Effects of Forward Head Rounded Shoulder Posture on Shoulder Girdle Flexibility, Range of Motion, and Strength

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ABSTRACT

Quinton L. Sawyer: The Effect of Forward Head Rounded Shoulder Posture on Shoulder Girdle Flexibility, Range of Motion, and Strength
(Under the direction of William E. Prentice, PhD, ATC)

The objective of this study was to determine if clinical measures of flexibility, range of motion and strength were different between people with and without Forward Head Rounded Shoulder Posture (FHRSP). In this study we measured the flexibility, range of motion, and strength of the right arm of twenty two FHRSP and fifteen ideal posture subjects. All measures of flexibility and range of motion were measured with a digital inclinometer. Mean and peak values (N) of strength were measured with a hand-held dynamometer. There were no significant differences ($p \leq 0.05$) seen in flexibility, range of motion, or strength between groups. The clinical assumptions of FHRSP were not supported in this study using common clinical tests. These findings introduce the idea that differences may be in the neuromuscular control of the shoulder girdle and not in the actual strength and flexibility of muscles and tissue.

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LIST OF ABBREVIATIONS

C7	seventh cervical vertebra
ER	external rotation
ERs	external rotators (infraspinatus/teres minor)
FHRSP	Forward Head Rounded Shoulder Posture
HA	Head Angle
ICC	interclass correlation coefficient
IR	internal rotation
N	Newtons
ROM	Range of Motion
SA	Shoulder Angle
SD	standard deviation

Chapter 1

Introduction

Posture is an important and often neglected part of overall health. Ideal posture maintains the structural integrity and optimum alignment of each component of the kinetic chain [1]. The kinetic chain consists of the myofascial system, articular system and the neural system [1]. When one component of this system is out of alignment, then the entire system is placed at a disadvantage. Postural malalignment is thought to create predictable patterns of tissue overload and dysfunction, initiating the cumulative injury cycle [1]. This cumulative injury cycle begins with tissue trauma and inflammation, leading to muscle spasm, adhesions, altered neuromuscular control, and muscle imbalance. This cycle is thought to cause decreased function and eventual injury [1].

Faulty posture is thought to be an identifier of muscle imbalances about the joints in mal-alignment [2]. In a position of faulty posture, the muscles that are in a shortened position are thought to be stronger and overactive, while the muscles that are in an elongated position are thought to be weaker [2]. Vladimir Janda and others have divided muscles into two functional divisions based on these ideas [3]. These groups are called the movement group and the stabilization group. The movement group is characterized as being prone to tightness, being overactive in movement patterns, and being readily active during most functional movements [1]. The stabilization group is characterized as being prone to weakness and inhibition, being easily fatigued during dynamic activities, and being less active during functional movements [1].

Forward head and rounded shoulder posture (FHRSP) is a common postural malalignment seen clinically [4, 5]. Forward head posture is defined as existing when the external auditory meatus is positioned anterior to the vertical postural line [2]. Rounded shoulder posture is defined as when the scapulae are abducted and the acromiom process is anterior to the vertical postural line [2]. The movement group of muscles for the shoulder girdle includes the pectoralis major and minor, upper trapezius, levator scapulae, and anterior deltoid. Therefore, these muscles are assumed to be tight and possess decreased flexibility in individuals with FHRSP. The stabilization group includes rhomboids, serratus anterior, lower trapezius, posterior deltoid, infraspinatus and teres minor, and these muscles are assumed to be lengthened and possess decreased strength in individuals with FHRSP.

FHRSP is commonly seen in individuals who compete in overhead-sports, such as baseball pitchers, swimmers, gymnasts, and volleyball players [1, 6-8]. FHRSP is also thought to cause numerous injuries in sedentary populations as well. Women with symptoms of cranialfacial pain display these postural malalignments more than do asymptomatic women [9]. FHRSP is also thought to alter scapular kinematics and shoulder function [10], as well as compromise the subacromial space, leading to injuries such as bicep or rotator cuff tendonitis or impingement [10, 11]. These injuries can be detrimental to an athlete's participation, especially if they participate in an overhead activity such as volleyball, baseball pitching, tennis, or swimming [8]. These injuries can also be harmful for the sedentary population, causing pain in otherwise healthy individuals [12].

Clinically, it is not clear what poor posture actually means. Clinical theory suggest that FHRSP causes a decreased flexibility of the movement group muscles including pectoralis major and minor as well as latissmus dorsi, as well as decreased range of motion at the glenohumeral joint. Additionally, the stabilization group, which includes the serratus anterior, posterior deltoid, infraspinatus/teres minor and lower trapezius, is suggested to be weaker when FHRSP is present.

Statement of Problem

The purpose of this study is to test the clinical assumptions of Forward Head Rounded Shoulder Posture (FHRSP). These assumptions are that musculature of the movement group (pectoralis major and minor, latissmus dorsi) has a decreased flexibility; shoulder range of motion (internal and external rotation) is decreased; and musculature of the stabilization group (serratus anterior, posterior deltoid, teres minor and infraspinatus, and lower trapezius) has decreased strength.

Dependant Variables

1. Flexibility as measured in degrees for the following muscles:
    a. pectoralis major / minor
    b. latissmus dorsi
2. Range of motion as measured in degrees of the following movements:
    a. internal rotation of the shoulder
    b. external rotation of the shoulder

3. Strength as measured in Newtons by hand-held dynamometer of the following muscles:
    a. serratus anterior
    b. posterior deltoid
    c. infraspinatus / teres minor
    d. lower trapezius

Independent Variables

1. Group- forward head rounded shoulder posture (FHRSP) vs. ideal posture differentiated by measures of posture:
    a. head posture
    b. shoulder posture

Research Question

Are there significant differences between the FHRSP group and the ideal posture group for the following dependent variables?

1. Flexibility as previously defined for the following muscles:
    a. pectoralis major / minor
    b. latissmus dorsi
2. Range of motion of the following movements:
    a. internal rotation of the shoulder
    b. external rotation of the shoulder
3. Strength as previously defined for the following muscles:

    - a. serratus anterior
    - b. posterior deltoid
    - c. infraspinatus / teres minor
    - d. lower trapezius

Null Hypothesis

There will be no significant difference between the FHRSP group and the ideal posture group on the following dependent variables.

1. Flexibility as previously defined for the following muscles:
    - a. pectoralis major
    - b. latissmus dorsi
2. Range of motion of the following movements:
    - c. internal rotation of the shoulder
    - d. external rotation of the shoulder
3. Strength as previously defined for the following muscles:
    - a. serratus anterior
    - b. posterior deltoid
    - c. infraspinatus / teres minor
    - d. lower trapezius

Research Hypothesis

There will be a significant decrease in the FHRSP group as compared to the ideal posture group in the following dependent variables.

1. Flexibility as previously defined for the following muscles:
    a. pectoralis major
    b. latissmus dorsi
2. Range of motion of the following movements:
    a. internal rotation of the shoulder
    b. external rotation of the shoulder
3. Strength as previously defined for the following muscles:
    a. serratus anterior
    b. posterior deltoid
    c. infraspinatus / teres minor
    d. lower trapezius

Definition of Terms

1. Forward head rounded shoulder posture (FHRSP) group: subjects presenting with forward head posture and rounded shoulder posture on assessment of sagital plane photo with superimposed lines and angles measured with Adobe ® Photoshop 7.0

2. Ideal posture group: subjects presenting with ideal head posture and ideal shoulder posture on assessment of sagital plane photo with superimposed lines and angles measured with Adobe ® Photoshop 7.0

3. Forward head posture: head angle $\geq 46^o$

4. Rounded shoulder posture: shoulder angle $\geq 52^o$

5. Head angle: angle formed by straight line from external auditory meatus to C7 spinous process and vertical plumb line through C7 spinous process as determined from digital photo (Figure1)

6. Ideal head posture: head angle $\leq 36^o$

7. Ideal shoulder posture: shoulder angle $\leq 22^o$

8. Shoulder angle: angle formed by straight line from acromiom process to C7 spinous process and vertical plumb line through C7 spinous process as determined from digital photo (Figure 1)

Chapter 2

Review of Literature

Posture

Assessment of posture has long been thought to be part of a thorough patient evaluation, specifically in head and upper extremity injuries [5, 12, 13]. Clark defines posture as the structural integrity and alignment of the kinetic chain [1]. Kendall [2] states that if a posture or joint position is habitual, then there will be a correlation between that joint position and the length of the muscles surrounding that joint. Clinically, ideal posture has been thought to have a specific set of properties [1, 5, 13]. These properties include an imaginary plumb line running slightly behind the lateral malleolus, through the middle of the femur, the center of the shoulder and the middle of the ear in the sagital plane. These properties also include the different joints and articulations of the body in specific positions. The ankle joints should be in a neutral position with the leg at a right angle to the sole of the foot. The hip joints should be neutral, neither flexed nor extended. The pelvis should be level, with the anterior superior spine in the same vertical plane as the symphysis pubis. The lumbar spine should have a normal curve, slightly convex to the anterior, while the thoracic spine should have a normal curve slightly concave to the posterior. The scapulae should be flat against the upper back, and the cervical spine should have a normal curve, slightly convex to the anterior. The head should be in a neutral position, not tilted forward or backward. Ideal posture is thought to maintain optimal length-tension relationships of muscles about a joint, as well as optimal force-couple relationships of those muscles [1]

Faulty posture of the head, neck, and shoulders has been thought to contribute to the onset of cervical pain dysfunction syndrome [5], temporomandibular joint dysfunction (TMJ) [9], as well as shoulder overuse injuries [4], specifically shoulder impingement [11]. Faulty posture is also thought to be indicative of muscle imbalances about the joints in mal-alignment [2]. This is because muscles in a shortened position are thought to be stronger and overactive, as opposed to those in an elongated position, which are thought to be weaker [2]. Vladimir Janda et. al [1, 3, 14] have divided muscles into two functional divisions based on these ideas. These groups are called the movement and stabilization groups. The movement group is characterized as being prone to tightness, being overactive in movement patterns, and being readily active during most functional movements [1]. The stabilization group is characterized as being prone to weakness and inhibition, being easily fatigued during dynamic activities, and being less active during functional movements [1].

These theories have been commonly accepted by clinicians as accurate, though few if any studies have been performed to test to validity of these assumptions. This is especially true in relation to the head and shoulder girdle, where forward head and rounded shoulder posture is commonly seen in the symptomatic as well as non-symptomatic population. One study found that sixty-six percent of healthy, pain-free subjects aged 20-50 were determined to have forward head posture [12]. In this same subject population, 38% were kyphotic, 73% had rounded right shoulders and 66% had rounded left shoulders [12]. Another study examining this relationship found that forward head posture was significantly greater in symptomatic patients that in non symptomatic patients [4].

Even though past research has shown the presence of postural malalignment being associated with pain and dysfunction, no studies to date have examined the relationship of strength, range of motion, and flexibility with postural malalignment.

Many authors mention postural abnormalities when talking about muscular imbalances about specific joints. While Janda [3] is generally credited with pioneering the field and identifying the two groups (movement group and stabilization group) and their specific imbalances, Kendall [2] also talked about posture and it's effect on muscular imbalances. In a position of faulty posture, muscles in slightly shortened positions tend to be stronger, while those shortened muscles tend to be weaker. Either of these two authors is often referenced when talking about the effects of posture on musculoskeletal issues. Garret references Kendall in speaking about how faulty posture, specifically forward head posture, put increasing stress on "specific regions of the musculoskeletal system" [5]. Greenfield sites both Kendall and Janda in speaking about how abnormal posture about the shoulder, specifically the thoracic cervical spine and thus the positioning of the scapula on the thorax, effect muscle balance and muscle length-tension relationships [4]. Griegel-Morris also mentions Kendall when speaking of proper posture being a state of "musculoskeletal balance" [12]. Kebaetse uses Kendall to explain how it is proposed that increased kyphosis alters the scapulohumeral relationship by leading to muscle weaknesses about the shoulder girdle [15]. Most recently, Sahrmann [16] has published material about movement impairment syndromes of the body. In this study, alignment or posture is listed as an indicator of possible muscle length changes and of joint alignments that need to be corrected to allow for optimal motion.

In most studies dealing with postural and correct postural alignment, Kendall is sited for the definition of correct posture and what it should entail. The generally accepted definition of ideal posture as per Kendall involves a vertical plumb line from the side view of the patient passing through the following structures [2]:

- Slightly posterior to the apex of the coronal suture
- Through the lobe of the ear
- Through the external auditory meatus
- Through the odontoid process of the axis
- Through the bodies of the cervical vertebrae
- Through the shoulder joint
- Approximately midway through the trunk
- Through the bodies of the lumbar vertebrae
- Through the sacral promontory
- Slightly posterior to the center of the hip joint
- Approximately through the greater trochanter of the femur
- Slightly anterior to the center of the knee joint
- Slightly anterior to the midline through the knee
- Through the calcaneo-cuboid joint
- Slightly anterior to the lateral malleolus

Using these guidelines, postural abnormalities are defined using more objective means. These objective measures include the external auditory meatus being positioned anterior to the vertical plumb line in the case of forward head posture [2], and the shoulder joint being positioned anterior to the vertical plumb line in the case of rounded shoulder posture [2].

Several studies have looked at the relationship between posture and different dysfunctions in the body. Braun contrasted the postural differences between asymptomatic men and women and craniofacial pain patients [9]. It was suggested that asymptomatic men and women did not differ in the three head and shoulder postural characteristics used. However, symptomatic women did display those postural characteristics to a greater extent than asymptomatic women.

Greenfield and colleagues [4] looked at the relationship between posture in patients with shoulder overuse injuries compared to healthy individuals. Again the author had were significant findings, as forward heat position and humeral elevation were significantly greater in the patient group than the healthy group. Humeral elevation was also greater for involved shoulders in the patient group as compared to uninvolved shoulders.

Griegel-Morris et al. [12] looked at the relationship between postural abnormalities in the cervical, shoulder, and thoracic regions and pain in two groups of healthy subjects. This study showed that subjects with more severe postural abnormalities had a significantly increased incidence of pain. Subjects in this study with kyphosis and rounded shoulders had an increased incidence of interscapular pain, while those with forward head posture had an increased incidence of cervical, interscapular and headache pain.

Forward Head Rounded Shoulder Posture

The forward head and rounded shoulder (FHRSP) is one that is commonly seen in individuals who develop a pattern of uni-dimensional training [1], including overhead athletes such as swimmers, baseball pitchers, gymnast, tennis and volleyball players. Others at risk for this condition include weight lifters or heavy laborers, cellist, and hairdressers who all work in uni-dimensional movement patterns [16]. Clark [1] has given the name "Upper Crossed Syndrome" (UCS) to this postural dysfunction. In describing UCS, Clark defines Janda's two specific muscle groups for this particular dysfunction. Clark [1] lists these groups as follows:

Movement Group (shortened muscles)

Pectoralis major
Levator scapulae
Upper trapezius
Subscapularis
Pectoralis minor
Teres major
Anterior deltoid
Latissimus dorsi

Stabilization Group (lengthened muscles)

Rhomboids
Serratus anterior
Infraspinatus
Longus coli/capitus
Rectus capitus
Lower trapezius
Teres minor
Posterior deltoid
Sternocleidomastoid
Scalenes

The qualities of these specific groups are not based on experimentation, but on clinical presentation. It is assumed that the muscles of the movement are actually shortened as compared to an individual without FHRSP. It is also assumed that the muscles of the stabilization group are lengthened and weaker as compared to an individual without FHRSP.

