impairments. This study found that in individuals with shoulder pathology, the scapula of the involved side had significantly less scapular elevation than the uninvolved side. Therefore, controversy exists with Kibler's (1998) contention that a significant difference between the scapulae indicated scapular dyskinesis and is a causative factor in shoulder pathology.

While we did not find evidence of scapula asymmetry, significant differences were found between the scapular position of healthy volunteers compared to subjects with shoulder pathology. Longer distances were measured from the thoracic spine to the scapula in subjects with shoulder pathology. This difference between healthy volunteers and subjects with shoulder pathology was present with measurements taken using either the tape measure or calipers and when the arm was at rest or elevated.

One explanation for this difference in scapular position is the postural deviations which commonly exist in individuals with shoulder pathology. An increased thoracic kyphosis, a postural deviation which would affect the scapula, has been linked to shoulder pathology (Endo et. al. 2004). Of the 20 subjects with shoulder pathology, 19 reported that the affected extremity was the dominant extremity. These results support the currently held belief that poor posture predisposes an individual to faulty scapula mechanics (Dayanidhi et. al., 2005 and Sahrman, 2002). Even though postural deviations affected both the left and right scapular position, shoulder pathology manifests only on the dominant side because of greater use. It is a possible that a significant difference was detected because of the difference in age between the healthy volunteers and subjects with shoulder pathology. Age has been associated with postural deviations, including an increased thoracic kyphosis, which could lead to changes in the scapular position (Endo, 2004). In order to better answer this objective, future work on scapular position should involve a group of healthy volunteers who are age and sex matched with those in the shoulder pathology group.

The results of the present study contrast with those found by Rundquist (2007) who completed both a side-by-side and between groups comparison of scapular position in individuals presenting with and without decreased shoulder range of motion. He did not find a significant difference in the position of the scapula between subjects who presented with and without shoulder pathology, however, he only compared the scapula of the non-impaired arm to that of the healthy subjects. There was no comparison of the scapula of the impaired shoulder to that of the healthy subjects. A difference was detected in scapula position with side-by-side comparisons in subjects with decreased shoulder range of motion. Subjects with shoulder pathology had greater upward rotation in the involved scapula which was explained as postural adaptation developed to compensate for the loss of glenohumeral joint range of motion.

Examining the distances measured on the affected arm of the group of individuals with shoulder pathology a moderate relationship was found between the position of the spine of the scapula and the subjects self reported pain score (NPRS) and shoulder function score (DASH) when the arm was at rest. A poor relationship was found between the NPRS and the DASH scores and the other three distances measured. In the resting position, a significant relationship was found between the DASH and NPRS scores and the distance measured from the spine of the scapula to the thoracic spine for all three measurement tools. In the elevated position a significant relationship between the pain scores and the distance measured from the spine of the scapula to the thoracic spine measured with the calipers was identified. The results of this study indicate that the distance from the spine of the scapula to the thoracic spine measured when the arm is at rest is the greatest correlate of pain and disability associated with shoulder pathology.

Clinically it is of benefit to note that the relationship between the position of the spine of the scapula and shoulder pain and dysfunction exists when all three measurement tools were used with the arm in the resting position. This relationship was less consistent with the arm in elevation, which could explain lack of agreement found with the arm in elevation. Since it is relatively easy to measure distance between the spine of the scapula and the thoracic spine when the arm in resting this approach may prove quite useful in clinical practice. There has been no research conducted looking at this relationship, therefore, further studies are warranted to explain this finding.

Lin et. al. (2006) found that scapula kinematics correlated significantly with the self-report FLEX-SF measure of shoulder dysfunction. Relative to the control group, the group of subjects presenting with shoulder pathology had greater amounts of altered scapular position, along with greater shoulder disability as determined by self-report measures.

Conclusions

The results of this study indicate that tape measure and calipers have good test-retest reliability when used to measure the distance from the scapula to the thoracic spine. These results were consistent for measurements taken with the arm at rest and in elevation.

Moderate concurrent validity was found for the four distances measured between the thoracic spine and the scapula using the tape measure and calipers with the arm at rest and in the elevated position. Only moderate to low agreement was found for the comparison of distances measured with the calipers and motion analysis and motion analysis and tape measure, indicating poor concurrent validity. A positive relationship was found between with the tape measure and calipers, calipers and motion analysis and motion analysis and tape measure for three of the four distances measured. The distance measured from the thoracic spine to the acromion did not yield a positive relationship for the comparison of the tape measure and motion analysis and calipers and motion analysis (r values < 0.17).