Sahrmann [16] has also discussed specific movement impairment syndromes in the body. This condition of rounded shoulder posture is labeled scapular abduction syndrome. The pectoralis major and minor are again assumed to be shortened and overactive, while trapezius and rhomboid muscles are thought to be elongated and weak [16].

Anatomy and Biomechanics

The shoulder represents a complex dynamic relationship of many muscle forces, ligament constraints, and bony articulations [17]. Because of it's anatomical makeup, the shoulder complex sacrifices stability to allow for increased mobility [18]. This causes the shoulder to be highly susceptible to injury. The mobility of the shoulder is achieved by three joints, the sternoclavicular joint, the acromioclavicular joint, the glenohumeral joint; and one pseudo-joint the scapulothoraic articulation. These joints, along with dynamic and static stabilizers work together to give the shoulder joint the greatest range of motion of any joint in the body [19]. This mobility is important in performing acts of daily living, while a level of stability is needed to prevent injury.

Sternoclavicular Joint

The manubrium of the sternum articulates with the proximal clavicle to form the sternoclavicular joint. This saddle joint serves as the only direct connection between the upper extremity and the trunk [17]. This joint's stability is attributed to its strong ligaments that anchor the sternal end of the clavicle toward the sternum [18]. These ligaments include the anterior and posterior sternoclavicular, which both prevent upward displacement of the clavicle, interclavicular, which prevents lateral displacement of the clavicle, and costoclavicular, which prevents lateral and upward displacement of the clavicle [18]. A fibrocartilaginous disk located between the two articulating surfaces functions as a shock absorber and also helps prevent upward displacement [18].

Acromioclavicular Joint

The acromion process of the scapula and the distal end of the clavicle articulate to form the acromioclavicular joint. This gliding joint gains the majority of its stability from static stabilizers, including joint capsule, ligaments, and intra-articular disk [17]. The acromioclavicular ligaments consist of anterior, posterior, superior and inferior portions. In addition, the coracoclavicular ligament, divided into the conoid and trapezoid ligaments, joins the coranoid process of the scapula to the clavicle [18]. A fibrocartilaginous disk is also located between the articulating surfaces of the acromion and the clavicle, though it is functionally absent by the fourth decade [17].

Glenohumeral Joint

The round head of the humerus articulates with glenoid cavity to form the glenohumeral joint. This enarthrodial or “ball and socket” joint is considered to be the primary shoulder articulation [18]. Because this joint is designed anatomically for mobility, it sacrifices stability. The glenohumeral joint has severely mismatched articulating surfaces, with the articular surface of the glenoid cavity being only one third to one fourth the size of the humeral head [17]. Therefore, the joint relies heavily on static stabilizers as well as dynamic stabilizers for stability and for mobility [17].

Glenohumeral Joint Static Stabilizers

Static stabilizers about the glenohumeral joint include the glenoid labrum and the joint capsule. The glenoid labrum serves to deepen the relatively shallow glenoid cavity of the scapula [20]. This dense, fibrocartilaginous structure is triangular on cross-section, serving as a wedge to keep the humerus on the articulating surface of the glenoid fossa [17]. The labrum also serves as an attachment site for the capsuloligamentous structures of the glenoidlabrum [17].

The surface area of the joint capsule is approximately twice the size of the humeral head, allowing for maximum mobility and range of motion of the glenohumeral joint [17]. The inferior portion of the capsule is the only portion that is not reinforced by a rotator cuff muscle and is the weakest area of the capsule [20]. The ligaments of the glenohumeral joint are intrinsic, meaning they are a part of the joint capsule [20]. These different ligaments become taut when the shoulder reaches certain end ranges of motion to limit translation of the humeral head [17]. These ligaments consist of the coracohumeral ligament and the three glenohumeral ligaments. The coracohumeral ligament strengthens the capsule superiorly as it travels from the base of the lateral coracoid and inserts into the lesser and greater tuberosities [17].

The superior, middle and inferior glenohumeral ligaments make up the other thickenings of the joint capsule. The superior glenohumeral ligament extends from the anterosuperior edge of the glenoid to the top of the lesser tuberosity and is similar in function to the coracohumeral ligament [17]. The middle glenohumeral ligament originates from the supraglenoid tubercle, superior labrum, or scapular neck and inserts on the medial aspect of the lesser tuberosity. It is the most variable of the three glenohumeral ligaments, being absent in 8-30% of patients [17]. It functions to limit anterior translation of the humeral head and inferior translation in adducted position [17]. The inferior glenohumeral ligament is the thickest and most consistent of the three ligaments. This ligament has three portions, the anterior band, axillary pouch, and posterior band. The anterior band extends from the anteroinferior labrum and glenoid lip to the lesser tuberosity of the humerus and is the primary stabilizer against the throwing position of shoulder abduction and external rotation [17]. The entire complex is a barrier to anterior translation of the humeral head.

Glenohumeral Joint Dynamic Stabilizers

The muscles that cross the glenohumeral joint provide significant dynamic stability and compensate for a bony and ligamentous arrangement that allows for a great deal of mobility [18]. These muscles can be put into two groups: muscles that originate on the scapula and attach to the humerus and muscles that originate on the axial skeleton and attach to the humerus [18].

The first group of muscles includes the rotator cuff muscles as well as the deltoid, teres major and coracobrachialis muscles. The rotator cuff consists of the supraspinatus, infraspinatus, teres minor, and subscapularus. These muscles contract together to pull the humeral head into the glenoid fossa during arm movements, specifically humeral abduction.

The supraspinatus originates from the supraspinous fossa of the scapula and inserts on the superior facet of the greater tuberosity of the humerus. Its tendon blends in with the joint capsule and the infraspinatus tendon below [17]. This muscle, in addition to stabilizing the glenohumeral joint, acts along with the deltoid to elevate the arm, specifically the first fifteen degrees of shoulder abduction [2]. The supraspinatus is innervated by the suprascapular nerve.

The infraspinatus originates from the infraspinous fossa of the scapula and inserts on the middle facet of the greater tuerousity of the humerus. The teres minor originates from the mid to upper axillary border of the scapula and inserts on the inferior facet of the greater tuberosity of the humerus. These two muscles together, in addition to stabilizing the joint, act to externally rotate the humerus. The infraspinatous muscle is innervated by the suprascapular nerve, while the teres minor is innervated by the axillary nerve [17].

The subscapularus muscle is the last of the four rotator cuff muscles. It originates from the subscapular fossa of the scapula and inserts on the lesser tubercle of the humerus. This muscle, in addition to being a shoulder stabilizer, is primarily responsible for internal rotation of the humerus and is innervated by the upper and lower subacapular nerves [2].

In speaking of the rotator cuff muscles and their role in dynamic stability, the long head of the biceps must also be considered. Its tendous attachment to the glenoid rim causes it to have a role in stabilizing the humeral head, and it acts as both a humeral head depressor and as another dynamic stabilizer to prevent anterior translation of the humerus during movement [17].

The deltoid muscle contains three portions: the anterior, middle, and posterior sections. The anterior deltoid originates from the lateral clavicle, while the middle portion originates from the acromion and the posterior portion originates from the spinous process of the scapula [17]. All three portions converge to insert on the deltoid tuberousity of the humerus, while all being innervated by the axillary nerve. The anterior and middle portions function in shoulder elevation in the scapular plane and assist in forward elevation.

The teres major muscle originates at the inferior angle of the scapula and rotates 180^{o} toward its insertion on the medial lip of the bicipital groove of the humerus [17]. Its functions to adduct and internally rotate the shoulder, as well as assist in shoulder extension, and is innervated by the lower subscapular nerve [17].

The coracobrachialis originates from the coracoid process and inserts onto the anteriomedial humerus [17]. This muscle acts along with the short head of the biceps to flex and adduct the glenohumeral joint, and is innervated by the musculocutaneous nerve [17].

The next group of muscles originates on the axial skeleton and attaches to the humerus. These muscles include the latissimus dorsi, pectoralis major and pectoralis minor. The latissimus dorsi is a large triangular muscle arising from the spines of the lower 6 thoracic vertebrae and thoracolumbar fascia. It attaches to the humerus on the floor of the bicipital groove and functions along with the teres major to adduct, extend, and internally rotate the humerus. In fact, their two tendinous insertions blend with each other. The latissimus dorsi is innervated by the thoracodorsal nerve [17].

The pectoralis major originates from the medial clavicle, sternum, and fifth and sixth ribs. It attaches to the humerus on the lateral lip of the bicipital groove, and functions in adduction and internal rotation of the humerus, as well as horizontal adduction. The pectoralis major is innervated by the lateral and medial pectoral nerves [17].

The pectoralis minor originates on ribs three to five near their costal cartilages and attaches to the medial border and superior surface of the coracoid process of the scapula [20]. This muscle functions to stabilize the scapula by drawing it inferiorly and against the thoracic wall and is innervated by the medial pectoral nerve [20].

Scapulothoracic Articulation

Another group of muscles exists about the shoulder girdle. These muscles originate on the axial skeleton and serve to anchor the scapula to the thoracic wall. These muscles are the scapular stabilizer muscles and they make up the scapulothoracic articulation. This articulation is critical to shoulder movement, because the movement at this articulating surface allows for optimal glenohumeral movement and helps decrease risk of injury associated with altered kinematics at the glenohumeral joint. This articulation also provides a base of support, which needs to remain stable. All other movements of the upper limb to move from this base of support [18]. These muscles include the trapezius, rhomboids, serratus anterior, and levator scapulae.

The trapezius is divided into upper, middle and lower sections, which all have different functions [20]. The origin of the entire muscle extends from the base of the skull to the upper lumbar vertebrae and the insertion site includes the lateral aspect of the clavicle, acromion, and scapular spine [17]. The upper trapezius serves to elevate the scapula, while the middle fibers retract the scapula and the lower fibers depress the scapula and lower the shoulder [20].

The rhomboid muscles, major and minor, are not always clearly defined from one another. These muscles lie deep to the trapezius, originating from spinous processes of C7 to T5 and inserting on the medial aspect of the scapula [17]. These muscles serve to retract and elevate the scapula and are innervated by the dorsal scapular nerve [20].

The serratus anterior originates from the bodies of the first nine ribs and anteriolateral aspect of the thorax and inserts from superior to inferior angle of the scapula [17]. The serratus anterior causes scapular protraction and upward rotation, as well as holds the scapula against the thoracic wall [20]. An injury to its innervating nerve, the long thoracic nerve, would result clinically in the condition known as "winging scapula" [17].

The levator scapulae muscle originates from the transverse processes of the cervical spine and inserts on the superior angle of the scapula [17]. This muscle serves to elevate the superior angle of the scapula, causing downward rotation of the scapula [17]. It also assists in laterally flexing the neck [20], and is innervated by the third and fourth cervical spinal nerves [17].

Range of Motion About the Shoulder Joint

Range of motion about the shoulder joint has been linked for some time to shoulder dysfunction [6, 21]. Several studies have looked at how increased or decreased motion may affect shoulder pain in competitive swimmers. One such study found no significant correlation between shoulder range of motion and pain [6]. In this study, external and internal rotation range of motion was tested in the supine position using a universal goniometer [6]. However this study only looked at active range of motion of selected movements.

Another study found internal rotation range of motion was reduced in painful shoulders as compared to pain free swimmers [21]. This study did not find any differences in external rotation. This study, however, did not list how they went about testing range of motion.

Myers et al. [22] found that glenohumeral internal rotation deficit was increased in individuals with internal or posterior impingement when matched with healthy individuals. This study also found that posterior shoulder tightness was increased in those with internal impingement. This study observed these differences in throwers, who are also considered overhead athletes.

Flexibility Assessment

Flexibility assessment about the shoulder joint is seen in literature less often than range of motion, but may be equally important. Flexibility looks at the length of specific muscle tissue [2], while range of motion observes the amount of movement about a specific joint [18]. In speaking about flexibility of the shoulder girdle, the pectoralis major and minor are major muscles that are commonly observed. There have been several methods of measuring pectoralis major and minor length seen in literature. Active horizontal abduction and adduction have been measured, with the shoulder flexed to 90°, the forearm in the neutral position and the elbow extended [6]. This study looked at the relationship between shoulder flexibility and pain. Shoulder abduction was also assessed, with the scapula supported on the table, the elbow extended and the palm facing up [6].

Greipp [23] performed a study in which he was able to predict, with 93% accuracy, teamwide incidence of swimmer's shoulder for the winter season based on a correlation between lack of flexibility and pain. Here, shoulder horizontal abduction tests were performed using a flexibility test that was validated in a preliminary study [21]. The swimmer in this test lay supine on an inclined bench and allowed gravity to pull the straightened arms toward the floor as far as possible without any undue pain. The arms were maintained at perpendicular to the torso and when the swimmer reported that their arms could drop no farther, the distances between the two styloid processes of the wrist was measured. This measure was then used in a regression equation to predict the occurrences of shoulder pain in the future season.

Most recently, Borstad [24] examined the relationship between posture, pectoralis minor length and movement alterations. In this study, the subjects were divided into groups based on normalized resting pectoralis minor muscle length. Significant group differences were demonstrated for several postural variables, including thoracic spine kyphosis and scapular rotation between groups [24].

Strength

The effect of upper extremity posture on shoulder strength has also been examined. Kebaetse et al. [15] looked at thoracic position effect on shoulder range of motion, strength, and scapular kinematics. The results showed that isometric scapular plane abduction muscle force was decreased 16.2% in the slouched posture position as compared to an erect posture position.

Smith et al. [25] also looked at the effect of posture and scapular position on isometric shoulder strength. The effects of scapular protraction and retraction on isometric shoulder elevation strength were studied. The authors of this study found that scapular protraction or retraction resulted in a statistically significant reduction in isometric shoulder elevation strength.

Scovazzo [26] found that there was no significant differences between muscle activity patterns of normal versus painful shoulders in the latissimus dorsi, pectoralis major, teres minor, supraspinatus, or posterior deltoid muscles. This does not mean that there were no differences in muscle strength, because this study only looked at electrical activity of the selected muscles and not at the actual strength of the muscles.

DiVeta et al. [27] also found that there was very little correlation between scapular abduction in a standing patient and muscular force of the middle trapezius and pectoralis minor muscles. This study used manual muscle testing for middle trapezius as described by Daniels and Worthingham, and manual muscle testing for pectoralis minor as described by Kendall [27].

Dynamometer

The dynamometer is a device used to assess muscle strength. Hand held dynamometers are used because of their increased convince and decreased price as compared to a larger equipment such as isokinetic machines [28]. Hand held dynamometers are also shown to be just as accurate, and therefore a viable alternative to the more costly and less mobile isokinetic machines, provided the assessor's strength is greater than the muscle group being tested [28]

One study tested elbow flexor strength of 32 healthy female volunteers under 4 different conditions, and found the dynamometer to be as accurate as the Kin-Com© isokinetic machine [28]. Another study looked at knee extension and elbow flexion strength measures of sample of 20 adults without any mental retardation and 10 adults with mental retardation [29]. This study also found the dynamometer to be a reliable tool, though validity was not conclusively established.

Another issue with hand-held dynamometers is that many times clinics may have multiple devices. One study found that while the Nicholas Manual Muscle Tester was valid and highly reliable for testing between trials and days, it had poor interdevice reliability [30]

Inclinometer

The electronic inclinometer is a reliable tool used to assess joint range of motion. In measurements of passive hip rotation, the electronic inclinometer was shown to have less varialibility than using a two-armed goniometer [31]. In measurements of active hip rotation, the inclinometer has been shown to have less variability with prone external rotation and sitting internal rotation [31]. Another study found inclinometers to have good reliability when measuring affected glenohumeral joints for passive glenohumeral external rotation and for abduction of the humerus, having ICCs of .90 and .83 respectively [32].

Goniometer

The universal goniometer is a reliable tool used to assess joint range of motion. The intraclass correlation coefficients (ICCs) for intratester reliability of measurements obtained with a universal goniometer were .99 for passive knee flexion and .98 for passive knee extension [33]. The intertester reliability for these same movements were .90 and .86 respectively [33]. Another study using the universal goniometer to examine access active knee flexion and extension found intratester ICCs of .997 for flexion and between .972-.985 for extension [34]. This study also found intertester ICCs of between .977-.982 for flexion and between .893-.926 for extension [34].

Conclusion

Based on previous studies, it is assumed that there will be a change in flexibility, range of motion, and strength that is directly associated with posture. It is expected that people with FHRSP would have a decrease in flexibility, range of motion, and strength when compared to those with ideal posture.

Chapter 3

Methods

Subjects

Subjects were recruited from the general population from University of North Carolina at Chapel Hill and ranged in age between 20-61 years. This population included university students, faculty, and staff. Subjects were recruited through mass emails and flyers placed around campus. Subjects were scheduled to a mass screening to determine if they met inclusion criteria for head and shoulder angle before being scheduled for actual testing session. Subjects were assigned to one of two different groups, Forward Head Rounded Shoulder Posture (FHRSP) or ideal posture, based on an assessment of head and shoulder angle as evaluated using Adobe® Photoshop and a digital photograph taken at the mass screening. Subjects that presented with forward head and rounded shoulder posture were assigned to the FHRSP group, while those who presented with ideal head and shoulder posture were assigned to the ideal posture group. Those subjects that did not fall into either group were excluded from the study and not tested. Subjects were also excluded if they had any formal shoulder rehabilitation in the previous three months; or, if they had a history of shoulder surgery; or, if they were currently experiencing neck, upper back or shoulder pain. The two groups were matched by age and gender. There were 15 subjects in the ideal posture group (n=15), and 22 subjects in the FHRSP group (n=22). Using a Post-Hoc power analysis, the power ranged from .05 to .48. Before testing, subjects read and signed an informed consent form approved by the University of North Carolina Biomedical IRB explaining the study and procedures. Flexibility of the pectoralis muscle group and latissmus dorsi was then tested, followed by range of motion for internal and external rotation at the shoulder. Finally, strength of the posterior deltoid, lower trapezius, infraspinatus/teres minor, and serratus anterior was measured. Subjects were not paid for their participation.

Instrumentation/Equipment

The presence of forward head and forward shoulder posture was evaluated using the Adobe® Photoshop and digital picture. Digital photos, with lines superimposed from the seventh cervical vertebrae to the external auditory meatus, and from the seventh cervical vertebrae to the posterior acromion, were used to determine if subjects fell into the FHRSP or ideal posture group. Those subjects that did not fall into either group were excluded from the study. Subjects with a head angle (HA) $\geq 46^{o}$ and a shoulder angle (SA) $\geq 52^{o}$ were assigned to the FHRSP group. Subjects with a head angle (HA) $\leq 36\ ^{o}$ and a shoulder angle (SA) $\leq 22^{o}$ were assigned to the ideal posture group. These cutoff measures represent the values that would separate the groups by one standard deviation based on calculating the head and shoulder angles for all of the potential subjects screened.

Flexibility and range of motion were measured using a digital inclinometer (Saunders Digital Inclinometer, The Saunders Group Inc., Chaska, MN). The inclinometer measures joint angles in degrees (^{o}). The inclinometer was zeroed before each testing session.

Isometric muscle strength was tested using a hand-held dynamometer (CDS 300 strength dynamometer, Chatillion a registered trademark of Ametek, Largo, FL). The dynamometer quantified the isometric strength measures of the shoulder muscles measuring Newtons (N) of force. The dynamometer was calibrated before each testing session. Hand-held dynamometers have been shown to have good reliability when compared to isokinetic dynamometers such as the Kin-Com, the gold standard in measuring muscle strength [28-30]. Dynamometers have also been shown to have good reliability between trials and between days [34].

A universal goniometer was used to ensure correct body positioning during each muscle test. Body positioning was checked before each trial of each muscle strength test.

Procedures

Postural Alignment Assessment

Patients stood in front of a grid screen, with reflective markers placed on the right external auditory meatus, acromion, and seventh cervical (C7) vertebrae spinous process. Photos were taken in the sagital plane to determine the plumb line through the C7 spinous process. The photos were then used to calculate the head angle and the shoulder angle for the subjects. The head angle (HA) is the angle between a straight line from the external auditory meatus and C7, and the vertical plumb line. The shoulder angle (SA) is the angle between a straight line from the acromion and C7, and the vertical plumb line. Subjects were considered to have forward head and rounded shoulder posture (FHRSP) if the HA $\geq 46^{o}$ and the SA $\geq 52^{o}$ (Figure 2). Subjects were considered to have ideal head and shoulder posture if the HA $\leq 36^{o}$ and the SA $\leq 22^{o}$ (Figure 3).

Flexibility Assessment

Flexibility of the right pectoralis major and minor muscle group and the latissmus dorsi muscle were measured using a digital inclinometer (Saunders Digital Inclinometer, The Saunders Group Inc., Chaska, MN). The inclinometer was leveled on a stable surface as indicated by a bubble level before each testing session. Kendall [2] describes patient positioning for measuring flexibility of these muscles as follows. When measuring pectoralis major, the patient was supine with the arm in full horizontal abduction and lateral rotation (Figure 4). For the latissmus dorsi, the patient was supine with the arm in full forward flexion. The patient was positioned and then instructed to relax in this position. Once the subject was relaxed, the angle between their arm and the level horizontal axis was measured with the inclinometer (Figure 5). Three trials were performed for each muscle, and the average of the three trials was used for data analysis. Testing revealed excellent intratester reliability [ICC $_{(2,1)}$ = 0.99 (pectoralis group), 0.99 (latissmus dorsi)]

Range Of Motion Assessment

Range of motion (ROM) was also assessed on the right shoulder using the digital inclinometer. Kendall [2] describes the proper testing positions for internal and external rotation ROM of the shoulder joint as having the patient supine, with the back flat on a table, arms at 90^o of abduction, elbow flexed to 90^o (Figures 6 and 7) The subject was told to relax as the examiner positioned the arm for measure. Three trials of passive ROM for internal rotation were averaged and used for data analysis. The same was done for external rotation, as three trials of passive ROM were averaged. Testing revealed excellent intratester reliability [ICC $_{(2,1)}$ = 0.99 (Internal Rotation), 1.0 (External Rotation)]

Strength Assessment

Isometric strength was assessed on the right shoulder using a hand-held dynamometer (CDS 300 strength dynamometer, Chatillion a registered trademark of Ametek, Largo, FL). This instrument calculates isometric strength in Newtons (N) of force. Body positions described by Kendall [2] were used to test strength. For each test, subjects were instructed on the testing positioning and direction of force output, and performed one or two sub-maximal contractions to familiarize themselves with the test. At the start of each test they were instructed to "Push into my resistance as hard as you can." During the test, they received verbal cues of "push, push, push, push", and at the end of the test they were told to "relax." The order in which the muscles were tested was randomly selected by the subject by picking from numbered slips of paper from a cup, labeled from 1-4. The number 1 corresponded to serratus anterior, 2 with posterior deltoid, 3 with the infraspinatus / teres minor group, and 4 with the lower trapezius. For each trial, the mean output and peak output were both measured and recorded. For each muscle group, three trials were performed, and the average of the three trials was calculated for the mean output of the trial and the peak output of the trial. The averages of the three trials for each person were then standardized to BMI and used for data analysis.

<u>Serratus anterior</u>: The subject was positioned supine on a table. The subject's right arm was placed in 90^o of forward flexion. A handle attached to the dynamometer via a chain was placed in the subject's hand. The chain was positioned parallel to the subject's humerus, and then the subject was instructed to protract the scapula while the examiner held the

dynamometer stable at the side of the testing table (Figure 8). The examiner applied a downward force while the subject pushed up, causing protraction of the scapula. Testing revealed excellent intratester reliability [ICC $_{(2,1)}$ = 0.99 (mean), 0.99 (peak)]

Posterior deltoid: The subject was positioned prone on a table, with the right arm in 90° horizontal abduction and 35° lateral rotation, and the elbow flexed to 90°. The investigator placed hand-held dynometer against the posterolateral surface of the arm and applied pressure obliquely downward (between adduction and horizontal adduction) [2]. The subject was instructed to push up against the dynamometer (Figure 9). Testing revealed excellent intratester reliability [ICC $_{(2,1)}$ = 0.98 (mean), 0.98 (peak)]

Infraspinatus/Teres minor (External Rotators): The subject was positioned prone on a table, with the right arm at 90° horizontal abduction, and the elbow at 90° of flexion. The investigator placed the dynamometer against the posterior surface of forearm, appling pressure to medially rotate arm [2]. The subject was instructed to push against the dynamometer, attempting to rotate the arm externally (Figure 10). Testing revealed excellent intratester reliability [ICC $_{(2,1)}$ = 0.97 (mean), 0.97 (peak)]

Lower trapezius: The subject was positioned prone on a table, with the right shoulder at the edge of the table. The right arm was positioned at 90° of horiaontal abduction and 135° of abduction, with the thumb facing superior. The instructor placed the hand-held dynometer against lateral surface of forearm, applying pressure towards floor [2]. The patient was instructed to push against the dynamometer, in a direction of shoulder flexion and abduction

(Figure11). Testing revealed excellent intratester reliability [ICC $_{(2,1)}$ = 0.98 (mean), 0.98 (peak)]

Data analysis

Independent samples t-tests were used to evaluate the comparison of muscle strength, ranges of motion, and flexibility between groups. An alpha level of p=0.05 was set for all statistical tests. Means and standard deviations were calculated for the demographic data for the two groups, including age, height, and weight. SPSS statistical software (version 13.0, SPSS Inc, Chicago, IL) was used to analyze all data.

Chapter 4

Results

Descriptive Statistics

A total of 37 subjects were tested for this study. Twenty-two subjects were determined to have a head angle $\geq 46^o$ and a shoulder angle $\geq 52^o$ and were assigned to the FHRSP group (6 males, 16 females). Fifteen subjects were determined to have a head angle $\leq 36^o$ and a shoulder angle $\leq 22^o$ and were assigned to the ideal posture group (5 males, 10 females). Descriptive statistics for the two groups are presented in Table 1. Statistical analysis revealed that there was a significant difference between groups in body weight and BMI, with the FHRSP being significantly higher in both.

Flexibility

Pectoralis major/minor, Latissmus Dorsi

Means and standard deviations for flexibility of the pectoralis major and minor muscle group and the latissmus dorsi are listed in Table 2. Statistical analysis revealed no significant differences (p=0.34, p=0.35 respectively) for muscle flexibility between the FHRSP and ideal posture groups.

Range of Motion

Internal Rotation, External Rotation

Means and standard deviations for passive internal rotation (IR) and external rotation (ER) ranges of motion are listed in Table 3. Statistical analysis revealed no significant differences (p=0.71, p=0.78 respectively) for range of motion between FHRSP and ideal posture groups.

Strength

Serratus Anterior, Posterior Deltoid, Infraspinatus / Teres Minor, Lower Trapezius

Means and standard deviations as well as ICCs, effect sizes and power for isometric strength testing means for serratus anterior, posterior deltoid, external rotators of the shoulder (infraspinatus / teres minor), and lower trapezius muscles are listed in Table 4. Means and standard deviations as well as ICCs, effect sizes and power for isometric strength testing peaks for serratus anterior, posterior deltoid, external rotators of the shoulder (infraspinatus / teres minor), and lower trapezius muscles are listed in Table 5. Figures 12 and 13 show bar graphs plotting these differences, including means and standard deviations for external rotator strength and lower trapezius mean and peak strength, respectively. Statistical analysis revealed no significant differences in serratus anterior mean or peak strengths, nor posterior deltoid mean or peak strengths (p=0.824, p=0.879, p=0.486, p=0.493 respectively). The ideal posture group tended to have increased strength of the mean and peak strengths of the external rotators and the lower trapezius, although statistical analysis revealed no significant differences (p=0.90, p=0.75, p=0.11, p=0.79 respectively).

Chapter 5

Discussion

The purpose of this study was to test the clinical assumptions of forward head rounded shoulder posture (FHRSP). Our results indicate that those individuals presenting with FHRSP do not necessarily have a decreased flexibility of the pectoralis major, minor, and latissmus dorsi, an increased internal rotation and decreased external rotation, and a decreased strength of serratus anterior, posterior deltoid, external rotators, or lower trapezius.

Strength

One of the clinical assumptions associated with FHRSP is that select muscles are prone to weakness because of their increased passive length [1, 14, 15, 35]. These muscles included but are not limited to the serratus anterior, posterior deltoid, infraspinatus/teres minor complex, and lower trapezius. It is thought that because of altered length tension relationship, these lengthened muscles would be at a mechanical disadvantage and therefore weaker. Our study found that there were differences in the mean and peak values for the infraspinatus/teres minor complex as well as for lower trapezius that were approaching significance (p=0.90, p=0.75, p=0.11, p=0.79 respectively). However, no differences were seen in mean or peak strengths for serratus anterior or posterior deltoid. This is contrary to what was expected given results in previous studies. One study showed that there was decreased activity in the serratus anterior on a shoulder flexion task and a reaching task in people with FHRSP when compared to people with ideal posture [36]. Another study found a decreased strength on upon isometric muscle testing of serratus anterior, external rotators, and lower trapezius in swimmers when compared to non-swimmers [37]. These swimmers were also shown to have FHRSP. Kebaetse et al. [15] looked at thoracic position effect on shoulder strength. The results showed that isometric scapular plane abduction muscle force was decreased 16.2% in the slouched posture position as compared to an erect posture position. Smith et al. [25] also looked at the effect of posture and scapular position on isometric shoulder strength. The effects of scapular protraction and retraction on isometric shoulder elevation strength were studied. The authors of this study found that scapular protraction or retraction resulted in a statistically significant reduction in isometric shoulder elevation strength.