A significant difference in scapular position was not found in side-by-side comparisons of scapular position for healthy volunteers and with subjects with shoulder pathology. This lack of asymmetry of scapular position occurred both with the arm at rest and in the elevated position. A significant difference in the position of the scapula was detected between healthy volunteers and subjects with shoulder pathology. Mean distances for all four measurements from the thoracic spine to the scapula were greater for the group of subjects presenting with shoulder pathology in both the rest and elevated positions. Differences in mean distances between healthy volunteers and individuals with shoulder pathology were greater than MDC_{90} suggesting these measures are due to more than the mean.

In subjects with shoulder pathology, pain (NPRS) and function scores (DASH) appear to correlate well with the distance measured from the spine of the scapula to thoracic spine. In elevation, the distance measured from the spine of the scapula to the thoracic spine correlated well to the pain and function scores when calipers are used as the measurement tool.

Clinical Relevance

The results of this study have relevance for clinicians treating individuals with shoulder pathology. A relationship exists between scapular position and shoulder pathology, therefore, physiotherapy treatment aimed at correcting the position of the scapulae in order to alleviate shoulder pathology is warranted. In addition the tape measure and calipers are measurement tools that have good test-retest reliability and moderate concurrent validity when used to measure the position of the scapula. These four distances can be measured easily in a clinical setting using either tape measure or calipers which are simple devices that can be readily obtained by practicing physiotherapists.

Study Limitations and Future Research

This study evaluated tools for measuring the static position of the scapula with the arm at rest and at end range elevation. Further research is warranted to develop tools to measure the position of the scapula dynamically. A further limitation of this study is that it used three dimensional motion analysis as the gold standard scapula measurement tool. Although research has been done to validate motion analysis as the gold standard for the lower extremity, there is limited research to support its use in the upper extremity. The reliability and validity of the motion analysis still needs to be examined. To avoid potential sampling bias, age and sex match subject samples would have insured that the healthy volunteer group and the group of subjects were shoulder pathology were equal on these two variables. This is a recommendation for future research and a limitation of the present study. A recommendation for future research and a limitation of the present study is that a Bonferroni correction be used in the statistical analysis which would have corrected for the large number of comparisons (>24) and resulted in more accurate results. With respect to the study methodology, the order of measurements taken using the tape measure, calipers and three-dimensional motion analysis should have been randomized which would have eliminated biased results due to subject fatigue or increases in pain as a result of the test position.

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Appendices

A- Initial Assessment Form

B – Shoulder Anatomy

C - Letter of Information

D – Ethics Approval Notice

E– DASH (Disabilities of the Arm, Shoulder and Hand)

F– Numerical Pain Rating Scale (NPRS)

Appendix A

Initial Assessment Form

Subject Information Sheet

Name: ____

Address:____

____

____

Telephone Number:____________________________________

Age:

Gender: Female Male

Dominant Hand: Right Left

Subject Number:____________________

Clinical Assessment Form

Subjective

Pain History

Mechanism of Injury: **slow/gradual** **sudden/traumatic**

Duration of Symptoms: ________________________________

Symptoms: **increasing** **decreasing**
unchanging

Frequency of Symptoms: **constant** **intermittent –**
frequency of episode ____ **duration of episodes** ____________

Symptom Intensity:

Previous Episodes:

Quality of Symptoms:

Tingling &/or Numbness:

History of Diagnostic Tests:

Surgery:

Use of Sling:

Data Collection Sheet

I Neutral glenohumeral position

Right Scapula

1. Inferior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
2. Superior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
3. Acromial tubercle to spinous process of
    a. Tape measure:
    b. Calipers:
4. Coracoid process to spinous process of
    a. Tape measure:
    b. Calipers:

Left Scapula

5. Inferior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
6. Superior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
7. Acromial tubercle to spinous process of
    a. Tape measure:
    b. Calipers:
8. Coracoid process to spinous process of
    a. Tape measure:
    b. Calipers:

II End Range of glenohumeral joint motion

Right Scapula

9. Inferior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
10. Superior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
11. Acromial tubercle to spinous process of
    a. Tape measure:
    b. Calipers:
12. Coracoid process to spinous process of
    a. Tape measure:
    b. Calipers:

Left Scapula

13. Inferior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
14. Superior Angle to spinous process of
    a. Tape measure:
    b. Calipers:
15. Acromial tubercle to spinous process of
    a. Tape measure:
    b. Calipers:
16. Coracoid process to spinous process of
    a. Tape measure:
    b. Calipers:

NPRS: ______________________________

DASH: ______________________________

Appendix B

Shoulder Anatomy

Anatomy of the Shoulder Girdle

The "shoulder" is a four joint complex that includes the acromioclavicular, sternoclavicular, glenohumeral and scapulothoracic joints (Figure 5). Dysfunction in any of these four joints can contribute to the development of shoulder pathology.