Other studies, however, have looked at strength and seen no differences. Diveta et al [27] examined relaxed standing scapular positioning in healthy individuals. In this study, the results indicated that there was no relationship between scapular positioning and strength of middle trapezius and pectoralis minor muscle strength. The results of our study help strengthen this indication, as we found that there were no significant differences in strength between individuals with and without FHRSP.

Flexibility and Range of Motion

It has been assumed that forward head rounded shoulder posture (FHRSP) causes a decrease in flexibility of the pectoralis major/minor complex, as well as the latissmus dorsi muscles [1, 10]. Flexibility assessment about the shoulder joint is seen in literature less often than range of motion, but may be equally important. Flexibility looks at the length of specific muscle tissue [2], while range of motion observes the amount of movement about a specific joint.

Greipp [23] performed a study in which he was able to predict, with 93% accuracy, teamwide incidence of swimmer's shoulder for the winter season based on a correlation between lack of flexibility and pain. Here, shoulder horizontal abduction tests were performed using a flexibility test that was validated in a preliminary study [21]. This test involved the individual supine with arm in horizontal abduction.

Our findings, however, do not support this clinical assumption. Although FHRSP does have the clinical appearance of the pectoralis complex and latissmus dorsi muscles being in a shortened resting position, this did not seem to directly indicate any decrease in muscle length on passive muscle testing in our study. This is contrary to previous findings, where forward flexion was significantly increased in swimmers as compared to non-swimmers [37]. In this study, swimmers were shown to have on increased incidence of FHRSP. However, this difference could be attributed to the fact that Division I collegiate swimmers are overhead athletes. This distinction includes the fact that they train and use their shoulder in positions of extreme flexion and abduction to a greater extent and with greater frequency then normal individuals [11].

Borstad [24] examined the relationship between posture, pectoralis minor length and movement alterations. Significant differences were demonstrated for several postural variables, including thoracic spine kyphosis and scapular rotation between individuals with short pectoralis minor muscles as compared to those with long pectoralis minor muscles [24]. Further research is needed to determine if differences are present during an active test in the general population.

Previous studies have examined how alterations in head and shoulder posture can lead to increased incidence of shoulder injury [10, 38]. Such injuries, including subacromial impingement are associated with a decreased range of motion of the affected arm. Studies have also looked at how range of motion at the shoulder joint is linked to shoulder dysfunction [6, 21].Other scholars have hypothesized that forward shoulder posture would be associated with a decrease in external rotation due to tightness of pectoralis major and minor, as well as latissmus dorsi muscles [1, 3]. Clinically, we would also expect internal rotation to be increased because of the increased internal rotation at rest in individuals with rounded shoulder posture. Our findings however do not support these assumptions. There were no significant differences in passive range of motion between the FHRSP group and the ideal posture group. Other studies have found similar findings. One study found no significant correlation between shoulder range of motion and pain in competitive swimmers [6].

These findings are contrary to other the findings of other studies. Myers et al. [22] found glenohumeral internal rotation deficit (GIRD) to be increased in individuals with internal impingement. Posterior shoulder tightness was also increased in those individuals with internal impingement. This study looked at throwers with impingement and compared them to asymptomatic throwers. Lewis et al. [38] found that changing posture improved shoulder active range of motion. In this study, shoulder flexion and abduction in the scapular plane were both increased with the application of posture changing tape applied to the back [38].

Several studies have looked at the relationship between posture and different dysfunctions in the body. Braun contrasted the postural differences between asymptomatic men and women and craniofacial pain patients [9]. It was suggested that asymptomatic men and women did not differ in the three head and shoulder postural characteristics used. However, symptomatic women did display those postural characteristics to a greater extent than asymptomatic women.

Greenfield and colleagues [4] looked at the relationship between posture in patients with shoulder overuse injuries compared to healthy individuals. Again the author had were significant findings, as forward heat position and humeral elevation were significantly greater in the patient group than the healthy group. Humeral elevation was also greater for involved shoulders in the patient group as compared to uninvolved shoulders.

Griegel-Morris et al. [12] looked at the relationship between postural abnormalities in the cervical, shoulder, and thoracic regions and pain in two groups of healthy subjects. This study showed that subjects with more severe postural abnormalities had a significantly increased incidence of pain. Subjects in this study with kyphosis and rounded shoulders had an increased incidence of interscapular pain, while those with forward head posture had an increased incidence of cervical, interscapular and headache pain.

Our study did present some interesting observations. The mean for weight of the FHRSP group was almost 20 kg higher than the mean for the ideal group (Table 1). This brings forth the question of if there is some correlation between body weight and posture for healthy sedentary individuals with and without FHRSP. Further research is needed to study if there in fact is a relationship.

Limitations

There are several limitations to this study. There has not been any validity tests performed on the clinical tests used in this study to date. Because of this fact, we are unable to say with certainty that the muscle groups that were targeted for each test were actually the muscle groups that were being measures. This means that those individuals who may actually have differences were able to compensate during tests, specifically the strength tests, with other muscles. This is may also be true during functional movements in individuals with altered posture. Further research is needed to validate the clinical test used to assess muscle strength and flexibility at the shoulder girdle.

Also, we studied healthy individuals. One of the exclusion criteria was the current presence of neck, upper back or shoulder pain. This means that even the individuals with poor posture were pain free. This is important because there may actually be differences in those individuals with pain in the measures that were used in this study. Further research should be done to compare measures of painful people with FHRSP to those without pain.

In this study we also looked at measures surrounding the glenohumeral joint. Although we found no differences at this joint, there may be differences at the scapulothoracic articulation in these same individuals. Continued research of this area should look at the relationship between how scapulothoracic movement problems can correlate to glenohumeral movement pattern changes.

Conclusions

This study was the first to test the clinical assumptions of forward head rounded shoulder posture (FHRSP) , specifically the differences in shoulder girdle flexibility, range of motion, and strength as compared to those with ideal posture. There were no significant differences in any of the variables measured. This is not to say that these differences are not present. As seen in previous studies, there is data that suggest these clinical assumptions are true. However, using the clinical test chosen for this study, the differences that were expected were not found. Although this is only one study, this introduces the idea that there may be different clinical tests that are more useful in diagnosing these variables, specifically muscle flexibility and strength. Future studies should compare the specificity of different clinical tests for measuring flexibility and strength of muscles in the shoulder girdle to determine if there are more accurate ways of measuring these variables that are still clinically feasible.

Given the results of our study, it may be inferred that people with poor posture may not be as different as previously thought from people with good posture in measures of flexibility, range of motion and strength of selected muscles. This will help treat people with poor posture and give clinicians the tools to target the problems that actually exist, rather than those that we now only think are present.

APPENDICES

APPENDIX A

Tables

Table 1. Means and standard deviations for subject characteristics (age, height, weight); mean (SD)

Variables	**FHRSP group**	**Ideal group**	**P-value**
N	22	15	
Age	36.50 (12.98)	32.71 (13.62)	0.408
Height (cm)	160.76 (33.76)	171.59 (11.15)	0.240
Weight (kg)	85.21 (19.89)	65.45 (12.74)	0.002*

* - denotes significant difference

Table 2. Means and standard deviations for pectoralis major/minor (pec) and latissmus dorsi (lat) flexibility in degrees (^{o}); mean (SD)

Flexibility variables	**FHRSP group**	**Ideal group**	**P-value**	**ICC$_{(2,1)}$ (SEM)**	**Effect size, power**
N	22	15			
Pec	41 (8.16)	44 (10.24)	0.340	0.99 (1.06)	0.29, .19
Lat	154 (12.61)	158 (13.32)	0.350	0.99 (1.27)	0.30, .20

Table 3. Means and standard deviations for internal rotation (IR) and external rotation (ER) in degrees(^{o}); mean (SD)

ROM variables	FHRSP group	Ideal group	P-value	ICC$_{(2,1)}$ (SEM)	Effect size, power
N	22	15			
IR	56 (8.47)	57 (9.43)	0.710	0.99 (1.01)	0.12, .09
ER	94 (15.76)	93 (16.22)	0.782	1.0 (0.83)	0.09, .08

Table 4. Means and standard deviations of average strength values (N) normalized to BMI; mean (SD)

Strength (mean)	FHRSP group	Ideal group	P-value	ICC$_{(2,1)}$ (SEM)	Effect size, power
N	22	15			
Serratus Anterior	8.11 (5.40)	8.09 (3.60)	0.988	0.99 (13.78)	<0.01, <.05
Posterior Deltoid	4.38 (1.91)	4.96 (1.42)	0.326	0.98 (6.83)	0.30, .20
External Rotators	4.06 (1.46)	4.88 (1.19)	0.078*	0.97 (7.39)	0.56, .44
Lower Trapezius	7.08 (2.79)	8.95 (3.23)	0.069*	0.98 (11.61)	0.58, .46

* - denotes approaching significance

Table 5. Means and standard deviations of peak strength values (N) normalized to BMI; mean (SD)

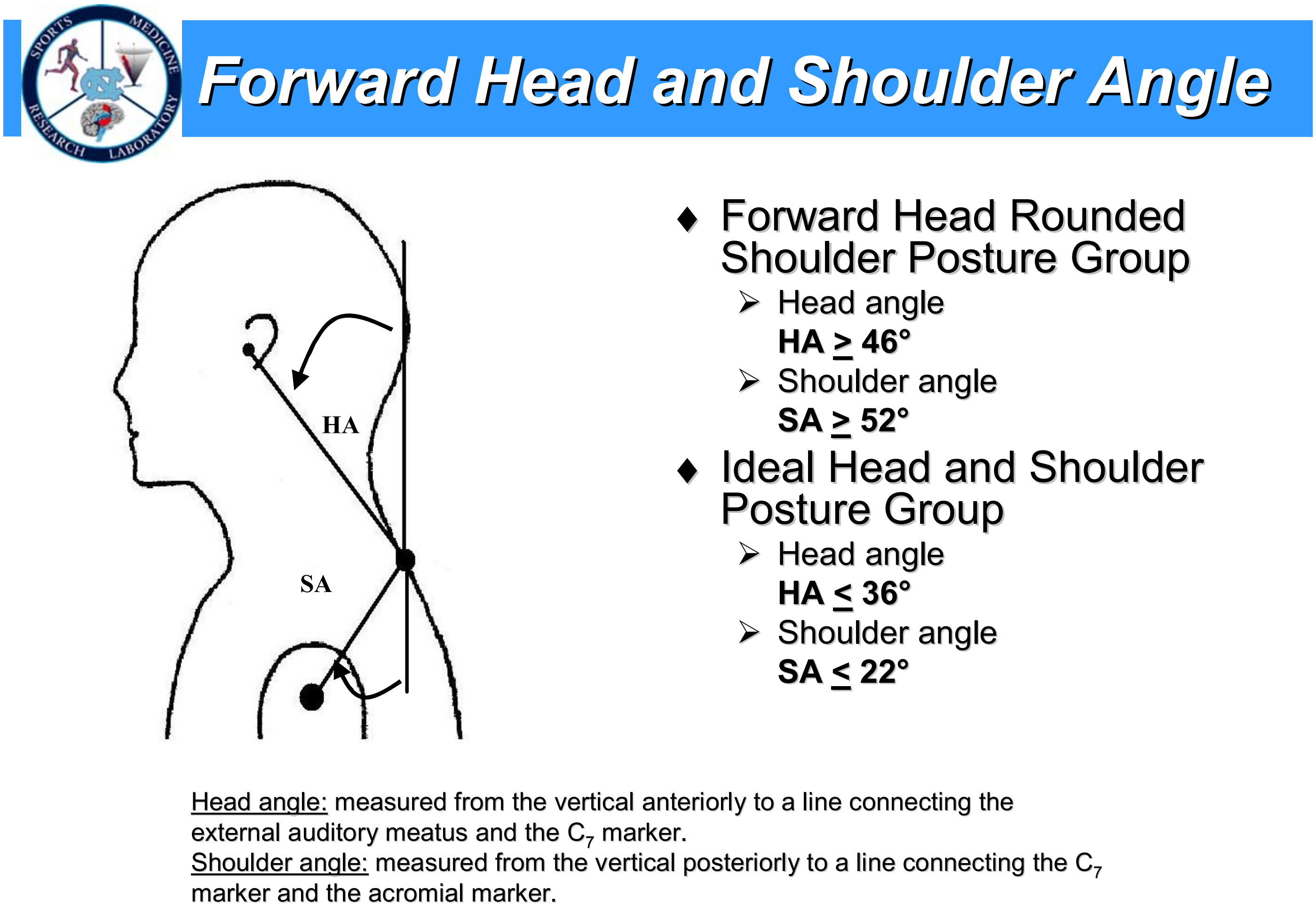
Strength (peak)	FHRSP group	Ideal group	P-value	$ICC_{(2,1)}$ (SEM)	Effect size, power
N	22	15			
Serratus Anterior	8.83 (6.03)	8.92 (4.32)	0.960	0.99 (15.68)	0.01, < .05
Posterior Deltoid	4.66 (2.03)	5.28 (1.60)	0.328	0.98 (7.22)	0.31, .21
External Rotators	4.31 (1.61)	5.28 (1.41)	0.067*	0.97 (8.37)	0.60, .48
Lower Trapezius	7.45 (2.99)	9.62 (3.62)	0.054*	0.98 (11.03)	0.60, .48

* - denotes approaching significance

APPENDIX B

Figures

Figure 1: Head angle and Shoulder angle measures

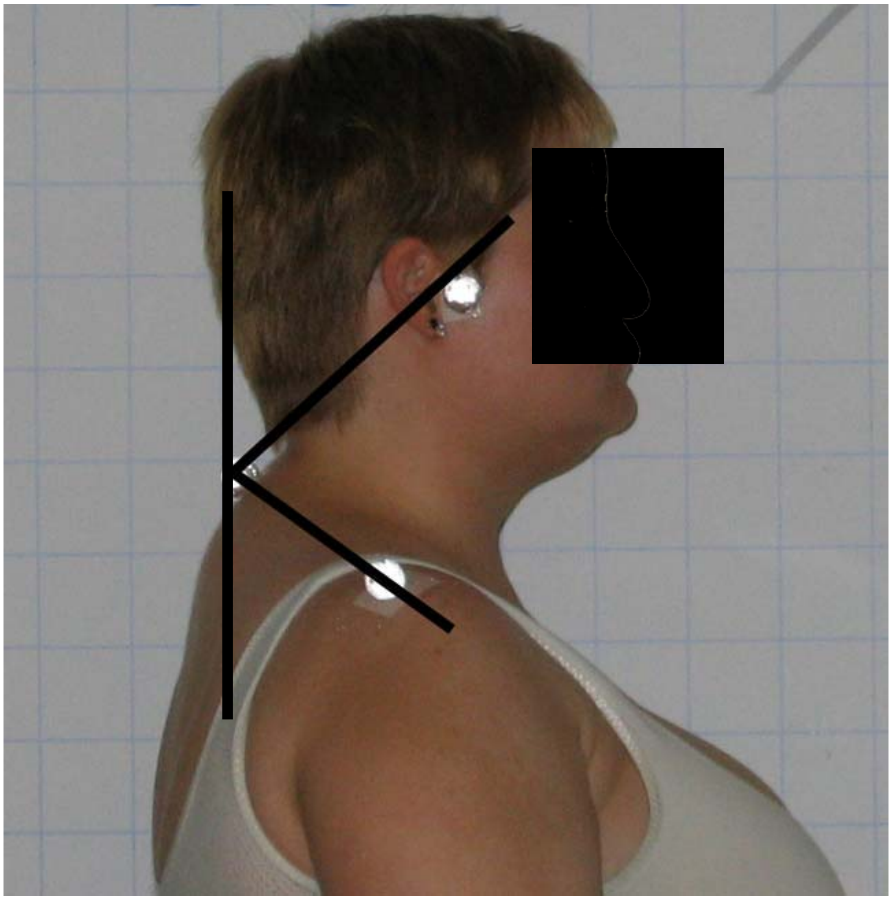


Forward Head and Shoulder Angle

- Forward Head Rounded Shoulder Posture Group
  - Head angle
    HA ≥ 46°
  - Shoulder angle
    SA ≥ 52°
- Ideal Head and Shoulder Posture Group
  - Head angle
    HA ≤ 36°
  - Shoulder angle
    SA ≤ 22°

Head angle: measured from the vertical anteriorly to a line connecting the external auditory meatus and the C_7 marker.
Shoulder angle: measured from the vertical posteriorly to a line connecting the C_7 marker and the acromial marker.

Figure 2: FHRSP individual



[redacted]

Figure 3: Ideal posture individual

[redacted]

Figure 4: Pectoralis major/minor flexibility

Figure 5: Latissimus dorsi flexibility

Figure 6: Internal Rotation Range of Motion

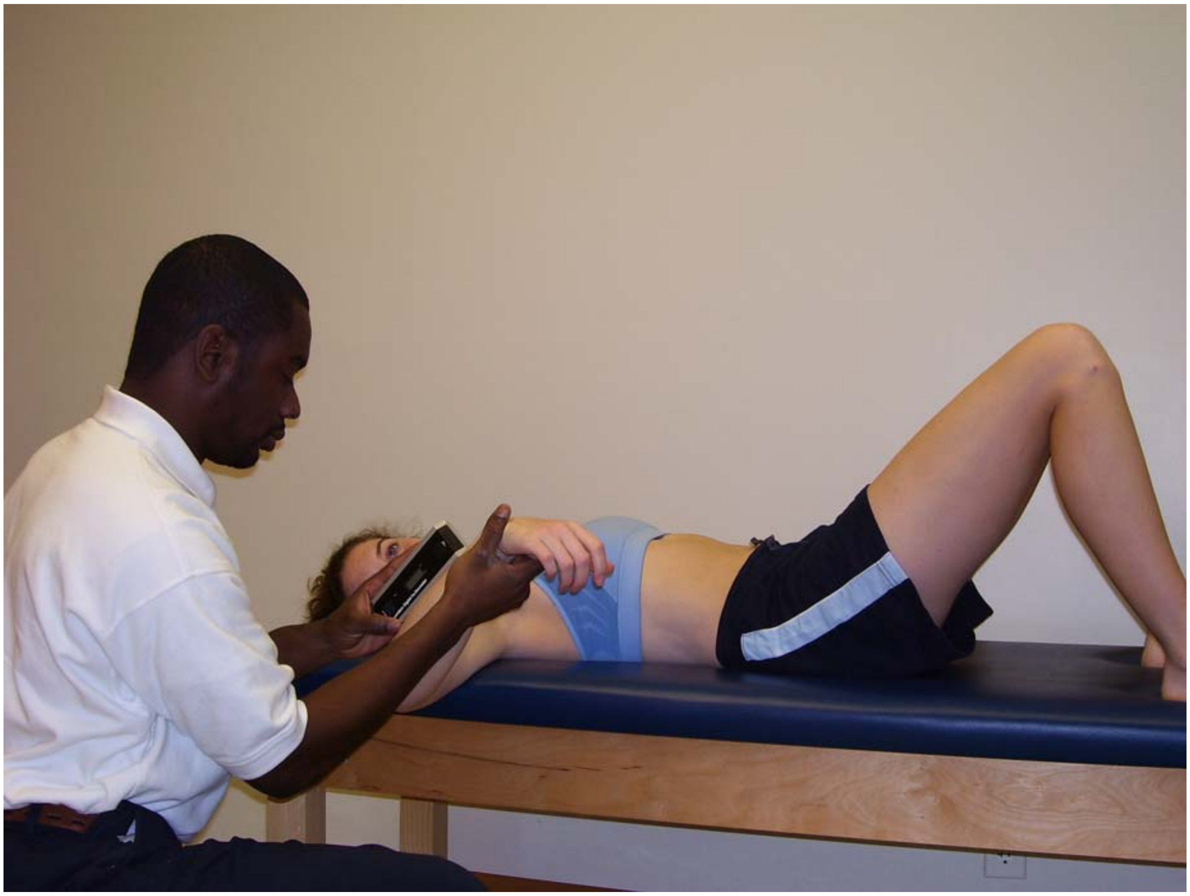


Figure 7: External Rotation Range of Motion

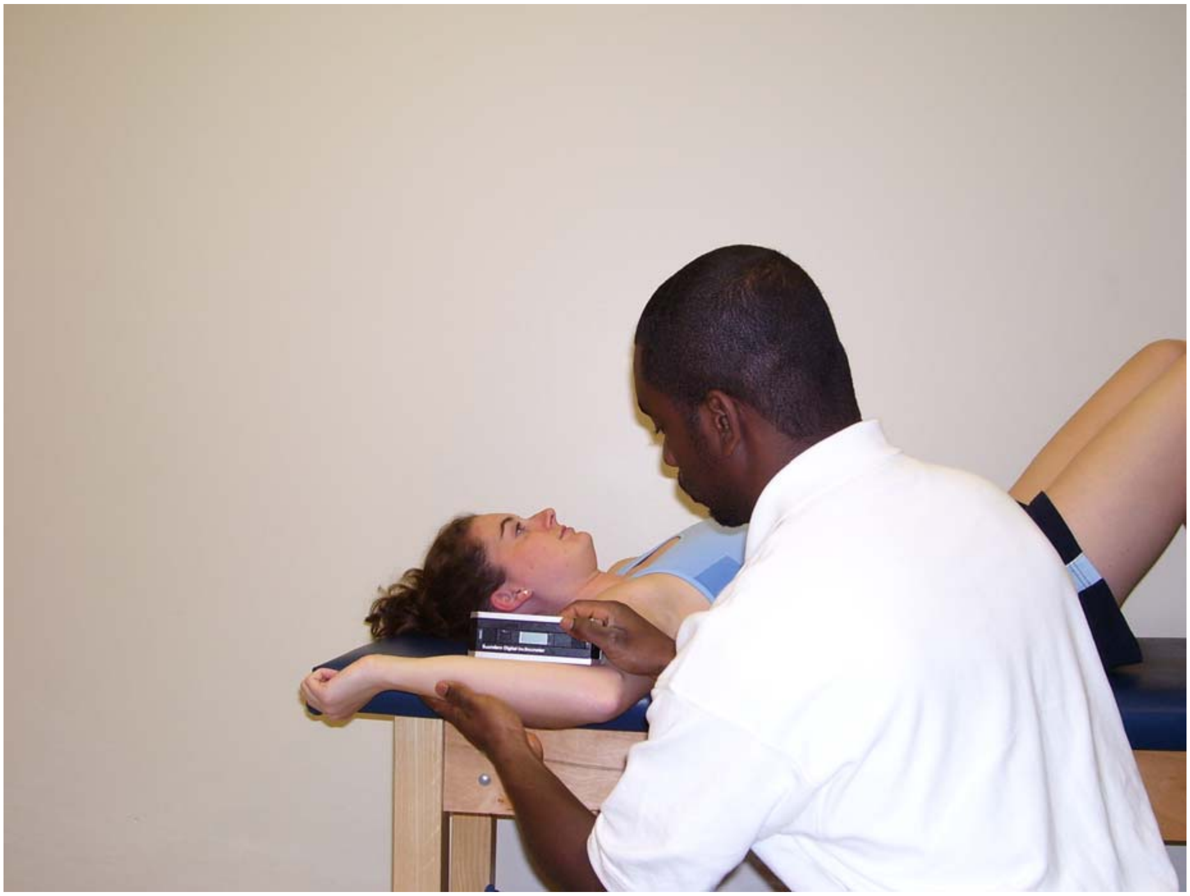


Figure 8: Serratus Anterior Strength

Figure 9: Posterior Deltoid Strength

Figure 10: External Rotators (infraspinatus, teres minor) Strength

Figure 11: Lower Trapezius Strength

Figure 12: External Rotator Strength graph

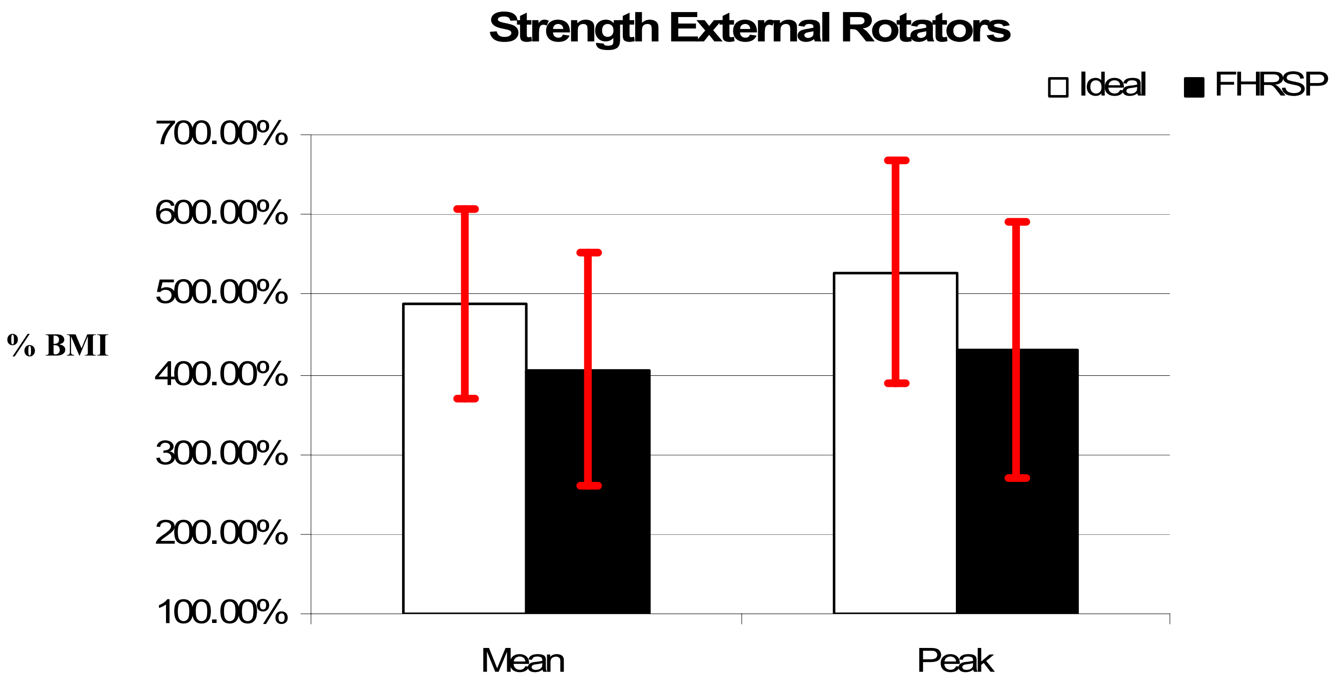
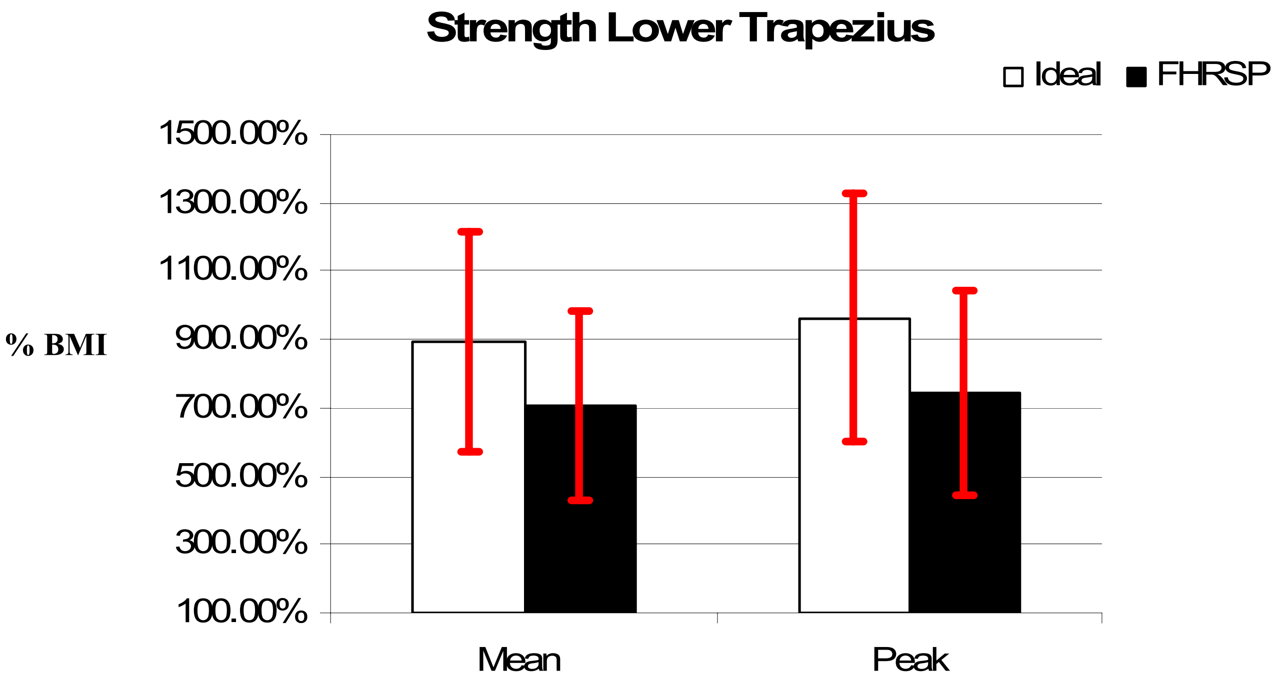
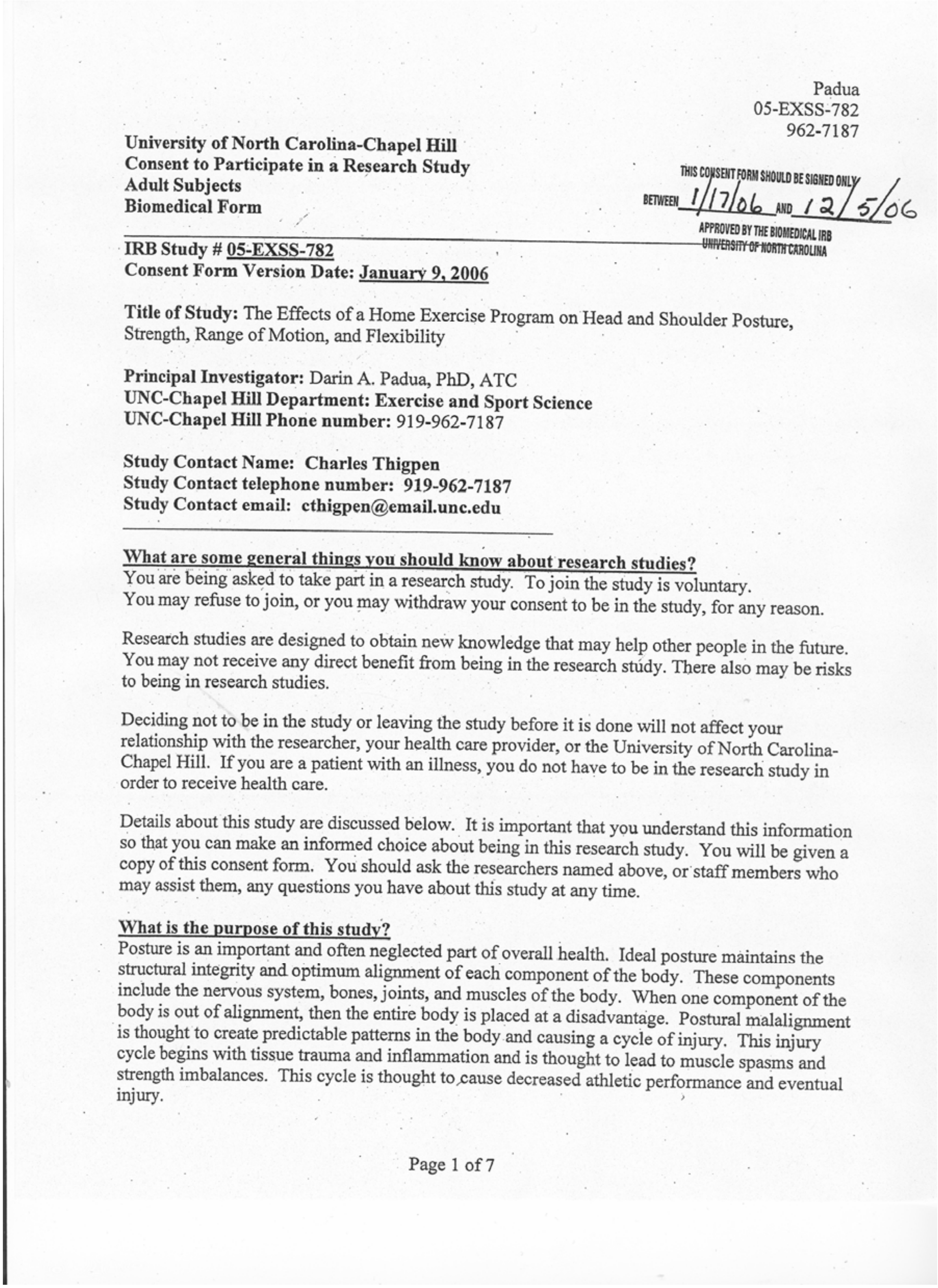