The shoulder girdle, which is made up of the scapula and the clavicle, functions to attach the upper limb to the axial skeleton, which is comprised of the skull, vertebral column, ribs and the sternum (Moore, 1992). The scapula is a flat, triangular shaped bone which lies on the posterior superior surface of the rib cage. This bone has a concave anterior surface referred to as the subscapular fossa. Projecting from the superior anterior surface of the scapula is the coracoid process, which resembles a bird's beak and serves as an attachment for the pectoralis minor and short head of biceps muscles. Posteriorly the surface of the scapula is convex from which the spine of the scapula projects. The spine of the scapula extends from the medial border of the bone horizontally, gradually flattening into the acromion process. This part of the scapula projects anteriorly and forms the acromioclavicular joint with the lateral aspect of clavicle. The shoulder girdle articulates with the sternum at the sternoclavicular joint, a sellar or saddle joint formed between the manubrium and sternum and the medial portion of the clavicle. The scapulothoracic joint is the "pseudo" joint formed between the flat, blade shaped scapula and the thoracic wall. The configuration of the scapulothoracic joint allows the scapula to glide in a three dimensional arc of motion over the rib cage during movement of the glenohumeral joint (Kibler 1998, Wilk et. al. 1998). See Figures 6 and 7 for illustration of the above points.

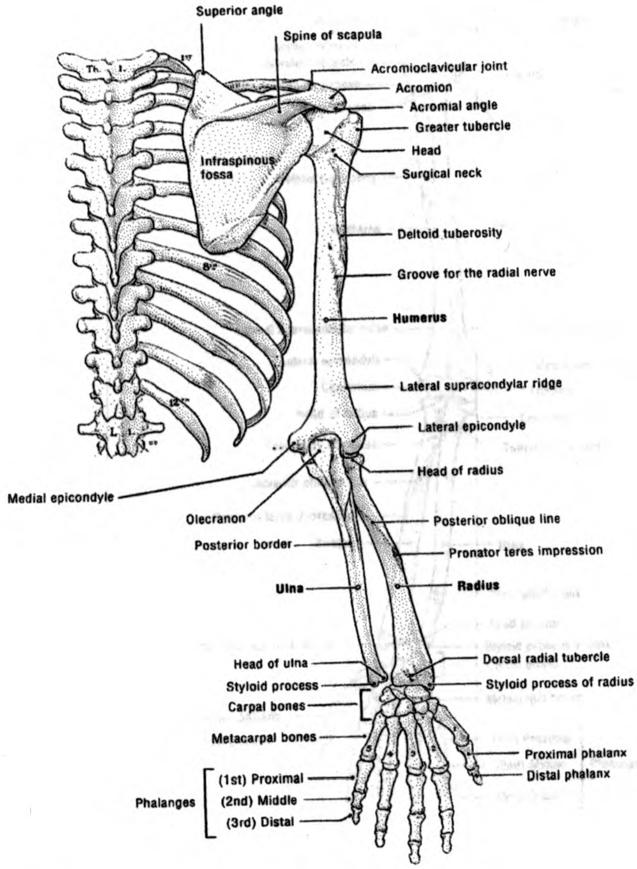


Figure 5: Bones of the Upper Limb: Posterior View (From Moore KL: Clinically Oriented Anatomy, 3rd Edition, Baltimore, Williams and Wilkins:1992.)

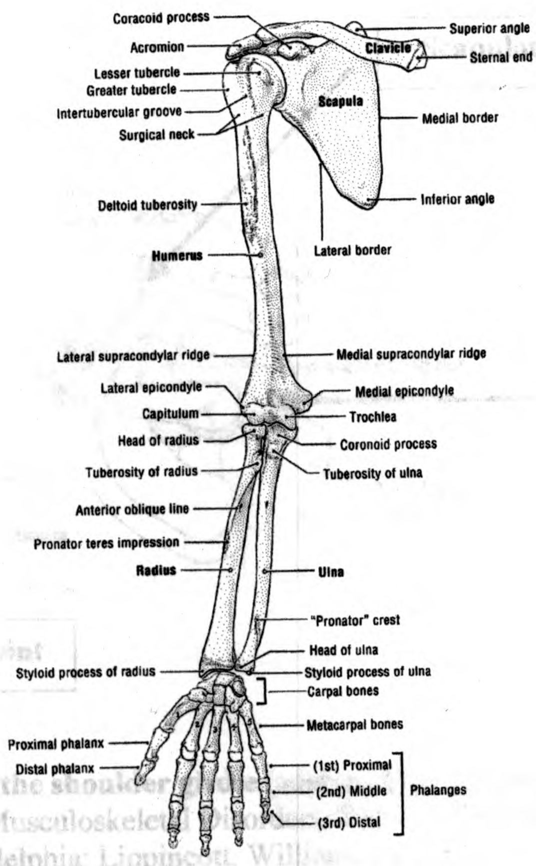


Figure 6: Bone of the Upper Limb: Anterior View (From Moore KL: Clinically Oriented Anatomy, 3rd Edition, Baltimore, Williams and Wilkins: 1992.)