Figure 13: Lower Trapezius strength graph



APPENDIX C

Informed Consent Form



University of North Carolina-Chapel Hill
Consent to Participate in a Research Study
Adult Subjects
Biomedical Form

THIS CONSENT FORM SHOULD BE SIGNED ONLY
BETWEEN 1/17/06 AND 12/5/06
APPROVED BY THE BIOMEDICAL IRB
UNIVERSITY OF NORTH CAROLINA

IRB Study # **05-EXSS-782**
Consent Form Version Date: **January 9, 2006**

Title of Study: The Effects of a Home Exercise Program on Head and Shoulder Posture, Strength, Range of Motion, and Flexibility

Principal Investigator: Darin A. Padua, PhD, ATC
UNC-Chapel Hill Department: Exercise and Sport Science
UNC-Chapel Hill Phone number: 919-962-7187

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Study Contact telephone number: 919-962-7187
Study Contact email: cthigpen@email.unc.edu

What are some general things you should know about research studies?

You are being asked to take part in a research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

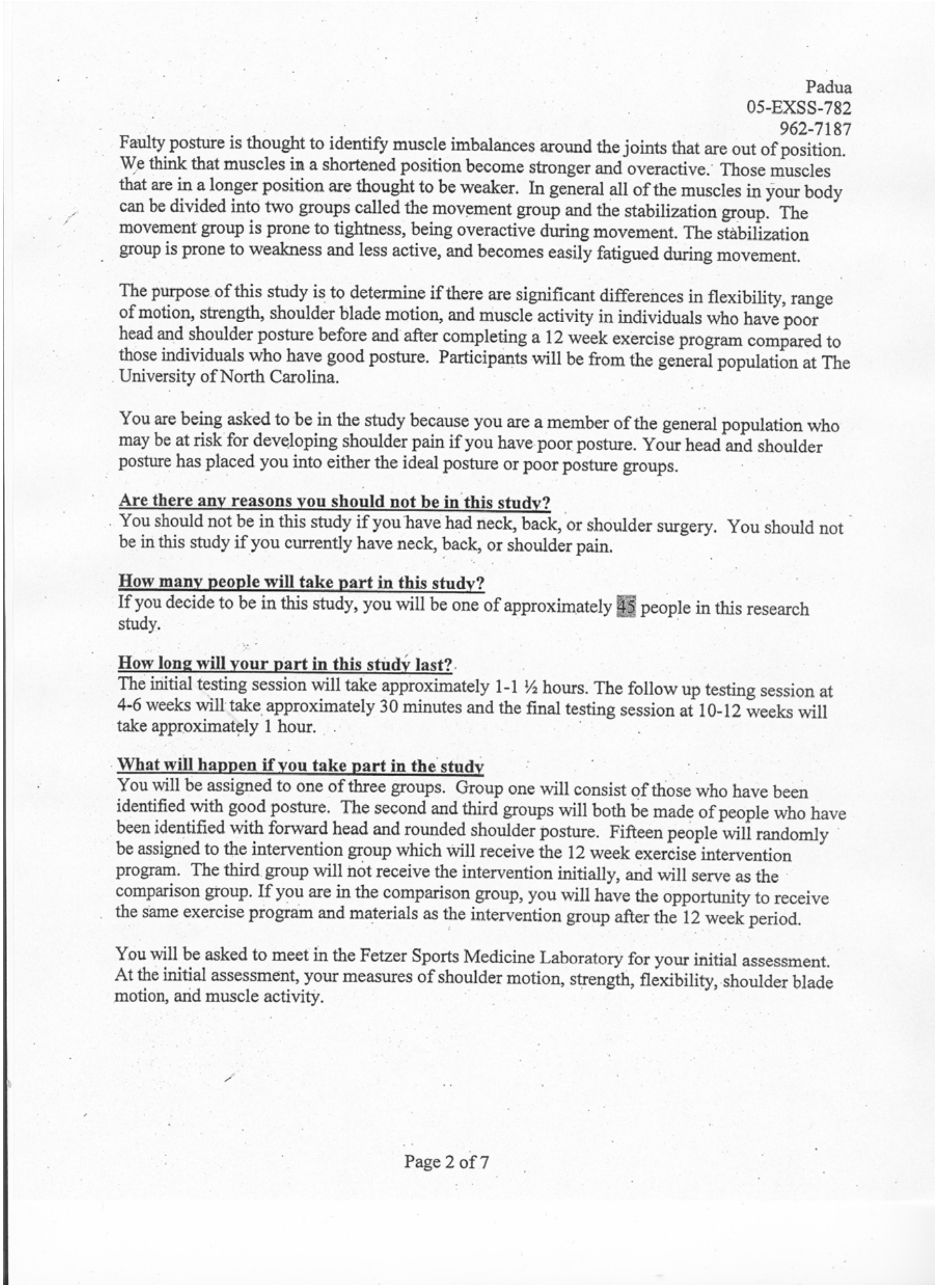
Research studies are designed to obtain new knowledge that may help other people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Deciding not to be in the study or leaving the study before it is done will not affect your relationship with the researcher, your health care provider, or the University of North Carolina-Chapel Hill. If you are a patient with an illness, you do not have to be in the research study in order to receive health care.

Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this research study. You will be given a copy of this consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?

Posture is an important and often neglected part of overall health. Ideal posture maintains the structural integrity and optimum alignment of each component of the body. These components include the nervous system, bones, joints, and muscles of the body. When one component of the body is out of alignment, then the entire body is placed at a disadvantage. Postural malalignment is thought to create predictable patterns in the body and causing a cycle of injury. This injury cycle begins with tissue trauma and inflammation and is thought to lead to muscle spasms and strength imbalances. This cycle is thought to cause decreased athletic performance and eventual injury.



Faulty posture is thought to identify muscle imbalances around the joints that are out of position. We think that muscles in a shortened position become stronger and overactive. Those muscles that are in a longer position are thought to be weaker. In general all of the muscles in your body can be divided into two groups called the movement group and the stabilization group. The movement group is prone to tightness, being overactive during movement. The stabilization group is prone to weakness and less active, and becomes easily fatigued during movement.

The purpose of this study is to determine if there are significant differences in flexibility, range of motion, strength, shoulder blade motion, and muscle activity in individuals who have poor head and shoulder posture before and after completing a 12 week exercise program compared to those individuals who have good posture. Participants will be from the general population at The University of North Carolina.

You are being asked to be in the study because you are a member of the general population who may be at risk for developing shoulder pain if you have poor posture. Your head and shoulder posture has placed you into either the ideal posture or poor posture groups.

Are there any reasons you should not be in this study?

You should not be in this study if you have had neck, back, or shoulder surgery. You should not be in this study if you currently have neck, back, or shoulder pain.

How many people will take part in this study?

If you decide to be in this study, you will be one of approximately 45 people in this research study.

How long will your part in this study last?

The initial testing session will take approximately 1-1 ½ hours. The follow up testing session at 4-6 weeks will take approximately 30 minutes and the final testing session at 10-12 weeks will take approximately 1 hour.

What will happen if you take part in the study

You will be assigned to one of three groups. Group one will consist of those who have been identified with good posture. The second and third groups will both be made of people who have been identified with forward head and rounded shoulder posture. Fifteen people will randomly be assigned to the intervention group which will receive the 12 week exercise intervention program. The third group will not receive the intervention initially, and will serve as the comparison group. If you are in the comparison group, you will have the opportunity to receive the same exercise program and materials as the intervention group after the 12 week period.

You will be asked to meet in the Fetzer Sports Medicine Laboratory for your initial assessment. At the initial assessment, your measures of shoulder motion, strength, flexibility, shoulder blade motion, and muscle activity.

If you have been assigned to the intervention group you will be given instruction and demonstration on the exercises at this time. You will be given a foam roller and elastic band needed to perform the exercises. These are yours to keep. You will also receive handouts detailing each exercise as well as a CD with videos of all of your exercises. Over the next 10-12 weeks you will be asked to keep a daily log of the exercises you have performed.

After 4-6 weeks from the initial assessment, if you are in the comparison or intervention groups, you will be asked to return for reassessment of shoulder motion, strength, and flexibility. At this time, your exercise technique will be reviewed and the difficulty of the exercises will be increased. You will receive a new CD and handouts at this time.

You will be asked to return between 10-12 weeks for the final assessment of your shoulder motion, strength, flexibility, shoulder blade motion, and muscle activity.

Postural Analysis
You will be asked to wear shorts and a either a sports bra if you are female or no shirt if you are male. Three reflective markers the size of a nickel will be placed on your right shoulder, neck, and ear. You will stand with your right side towards the camera and three pictures will be taken.

Shoulder Blade Motions and Muscle Activity
You will have motion-tracking sensors placed over your neck, shoulder blade, and arm that are designed to measure the movement patterns of the shoulder. You will have electrodes placed over your upper trapezius (junction between shoulder and neck), lower trapezius (inside, lower tip of your shoulder blade), and serratus anterior (underneath your armpit). You will be asked to perform a series of arm motions while standing in place. The arm motions will be directed at a target and will consist of lifting your arm up straight in front of you, and reaching to a shelf just above head height in front of you while lifting a weight equal to 3% of your body weight. Before you perform the motions, a practice session will consist of performing the motion 5 times to learn the motion and allow you to get comfortable with the testing procedures. You will perform the each motion one time for 25 repetitions.

Flexibility assessment
Flexibility of the right chest muscle and one of the posterior shoulder muscles will be measured using an inclinometer, a device that measures angles. When measuring chest flexibility, you will lay on your back with your arm relaxed straight out to your side. For measuring flexibility of the posterior shoulder muscle, your body will be in the same position except this time with your arm above your head as far as you can. You will be positioned and then instructed to relax in position. Once you are relaxed, the angle between your trunk and arm will be measured using the inclinometer. Three trials will be performed for each muscle, and the average of the three trials will be used for calculation.

Range Of Motion Assessment
Internal and external rotation range of motion of your right shoulder will be assessed using the inclinometer. Internal rotation is when you rotate your arm toward your body, and external rotation is when you rotate your arm away from your body. For these test, you will be laying flat on your back with your arm at your straight out to the side and your elbow bent to 90° of flexion.

You will be told to relax as the examiner positions the arm for measure. Three trials of passive range of motion for each movement (internal and external rotation) will be averaged.

Strength assessment
The strength of 4 muscles in your right shoulder will be assessed using a hand-held dynamometer. For each test, you will perform two easy contractions and one contraction as hard as you can to familiarize yourself with the test. Before each test they will be instructed to "Push into my resistance as hard as you can." During the test, they will receive verbal cues of "push, push, push, push". You will do 3 trials of each test and they will be averaged for calculation.

Muscle #1: This will be a test of the muscle that holds your shoulder blade onto your trunk. For this test, you will be lying on your back on a table. Your right arm will be held straight up in the air. A handle attached to the dynamometer via a chain will be placed in your hand. The chain will positioned parallel to your arm, and then you will be instructed to push straight up with your hand while the examiner holds the dynamometer stable at the side of the testing table. A strap will be placed around your hips, providing additional stability and preventing your trunk from rotation.

Muscle #2: This will be a test of the muscle that helps raise your arm to the side and to the rear. For this test you will be lying on your stomach on a table, with your right arm out to the side and slightly rotated up. Your elbow will also be bent to 90° of flexion. The examiner will place the hand-held dynamometer against the back surface of your arm and apply pressure downward. You will be instructed to push up against the dynamometer.

Muscle #3: This will be a test of the muscles that rotate your arm away from your body. For this test you will be lying on your stomach on a table with your right arm out to the side. Your elbow will be bent to 90° of flexion. The investigator will place dynamometer against rear surface of your forearm. You will then be instructed to push against the dynamometer as hard as you can.

Muscle #4: This will be a test of the muscle that causes your shoulder blade to move down and toward the spine. For this test you will be lying on your stomach with your right arm positioned up and out to the right of your head, with your thumb facing up. The instructor will place hand-held dynamometer against side of your forearm and apply pressure towards floor. You will be instructed to push against the dynamometer.

Interventions
After the initial testing, those subjects who have been identified to have poor posture will be divided into two groups of fifteen. One group will serve as the intervention group who will perform a 12 week home exercise program and the other group will serve as the comparison group. If you are assigned to the intervention group, you will be asked to perform a series of three massage techniques three times a week which will take approximately 10 minutes to perform, as well as a series of three stretches and two strengthening exercises five times a week that will take approximately 20-30 minutes to perform. These exercises include: 1) massage techniques to release your posterior shoulder, chest, and upper back, 2) chest stretches, 3) neck stretches, 4) posterior shoulder stretches, and 5) two strengthening exercises for the muscles that hold your shoulder blades back.

What are the possible benefits from being in this study?

There may be a benefit for all groups that participate in this study. The benefits to subjects for participating in this study may be receiving an objective evaluation of your posture and an instrumented evaluation of your shoulder motion and muscle activity from a licensed physical therapist. Benefits for those who perform the intervention exercises could include, improved postural strength and flexibility and a possible decrease in pain for those who may have reported pain before beginning this study. The two non-intervention groups will be receive instruction and demonstrations about the intervention exercises after the study is completed to potentially receive the benefits mentioned above. Faulty posture is an important risk factor in the development of shoulder pain. Understanding the qualities of bad posture and how to correct them may help decrease shoulder pain in society.

What are the possible risks or discomforts involved with being in this study?

This study involves arm motion and might involve the following risks and/or discomforts to you:

- Possibility of muscle strains/pulls/soreness in your upper extremity
- Possibility of skin irritation due to electrode preparation
- In addition, there may be uncommon or previously unknown risks that might occur. You should report any problems to the researchers.

What if we learn about new findings or information during the study?

You will be given any new information gained during the course of the study that might affect your willingness to continue your participation.

How will your privacy be protected?

- **Your privacy is important.** Your identifying information including pictures will not be seen by anyone except the principal investigator. We will protect your privacy in the following ways:
    - All records will be stored either on a secure computer or in a locked filing cabinet in the Sports Medicine Research Laboratory.
    - This consent form will be the only piece of identifying information from you. You will be assigned a code number and this will be attached to all other data.
- **The pictures for the postural analyses will show your face. To protect your privacy:**
    - You will not be identified in any report or publication about this study.
    - When pictures are used for descriptive purposes such as presentations or publications your face will be covered so you can not be identified.
    - While the publication would become a permanent record, your face would be completely covered to conceal your identity.
    - Original pictures will be destroyed after the study and only the pictures with identification removed will be used going forward.
    - If you do not qualify for further testing your pictures and information will be immediately destroyed.
- The video will be taken from behind and your face will not be shown. These files will be digitally stored on a computer in the Sports Medicine Research Laboratory.

Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies for purposes such as quality control or safety.

What will happen if you are injured by this research?
All research involves a chance that something bad might happen to you. This may include the risk of personal injury. In spite of all safety measures, you might develop a shoulder injury from being in this study. If such problems occur, the researchers will help you get medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

What if you want to stop before your part in the study is complete?
You can withdraw from this study at any time, without penalty. The investigators also have the right to stop your participation at any time. This could be because you have had an unexpected reaction, or have failed to follow instructions, or because the entire study has been stopped.

Will you receive anything for being in this study?
There will be no financial benefit.

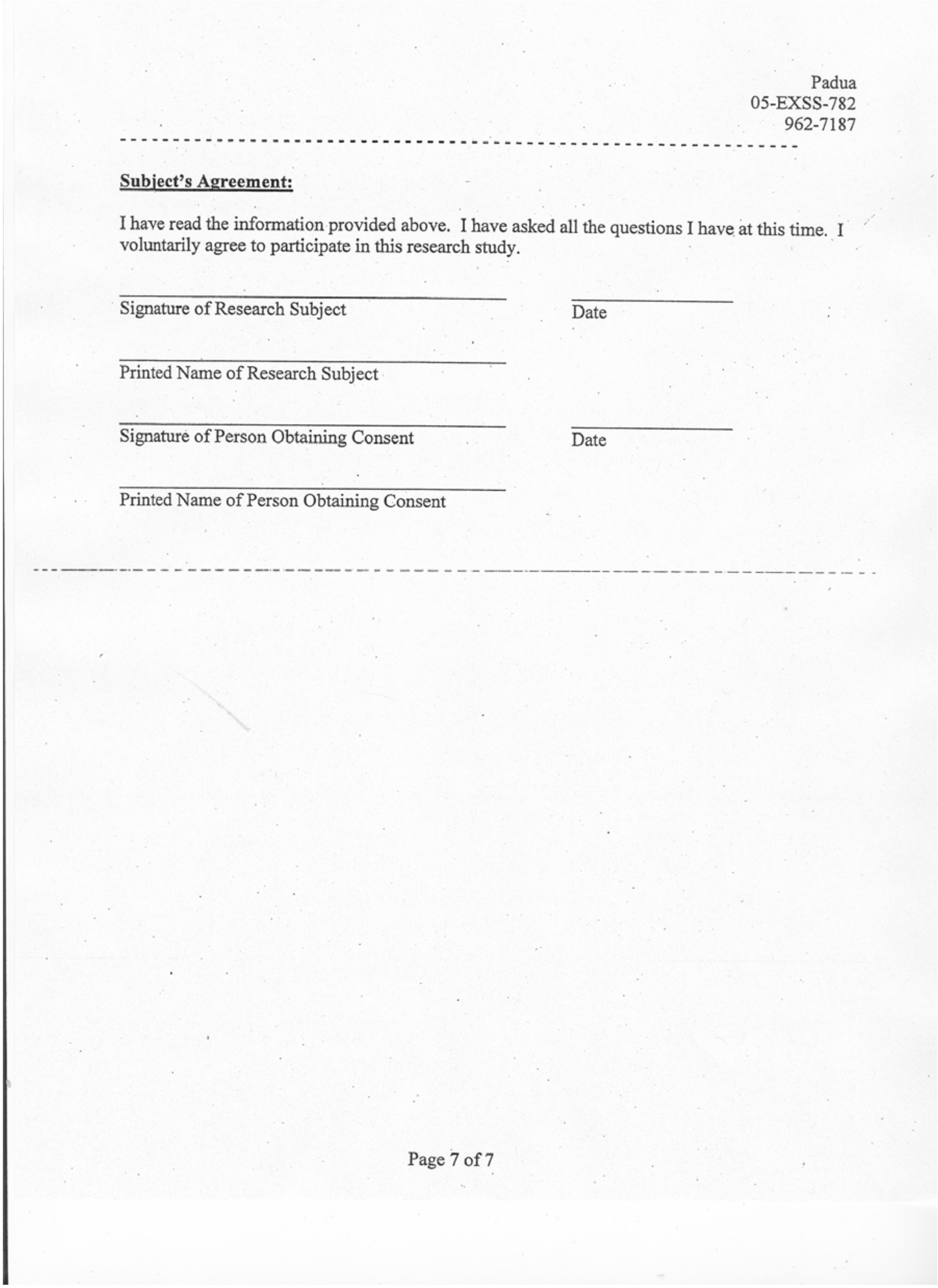
Will it cost you anything to be in this study?
It will not cost you anything except the routine transportation costs to the Sports Medicine Research Laboratory.

What if you are a UNC student?
You may choose not to be in the study or to stop being in the study before it is over at any time. This will not affect your class standing or grades at UNC-Chapel Hill. You will not be offered or receive any special consideration if you take part in this research.

What if you are a UNC employee?
Taking part in this research is not a part of your University duties, and refusing will not affect your job. You will not be offered or receive any special job-related consideration if you take part in this research.

What if you have questions about this study?
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, or if a research-related injury occurs, you should contact the researchers listed on the first page of this form.

What if you have questions about your rights as a research subject?
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.



Subject's Agreement:

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

Signature of Research Subject ____________________ Date ____________

Printed Name of Research Subject ____________________

Signature of Person Obtaining Consent ____________________ Date ____________

Printed Name of Person Obtaining Consent ____________________

APPENDIX D

Raw Data

Subject #	Group (1=Good, 2=Poor)	Age	Gender (1=Male, 2=Female)
1	1	48	2
2	2	51	2
3	2	35	2
4	1	20	2
5	2	52	2
6	1	45	1
7	1	61	2
8	2	52	1
9	2	48	1
10	2	26	1
11	2	47	1
12	2	25	2
13	1	33	2
14	2	22	1
15	2	22	2
16	2	21	2
17	1	53	2
18	2	53	2
19	2	44	2
20	2	26	1
21	1	21	1
22	2	23	2
23	1	25	1
24	1	20	2
25	2	25	2
26	2	24	2
27	2	54	2
28	1	32	2
29	1		1
30	1	27	2
31	2	33	2
32	1	23	2
33	2	24	2
34	2	53	2
35	1	30	2
36	2	43	2
37	1	20	1

Dominant Hand (1=R, 2=L)	Height (cm)	ht (m)	Weight (kg)	BMI
1	167.6	1.676	52.3	18.6
1	157.48	1.5748	70.91	28.6
1	167.6	1.676	109.1	38.8
1	175.26	1.7526	65.91	21.5
1	154.8	1.548	89.55	37.4
1	172.72	1.7272	74.09	24.8
1	160	1.6	50.07	19.6
1	167.64	1.6764	74.55	26.5
1	185.42	1.8542	112.72	32.8
1	177.8	1.778	77.3	24.5
1	177.8	1.778	109	34.5
1	162.56	1.6256	70.91	26.8
1	175.26	1.7526	55.9	18.2
2	170	1.7	75.6	26.2
1	167.64	1.6764	71.82	25.6
1	160.02	1.6002	67.3	26.3
1	157.48	1.5748	57.5	23.2
1	167.64	1.6764	81.82	29.1
1	155	1.55	93	38.7
1	176	1.76	93	30.0
1	185.42	1.8542	75	21.8
1	155	1.55	69.4	28.9
1	170.18	1.7018	93.18	32.2
1	154.94	1.5494	57	23.7
1	151.8	1.518	75	32.5
1	166	1.66	58.8	21.3
1	171	1.71	71	24.3
1	167	1.67	63.2	22.7
	193	1.93	76.8	20.6
1	175	1.75	52.2	17.0
1	160	1.6	84.2	32.9
1	172	1.72	80.4	27.2
1	186	1.86	93	26.9
1	166	1.66	80.2	29.1
1	160	1.6	55	21.5
1	172.72	1.7272	146.4	49.1
1	188	1.88	73.2	20.7

pec1	**pec2**	**pec3**	**pec**	**lat1**	**lat2**	**lat3**	**lat**
50	48	49	49	127	123	123	124.3333
31	30	30	30.33333	160	158	161	159.6667
38	34	35	35.66667	150	147	148	148.3333
39	39	38	38.66667	164	162	161	162.3333
39	46	47	44	151	152	150	151
25	24	27	25.33333	170	168	170	169.3333
31	33	33	32.33333	143	142	142	142.3333
39	39	40	39.33333	146	147	143	145.3333
28	28	27	27.66667	148	147	149	148
30	28	23	27	145	148	151	148
40	38	38	38.66667	157	152	158	155.6667
35	37	33	35	148	141	143	144
31	32	32	31.66667	158	156	157	157
49	43	50	47.33333	115	118	115	116
43	39	40	40.66667	149	148	150	149
48	48	47	47.66667	158	160	161	159.6667
59	61	62	60.66667	162	161	163	162
42	40	40	40.66667	159	162	158	159.6667
41	37	38	38.66667	169	172	169	170
26	30	29	28.33333	161	161	159	160.3333
45	42	44	43.66667	162	163	161	162
42	42	40	41.33333	174	174	176	174.6667
44	42	43	43	176	175	174	175
41	38	38	39	153	160	161	158
50	53	49	50.66667	145	138	137	140
46	49	48	47.66667	167	164	168	166.3333
49	44	46	46.33333	157	155	154	155.3333
58	60	59	59	163	170	168	167
40	40	41	40.33333	177	171	172	173.3333
52	53	54	53	164	167	165	165.3333
43	43	44	43.33333	165	166	164	165
55	57	54	55.33333	164	167	166	165.6667
57	57	57	57	153	150	151	151.3333
52	52	55	53	156	159	159	158
45	46	48	46.33333	144	143	141	142.6667
39	39	37	38.33333	167	172	172	170.3333
38	40	40	39.33333	151	150	151	150.6667

IR1	IR2	IR3	IR	ER1	ER2	ER3	ER
54	47	52	51	70	70	72	70.66667
50	50	51	50.33333	86	84	85	85
46	45	44	45	80	81	82	81
50	48	49	49	105	106	105	105.3333
56	57	56	56.33333	107	107	108	107.3333
50	51	48	49.66667	76	79	76	77
49	50	52	50.33333	74	75	73	74
46	45	49	46.66667	75	73	75	74.33333
59	57	55	57	75	78	79	77.33333
57	56	60	57.66667	83	86	86	85
43	43	44	43.33333	90	92	94	92
37	43	41	40.33333	79	79	79	79
54	57	54	55	107	108	107	107.3333
52	54	54	53.33333	91	93	93	92.33333
55	54	52	53.66667	101	100	98	99.66667
54	54	53	53.66667	117	119	117	117.6667
52	52	56	53.33333	100	100	103	101
64	61	61	62	114	117	118	116.3333
57	59	62	59.33333	74	72	72	72.66667
51	55	51	52.33333	72	70	72	71.33333
58	61	59	59.33333	81	81	81	81
72	71	72	71.66667	97	103	105	101.6667
49	48	51	49.33333	110	110	110	110
75	75	76	75.33333	78	80	82	80
66	64	68	66	119	116	116	117
62	64	64	63.33333	82	82	82	82
61	57	57	58.33333	101	103	101	101.6667
63	61	65	63	102	105	106	104.3333
45	47	43	45	105	106	106	105.6667
66	67	68	67	70	71	69	70
62	66	65	64.33333	115	115	116	115.3333
74	75	74	74.33333	108	108	109	108.3333
49	53	51	51	114	117	115	115.3333
52	51	51	51.33333	100	101	101	100.6667
60	62	62	61.33333	115	113	113	113.6667
71	74	71	72	92	90	93	91.66667
51	51	53	51.66667	86	85	84	85