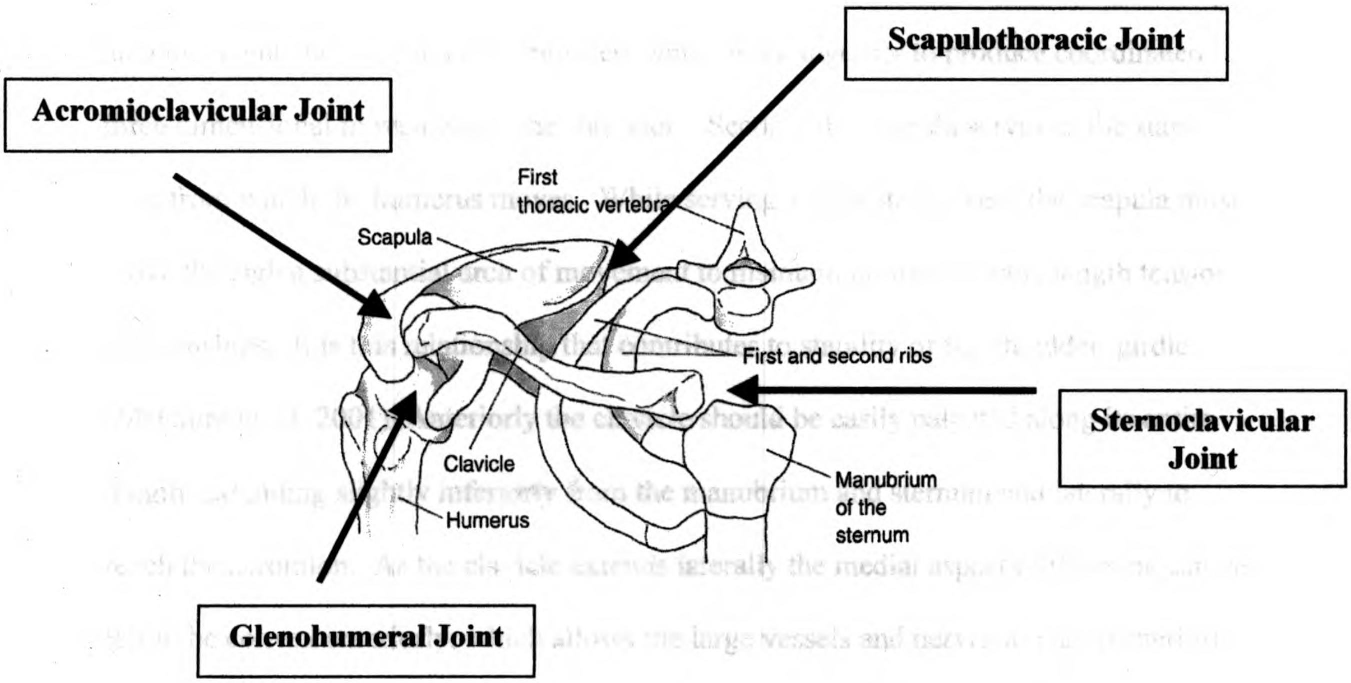


Figure 7: Articulations of the shoulder girdle (adapted from:Hertling D, Kessler, RM. Management of Common Musculoskeletal Disorders: Physical Therapy Principles and Management, 3rd Ed, Philadelphia: Lippincott, Williams and Wilkins: 1996.)

The role of the scapula is twofold. First the flat blade shape of the scapula serves as an attachment site for numerous muscles, which work together to produce coordinated three dimensional movement of the shoulder. Second, the scapula serves as the stable base from which the humerus moves. While serving as this stable base, the scapula must move through a substantial arch of movement to maintain optimal muscle length tension relationships. It is this relationship that contributes to stability of the shoulder girdle (McClure et. al. 2001). Anteriorly the clavicle should be easily palpated along its entire length, extending slightly inferiorly from the manubrium and sternum and laterally to reach the acromion. As the clavicle extends laterally the medial aspect of the bone can be felt to be convex anteriorly, which allows the large vessels and nerves to pass posteriorly to this convexity. The lateral aspect of the clavicle articulates with the acromion, which can be palpated two to three cm medially to the lateral border of the acromion. The acromioclavicular joint or "point of the shoulder" is quite prominent in most individuals and is considered by clinicians to be an easily palpable landmark. The acromion can be palpated posteriorly as it forms the spine of the scapula, projected medially in the horizontal place to the medial border of the spine of the scapula. The superior angle or top of the scapula is somewhat more difficult to palpate due to the bulk of muscle tissue lying over it. The superior portion of the spine is reported to sit at approximately the level of the second thoracic vertebrae (Sahrman, 2002). The inferior angle or caudal most point of the scapula is palpation at approximately the level of the seventh thoracic vertebrae. Anteriorly the coracoid process of the scapula can be palpated lateral to the deltopectoral triangle (Moore, 1992).

The bony configuration of the shoulder girdle sacrifices stability for mobility, relying largely on muscles and ligaments to stabilize the joints. (Kibler 1998) The muscles that attach to the scapula can be divided into three main groups. The first group includes the trapezius (upper, middle and lower fibres), rhomboids major and minor, levator scapulae and the serratus anterior all of which function to stabilize the scapula and produce rotation of the bone. The second group includes the extrinsic muscles of the shoulder joint, the deltoid, biceps and triceps which use the scapula as a base to move the humerus while providing stability at the glenohumeral joint (Wilk et. al. 1997). The intrinsic muscles of the shoulder, including the supraspinatus, infraspinatus, teres minor and subscapularis make up the third group which function to produce movement at the glenohumeral joint while serving as part of the force couple which keeps the humeral head centred in the glenoid fossa. (Kibler 1998, Wilk et. al. 1997)

Normal Alignment of the Scapulothoracic Joint

According to the Movement Impairment Syndromes theory developed by Shirley Sahrmann (2002) alignment is important to any mechanical system since optimal alignment will allow for optimal movement to occur. Therefore if an abnormality exists in the alignment prior to movement, the system will not be able to achieve optimal movement. The faulty alignment in the resting position must be corrected to restore proper movement and in the case of the shoulder girdle, reduce pain and or pathology. Although much controversy exists regarding the optimal alignment of the scapulothoracic joint, work by Sahrmann (2002) appears to be the most accepted clinical view. Sahrmann reports that the medial or vertebral border of the scapula should lie approximately three inches parallel to the spinous processes of the thoracic spine. Manske et. al. (2004) further reported that at rest the scapula should sit positioned with the superior angle at the second rib and the inferior angle at the seventh rib. These researchers described the position of the scapula being approximately rotated 30 to 40 degrees anterior to the frontal plane and tipped anteriorly approximately 10-12 degrees in the vertical plane. This static position of the scapula is often termed the "plane of the scapula" and movement in this plane is referred to as scaption (Manske et. al. 2004). Kendall et. al. (2005) have made the distinction that resting position of the scapula is influenced by hand dominance with the dominant hand having a depressed scapula.

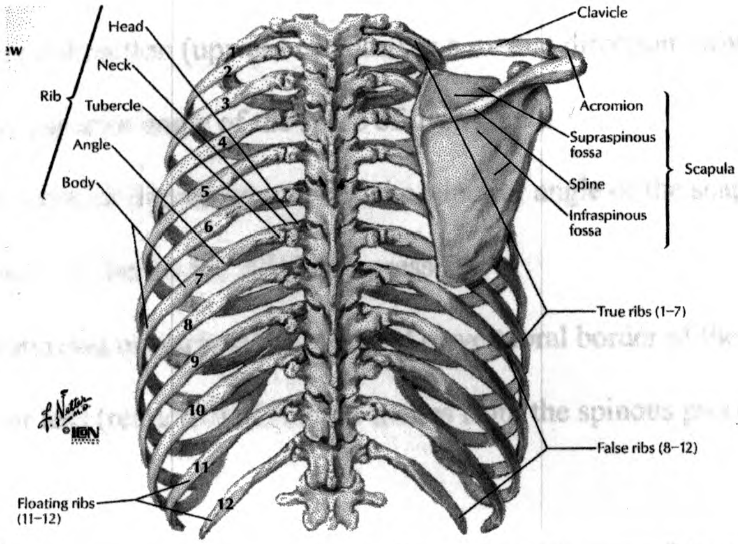


Figure 8: Normal Alignment of the Scapulothoracic Joint (Netter FH. Atlas of Human Anatomy, 3rd Ed, New Jersey: Icon Learning Systems, 2004.)