SAM1	SAM2	SAM3	SAM	SAM nor	SAMbmi	SAP1	SAP2
150	86	152	129.3333	2.472913	6.946352	162	96
80	104	82	88.66667	1.250411	3.101014	100	108
206	226	216	216	1.979835	5.561309	210	236
210	208	228	215.3333	3.267081	10.03519	218	218
138	154	140	144	1.60804	3.853353	144	164
182	166	140	162.6667	2.195528	6.549743	186	168
146	136	126	136	2.716197	6.953465	160	142
338	390	391	373	5.003353	14.06101	376	432
462	598	578	546	4.843861	16.65347	472	638
620	570	568	586	7.580854	23.96523	674	638
352	320	294	322	2.954128	9.338839	364	338
238	210	218	222	3.130729	8.273188	252	232
172	168	188	176	3.148479	9.670891	172	172
434	400	446	426.6667	5.643739	16.31041	458	442
298	222	240	253.3333	3.527337	9.912935	320	290
210	160	148	172.6667	2.565627	6.569646	224	164
136	146	146	142.6667	2.481159	6.153263	140	148
244	292	296	277.3333	3.389554	9.525722	250	304
170	196	218	194.6667	2.09319	5.028889	182	206
306	274	276	285.3333	3.0681	9.503748	312	286
278	332	314	308	4.106667	14.11896	358	356
134	128	90	117.3333	1.690682	4.061864	154	160
538	546	526	536.6667	5.759462	16.68011	624	620
166	166	166	166	2.912281	6.991339	176	178
166	184	156	168.6667	2.248889	5.182169	176	202
150	136	162	149.3333	2.539683	6.998349	178	148
138	142	122	134	1.887324	5.518724	144	152
114	102	122	112.6667	1.7827	4.971773	120	112
210	202	196	202.6667	2.638889	9.829597	254	214
128	128	122	126	2.413793	7.392241	134	198
134	150	126	136.6667	1.62312	4.155186	146	154
120	126	106	117.3333	1.45937	4.3174	126	128
162	124	154	146.6667	1.577061	5.456	172	160
76	98	118	97.33333	1.213633	3.344286	82	102
46	70	70	62	1.127273	2.885818	52	74
114	96	98	102.6667	0.701275	2.092058	116	102
176	134	176	162	2.213115	7.822033	186	142

SAP3	**SAP**	**SAP nor**	**SAPbmi**	**PDM1**	**PDM2**	**PDM3**	**PDM**
160	139.3333	2.664117	7.483441	92	110	96	99.33333
88	98.66667	1.391435	3.450752	56	62	72	63.33333
222	222.6667	2.040941	5.732954	136	132	130	132.6667
240	225.3333	3.418803	10.50122	110	128	122	120
142	150	1.675042	4.01391	102	112	100	104.6667
148	167.3333	2.258514	6.737645	108	148	156	137.3333
136	146	2.915918	7.464749	72	90	92	84.66667
448	418.6667	5.615918	15.78251	162	154	152	156
610	573.3333	5.08635	17.48716	202	214	222	212.6667
676	662.6667	8.572661	27.10061	158	188	208	184.6667
310	337.3333	3.094801	9.783546	194	224	214	210.6667
240	241.3333	3.403375	8.993675	116	108	100	108
192	178.6667	3.196184	9.817419	92	100	116	102.6667
508	469.3333	6.208113	17.94145	242	250	238	243.3333
280	296.6667	4.130697	11.60857	116	120	106	114
158	182	2.704309	6.924762	142	126	114	127.3333
154	147.3333	2.562319	6.354538	76	92	94	87.33333
310	288	3.519922	9.892096	110	116	106	110.6667
236	208	2.236559	5.373333	104	114	104	107.3333
282	293.3333	3.154122	9.770208	186	210	186	194
354	356	4.746667	16.31931	178	164	170	170.6667
102	138.6667	1.998079	4.800384	108	112	118	112.6667
666	636.6667	6.832654	19.78821	214	256	216	228.6667
182	178.6667	3.134503	7.524814	104	108	88	100
166	181.3333	2.417778	5.571343	104	106	96	102
176	167.3333	2.845805	7.8419	98	104	108	103.3333
134	143.3333	2.018779	5.903113	64	80	66	70
138	123.3333	1.951477	5.442474	82	72	88	80.66667
216	228	2.96875	11.0583	92	124	102	106
136	156	2.988506	9.152299	70	68	70	69.33333
132	144	1.710214	4.378147	104	116	114	111.3333
142	132	1.641791	4.857075	84	86	92	87.33333
168	166.6667	1.792115	6.2	108	118	116	114
122	102	1.27182	3.504628	48	66	58	57.33333
70	65.33333	1.187879	3.04097	60	60	64	61.33333
102	106.6667	0.728597	2.173566	86	112	82	93.33333
186	171.3333	2.340619	8.272685	140	122	124	128.6667

PDM nor	PDMbmi	PDP1	PDP2	PDP3	PDP	PDP nor	PDPbmi
1.899299	5.335085	98	114	108	106.6667	2.039516	5.72895
0.893151	2.21501	58	62	76	65.33333	0.921356	2.284958
1.21601	3.415742	138	144	132	138	1.264895	3.553059
1.820665	5.592366	118	132	124	124.6667	1.891468	5.809846
1.168807	2.800817	106	116	108	110	1.228364	2.943534
1.853601	5.529701	110	148	158	138.6667	1.871598	5.583387
1.690966	4.328873	72	92	92	85.33333	1.704281	4.362959
2.092555	5.880744	172	162	162	165.3333	2.217751	6.232583
1.886681	6.486518	218	220	248	228.6667	2.028626	6.974531
2.388961	7.552183	170	196	222	196	2.535576	8.015675
1.932722	6.109882	212	238	226	225.3333	2.067278	6.535254
1.523057	4.024794	126	130	128	128	1.805105	4.770126
1.836613	5.641353	94	106	126	108.6667	1.943948	5.971042
3.218695	9.302028	256	262	250	256	3.386243	9.786243
1.587302	4.460821	120	136	116	124	1.726539	4.852121
1.892026	4.844797	142	128	118	129.3333	1.921743	4.920893
1.518841	3.766717	80	96	102	92.66667	1.611594	3.996746
1.352563	3.801129	114	120	110	114.6667	1.40145	3.93852
1.154122	2.772778	118	116	104	112.6667	1.21147	2.910556
2.086022	6.46166	194	214	192	200	2.150538	6.661505
2.275556	7.823491	192	176	186	184.6667	2.462222	8.465262
1.623439	3.900312	110	112	120	114	1.642651	3.94647
2.454032	7.107178	242	292	238	257.3333	2.76168	7.998165
1.754386	4.21165	106	114	102	107.3333	1.883041	4.520504
1.36	3.133881	120	124	122	122	1.626667	3.748367
1.75737	4.842608	108	118	110	112	1.904762	5.248762
0.985915	2.882915	70	84	82	78.66667	1.107981	3.239848
1.276371	3.559672	86	72	92	83.33333	1.318565	3.677347
1.380208	5.141138	110	130	108	116	1.510417	5.626151
1.328225	4.067688	84	76	74	78	1.494253	4.576149
1.322249	3.384956	110	116	114	113.3333	1.346002	3.445764
1.086235	3.213519	90	86	102	92.66667	1.15257	3.409765
1.225806	4.2408	120	124	120	121.3333	1.304659	4.5136
0.714879	1.969922	48	66	60	58	0.723192	1.992828
1.115152	2.854788	60	60	66	62	1.127273	2.885818
0.637523	1.901871	88	112	82	94	0.642077	1.915455
1.757741	6.212561	152	128	126	135.3333	1.848816	6.534455

ERM1	**ERM2**	**ERM3**	**ERM**	**ERM nor**	**ERMbmi**	**ERP1**	**ERP2**
86	88	92	88.66667	1.695347	4.76219	86	88
64	60	54	59.33333	0.836741	2.075115	68	66
118	124	116	119.3333	1.093798	3.072452	120	128
108	94	88	96.66667	1.466646	4.504961	112	102
90	90	90	90	1.005025	2.408346	92	90
126	110	106	114	1.538669	4.590188	128	112
74	66	80	73.33333	1.464616	3.749417	74	66
150	142	140	144	1.93159	5.428379	152	142
186	190	178	184.6667	1.638278	5.632493	202	200
146	154	104	134.6667	1.74213	5.507368	174	162
188	206	208	200.6667	1.840979	5.819856	190	208
92	92	90	91.33333	1.288018	3.403684	108	98
92	92	88	90.66667	1.621944	4.981974	100	92
204	194	192	196.6667	2.601411	7.518078	224	220
100	100	92	97.33333	1.35524	3.808654	102	104
102	84	82	89.33333	1.32739	3.398967	106	86
82	66	68	72	1.252174	3.105385	82	70
112	106	112	110	1.344415	3.778231	118	114
92	92	88	90.66667	0.97491	2.342222	98	100
216	166	182	188	2.021505	6.261815	220	178
172	166	130	156	2.08	7.15116	182	182
96	90	90	92	1.325648	3.18487	96	96
216	174	166	185.3333	1.988982	5.760337	240	196
104	98	92	98	1.719298	4.127417	104	104
108	96	106	103.3333	1.377778	3.174846	116	106
96	90	92	92.66667	1.575964	4.342726	98	96
112	90	88	96.66667	1.361502	3.981169	118	96
92	94	96	94	1.487342	4.148047	96	94
136	130	130	132	1.71875	6.402172	142	154
82	86	84	84	1.609195	4.928161	84	90
114	100	104	106	1.258907	3.222803	116	102
126	106	142	124.6667	1.55058	4.587237	138	126
152	150	116	139.3333	1.498208	5.1832	174	168
88	98	100	95.33333	1.188695	3.275568	94	100
80	74	76	76.66667	1.393939	3.568485	80	80
108	120	130	119.3333	0.815118	2.431677	122	120
150	158	118	142	1.939891	6.85635	152	162

ERP3	ERP	ERP nor	ERPbmi	LTM1	LTM2	LTM3	LTM
94	89.33333	1.708094	4.797996	202	216	216	211.3333
56	63.33333	0.893151	2.21501	80	112	106	99.33333
122	123.3333	1.130461	3.175439	240	216	262	239.3333
90	101.3333	1.53745	4.722442	306	294	242	280.6667
90	90.66667	1.01247	2.426185	68	74	86	76
106	115.3333	1.556665	4.643875	184	166	176	175.3333
80	73.33333	1.464616	3.749417	110	120	126	118.6667
154	149.3333	2.00313	5.62943	220	276	284	260
186	196	1.738822	5.97817	266	248	316	276.6667
120	152	1.966365	6.216238	230	190	192	204
210	202.6667	1.859327	5.877861	342	358	346	348.6667
98	101.3333	1.429042	3.77635	178	152	158	162.6667
88	93.33333	1.669648	5.128503	202	222	242	222
206	216.6667	2.865961	8.282628	240	292	282	271.3333
104	103.3333	1.438782	4.043434	198	222	212	210.6667
86	92.66667	1.376919	3.525795	210	218	232	220
74	75.33333	1.310145	3.249153	146	160	146	150.6667
116	116	1.417746	3.984316	250	254	250	251.3333
94	97.33333	1.046595	2.514444	136	164	148	149.3333
184	194	2.086022	6.46166	364	322	362	349.3333
158	174	2.32	7.976294	286	268	300	284.6667
96	96	1.383285	3.323343	188	220	232	213.3333
218	218	2.339558	6.775648	420	470	466	452
192	133.3333	2.339181	5.615533	200	238	180	206
112	111.3333	1.484444	3.420641	150	160	146	152
98	97.33333	1.655329	4.561424	186	218	238	214
100	104.6667	1.474178	4.310645	132	124	128	128
100	96.66667	1.529536	4.265723	126	122	122	123.3333
142	146	1.901042	7.08119	182	162	158	167.3333
92	88.66667	1.698595	5.201948	176	162	194	177.3333
110	109.3333	1.298496	3.324149	170	206	200	192
156	140	1.741294	5.151443	158	198	202	186
138	160	1.72043	5.952	260	282	276	272.6667
100	98	1.221945	3.367192	100	104	124	109.3333
76	78.66667	1.430303	3.661576	74	68	70	70.66667
130	124	0.846995	2.526771	126	148	188	154
134	149.3333	2.040073	7.210434	160	154	190	168

LTM nor	LTMbmi	LTP1	LTP2	LTP3	LTP	LTP nor	LTPbmi
4.04079	11.35048	202	222	218	214	4.091778	11.49371
1.400837	3.474068	80	114	110	101.3333	1.429042	3.544016
2.193706	6.162068	246	242	266	251.3333	2.303697	6.471029
4.258332	13.07992	318	304	252	291.3333	4.420169	13.57702
0.848688	2.033714	68	76	90	78	0.871022	2.087233
2.366491	7.059764	184	168	178	176.6667	2.384487	7.11345
2.370015	6.067239	114	128	130	124	2.476533	6.339924
3.487592	9.80124	238	286	302	275.3333	3.693271	10.37926
2.454459	8.438573	280	270	328	292.6667	2.596404	8.926587
2.639069	8.342845	250	228	202	226.6667	2.932298	9.269828
3.198777	10.11224	358	366	362	362	3.321101	10.49894
2.293988	6.062035	184	166	162	170.6667	2.406807	6.360168
3.971377	12.19851	232	242	244	239.3333	4.281455	13.15095
3.589065	10.3724	248	298	302	282.6667	3.738977	10.80564
2.933259	8.243388	202	228	218	216	3.007519	8.452081
3.268945	8.370592	212	222	240	224.6667	3.338286	8.54815
2.62029	6.498306	150	168	146	154.6667	2.689855	6.670827
3.071784	8.632686	262	260	258	260	3.177707	8.930364
1.605735	3.857778	144	166	162	157.3333	1.691756	4.064444
3.756272	11.63543	374	338	382	364.6667	3.921147	12.14614
3.795556	13.04934	340	300	314	318	4.24	14.57736
3.073967	7.385207	202	242	240	228	3.285303	7.892939
4.850826	14.04859	500	530	522	517.3333	5.551978	16.07921
3.614035	8.675998	208	240	218	222	3.894737	9.349862
2.026667	4.670097	156	166	146	156	2.08	4.792994
3.639456	10.02888	204	248	240	230.6667	3.922902	10.80995
1.802817	5.271617	142	138	134	138	1.943662	5.683462
1.951477	5.442474	138	126	126	130	2.056962	5.736661
2.178819	8.115885	196	182	180	186	2.421875	9.021242
3.39719	10.4039	184	168	222	191.3333	3.66539	11.22526
2.280285	5.83753	174	210	204	196	2.327791	5.959145
2.313433	6.84406	192	214	206	204	2.537313	7.506388
2.9319	10.1432	278	326	302	302	3.247312	11.2344
1.363259	3.756595	104	106	124	111.3333	1.388196	3.825313
1.284848	3.289212	78	70	80	76	1.381818	3.537455
1.051913	3.138086	130	154	192	158.6667	1.083789	3.23318
2.295082	8.111738	176	162	220	186	2.540984	8.980852

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