Sahrmann Theory

Sahrmann (2002) described five common abnormalities in scapular alignment

1) Downward or upwardly rotated scapula: the inferior angle of the scapula is rotated in lateral direction (upward rotation) or a medial direction (downward rotation) in relation to the superior angle of the spine of the scapula

2) Elevated or depressed scapula: the superior angle of the scapula lies above the 2nd rib (elevated) or below the 2nd rib (depressed)

3) Protracted or retracted: the medial or vertebral border of the scapula lies more (protracted) or less (retracted) than three inches from the spinous process of the thoracic spine

4) Tipped: the inferior angle protrudes posteriorly away from the ribcage

5) Winging: the medial border protrudes posteriorly away from the ribcage

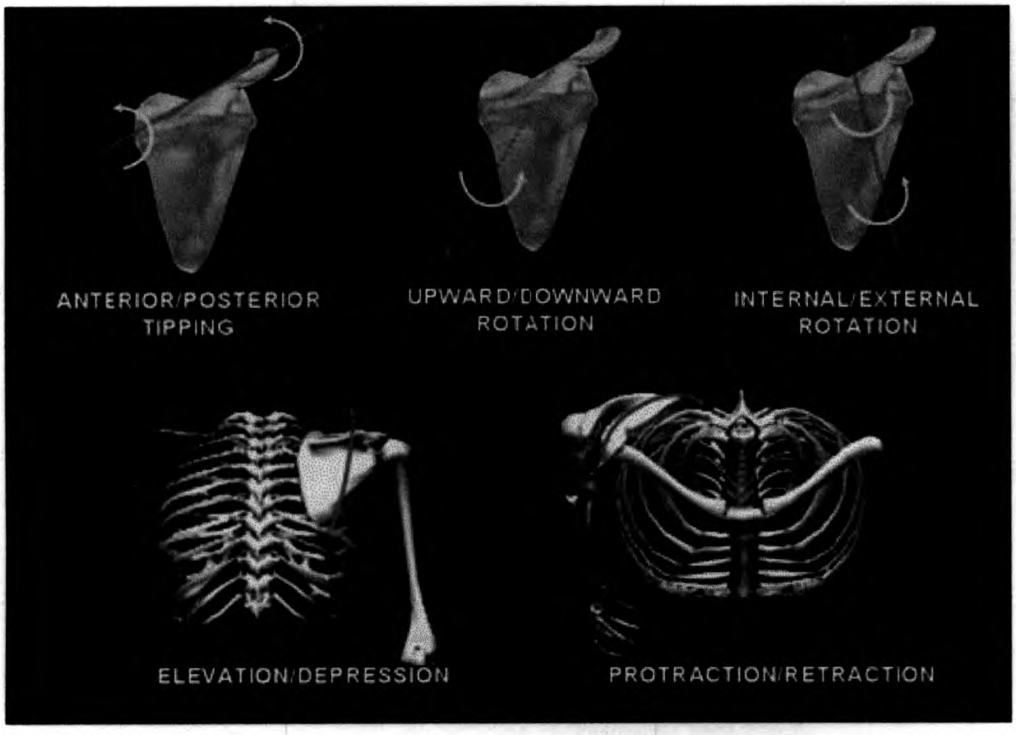


Figure 9: Scapula Position and Orientation (Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Scapular position and orientation in throwing athletes. *The American Journal of Sports Medicine* 2005)

Appendix C

Letter of Information

Letter of Information

Title of Study: Static Scapula Position: Reliability and Validity of a three Dimensional Palpation Technique

Investigators: Pamela Houghton PhD (supervisor), Trevor Birmingham PhD, Thomas Jenkyn PhD, Lorie Forwell PT, Kayley Mills PT, MSc Candidate

The purpose of this letter is to provide you with the information you require to make an informed decision regarding your participation in this research study.

You have been invited to participate in a research study which is examining different methods of measuring the position of the shoulder blade or scapula in individuals with and without shoulder pain. We wish to develop a new clinical measure of scapula position using a tape measure and calipers. To do so we will compare measurements from these tests to those obtained using a standard physiotherapy assessment and a state of the art digital camera system. You have been asked to participate in this study since; 1) you have been diagnosed with a shoulder condition by your orthopaedic surgeon or physical physiotherapist or 2) you have no history of shoulder pathology.

If you agree to participate in this study, you will be asked to change into a standard hospital gown which will allow the exposure of both of your shoulder blades. You will remain wearing the gown for the duration of the study. You will undergo a standard physiotherapy shoulder assessment completed by a licensed physiotherapist. As part of this assessment you will be asked to fill out a questionnaire which is aimed at determining if shoulder pain affects your ability to perform daily tasks. You will then have three measurements taken of the position of your shoulder blade, the order of which will be varied amongst study participants. The study investigator will measure four distances between your shoulder blade and spine using both a flexible tape measure and calipers. For the third measurement, the assessor will use a marker to identify seven points on your spine and shoulder blade. After each point is identified a "picture" will be taken using eight special cameras mounted on the wall. Each set of three measurements will be taken on both your left and right shoulders, with your arm at your side and then again with your arm raised as high as comfortable. In order to prevent your arm from fatiguing you will be able to rest your arm/hand on a ledge that is attached to a pole for the duration of the measurements.

The shoulder assessment and three measurements will be taken either at the Wolf Orthopaedics Biomechanics Lab, the Fowler Kennedy Sports Medicine Clinic at the University of Western Ontario or the outpatient physiotherapy department at St. Joseph's Health Care. Seventy two hours following the initial testing, you will be asked to return to your physiotherapist either at the Fowler Kennedy Sports Medicine Clinic or the outpatient orthopaedic physiotherapy clinic at St. Joseph's Health Care to have the measurements with the tape measure and calipers repeated. It is anticipated that both visits, which include the three measurements, should take no longer than 90 minutes of your time to complete.

There are no known risks and no direct benefits to your participation in this study. You may experience a slight increase in your pain symptoms following testing however this pain should resolve within one hour following testing. If at any time during testing you experience an increase in pain, please inform the primary investigator and testing will be stopped. Participation in this study is voluntary and you may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect of your future care, employment or academic status. In addition you may stop the test procedures at any point during the study, however your withdrawal from the study may not result in the withdrawal of data already obtained through your participation. Your involvement in this study will not involve any additional costs to you or your health care insurer and you will be reimbursed for the cost of parking up to a maximum of $10.00.

Any information that you provide may be shared amongst the study investigators and will be kept in a locked filing cabinet in a secure office at Elborne College at the University of Western Ontario. All data produced as a result of this study will be retained indefinitely. All information will be kept confidential. If the results of this study are published, your name will not be used and no information that discloses your identity will be released or published.

The study investigator, Kayley Mills from the outpatient physiotherapy department at St. Joseph's Health Centre and the University of Western Ontario will be coordinating this study. If you have any questions about the study procedures, you can contact Kayley Mills or principal investigator Dr. Pamela Houghton. If you have any questions about your rights as a research participant or the conduct of the study you may contact the Vice President Research, c/o the Lawson Health Research Institute, (519) 667-6649

Thank you for your time.

Kayley Mills

Consent Form

Title of Study: Static Scapula Position: Reliability and Validity of a three Dimensional Palpation Technique

Investigators: Pamela Houghton PhD (supervisor), Trevor Birmingham PhD, Thomas Jenkyn PhD, Lorie Forwell PT, Kayley Mills PT, MSc Candidate

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

--------------------------------------- ---------------------------------------

Printed Name of Participant Date

Signature of Participant

--------------------------------------- ---------------------------------------

Printed Name of Person Obtaining Consent Date

Signature of Person Obtaining Consent

Appendix D

Ethics Approval Notice

Office of Research Ethics
The University of Western Ontario
Room 00045 Dental Sciences Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
Website: www.uwo.ca/research/ethics

Western

Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. P. Houghton
Review Number: 12289E **Revision Number:**
Protocol Title: Static and Dynamic Scapula Position: The Reliability and Validity of a 3 Dimensional Clinical Measurement Technique
Department and Institution: Physical Therapy, University of Western Ontario
Sponsor:
Ethics Approval Date: June 6, 2006 **Expiry Date:** September 30, 2007
Documents Reviewed and Approved: UWO Protocol, Letter of Information & Consent, Advertisement
Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted expedited approval to the above named research study on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:
a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

Susan Underhill

Chair of HSREB: Dr. John W. McDonald
Deputy Chair: Susan Hoddinott

Ethics Officer to Contact for Further Information		
☑ Ethics Officer (ethics@uwo.ca)	☐ Janice Sutherland (jsutherl@uwo.ca)	☐ Jennifer McEwen (jmcewen4@uwo.ca)

This is an official document. Please retain the original in your files.

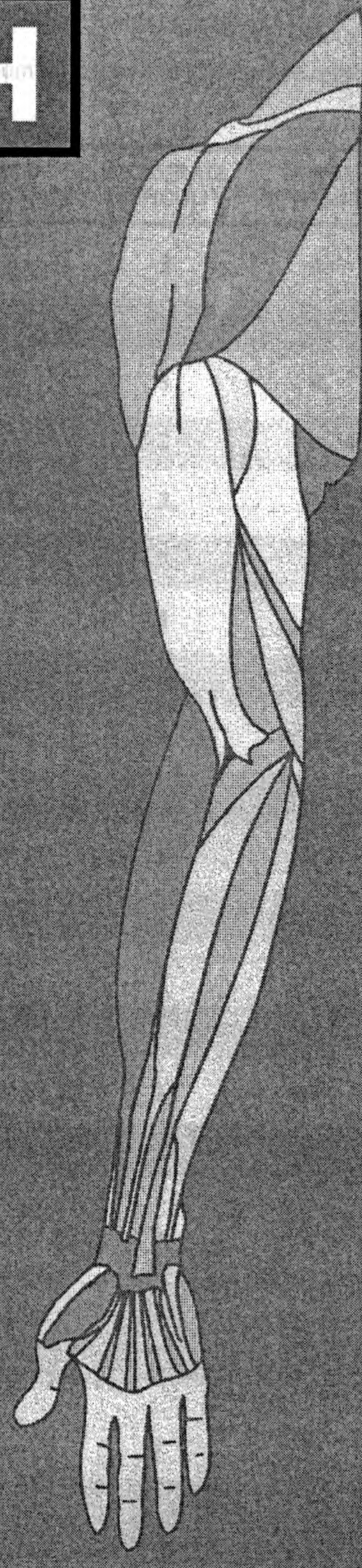
cc: ORE File
LHRI
Faxed: Y / N

Appendix E

The DASH (Disabilities of the Arm, Shoulder and Hand) Outcome Measure

DISABILITIES OF THE ARM, SHOULDER AND HAND

THE DASH



INSTRUCTIONS

This questionnaire asks about your symptoms as well as your ability to perform certain activities.

Please answer *every question*, based on your condition in the last week, by circling the appropriate number.

If you did not have the opportunity to perform an activity in the past week, please make your *best estimate* on which response would be the most accurate.

It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.

DISABILITIES OF THE ARM, SHOULDER AND HAND

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 10 lbs).	1	2	3	4	5
12. Change a lightbulb overhead.	1	2	3	4	5
13. Wash or blow dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover sweater.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g., cardplaying, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
22. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? *(circle number)*	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? *(circle number)*	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(circle number)*

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(circle number)*	1	2	3	4	5

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. *(circle number)*	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE = $\left[\frac{\text{sum of n responses}}{n} - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may <u>not</u> be calculated if there are greater than 3 missing items.

DISABILITIES OF THE ARM, SHOULDER AND HAND

WORK MODULE (OPTIONAL)

The following questions ask about the impact of your arm, shoulder or hand problem on your ability to work (including homemaking if that is your main work role).

Please indicate what your job/work is:_____________________________

p I do not work. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty:

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. using your usual technique for your work?	1	2	3	4	5
2. doing your usual work because of arm, shoulder or hand pain?	1	2	3	4	5
3. doing your work as well as you would like?	1	2	3	4	5
4. spending your usual amount of time doing your work?	1	2	3	4	5

SPORTS/PERFORMING ARTS MODULE (OPTIONAL)

The following questions relate to the impact of your arm, shoulder or hand problem on playing *your musical instrument or sport or both*.
If you play more than one sport or instrument (or play both), please answer with respect to that activity which is most important to you.

Please indicate the sport or instrument which is most important to you:_

o I do not play a sport or an instrument. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty:

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. using your usual technique for playing your instrument or sport?	1	2	3	4	5
2. playing your musical instrument or sport because of arm, shoulder or hand pain?	1	2	3	4	5
3. playing your musical instrument or sport as well as you would like?	1	2	3	4	5
4. spending your usual amount of time practising or playing your instrument or sport?	1	2	3	4	5

SCORING THE OPTIONAL MODULES: Add up assigned values for each response; divide by 4 (number of items); subtract 1; multiply by 25.
An optional module score may <u>not</u> be calculated if there are any missing items.

INSTITUTE FOR WORK & HEALTH
INSTITUT DE RECHERCHE SUR LE TRAVAIL ET LA SANTÉ

Appendix F

Numerical Pain Rating Scale

Numerical Pain Rating Scale

Describe how much pain you feel

Using a pain rating scale, like the one below, is helpful in describing how much pain you are feeling. Please assign a number from 0(zero) to 10 (ten) to represent your pain level. If you have no pain, then use a zero. As the numbers get higher, they stand for increasing amounts of pain. A 10 means the pain is the worst that it can be.