University of Alberta

TEST-RETEST RELIABILITY OF ISOKINETIC MUSCLE STRENGTH MEASUREMENTS OF THE SHOULDER INTERNAL AND EXTERNAL ROTATORS IN SITTING AND SUPINE LYING

by

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DEDICATION

This work is dedicated most of all to God almighty, for His grace and mercies, and also to my parents, Mr. and Mrs. S.O. Eboikpomwen, for their love and support. I also dedicate this work to my siblings, especially Osarobo for his help and support in making this work become a reality, and Osayi, Omorodion and Aifuwa, for their encouragement and love.

ABSTRACT

Objective- To establish test-retest reliability of isokinetic muscle strength measurements for the shoulder internal and external rotators in sitting and supine lying.

Participants- 20 subjects aged between 18 and 32 years participated in the study.

Methods- Each subject participated in isokinetic muscle strength measurement with the shoulder placed at 45 degrees anterior to the frontal plane (protocol A) and the shoulder in 90 degrees of abduction and 90 degrees of elbow flexion (protocol B). The subjects were tested at velocities of 60°/sec and 180°/sec, and sitting and supine for both protocols. Each subject came for three test sessions, with the first session dedicated to subject education and familiarization. Peak torque values for the contractions were recorded for the last two session.

Results- ICC values ranging from 0.858 to 0.962 were obtained.

Conclusions- The positions of sitting and supine have good to excellent reliability clinically for these protocols. Overall, the position of sitting with the glenohumeral joint in 90 degrees of abduction and 90 degrees of elbow flexion proved most reliable. This may be due to the fact that this position is more comfortable and more reproducible.

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CHAPTER 1

1.1 INTRODUCTION AND PROBLEM STATEMENT

The glenohumeral joint is unstable because the large humeral head is situated in the relatively small glenoid fossa. This arrangement allows the shoulder to have tremendous mobility at the expense of osseous stability. Stability of this joint is mostly maintained by ligaments and musculotendinous units.[1,2,3,4] The kinematics of the glenohumeral joint and its relatively extensive joint mobility make reliable isokinetic assessment of the shoulder musculature an ongoing challenge. The implications that muscle imbalances play a role in shoulder pathology however, are clinically significant and serve as motivation to improve available methods of providing strength information about the shoulder complex.[1,5]

Isokinetic dynamometry of the shoulder muscles has been used in clinical practice since 1980,[1] and has provided a tool for quantifying muscle performance.[5] Several studies on isokinetic dynamometry exist, but only a few address the test-retest reliability of the measurements.[1,6] The majority of test-retest reliability studies on isokinetic dynamometer have been performed on the muscles acting on the knee joint. This joint may be more frequently chosen because of ease of testing, excellent stabilization, isolation of movement, and because it is the most frequently tested.[1,7]

Once the velocity of an isokinetic device is set, it permits and demands muscular contraction up to, but not beyond that velocity.[8] Theoretically, it can be viewed as a series of isometric contractions as the muscles work maximally at each point in the range of motion. As the loading speed is controlled, the device can be set at specific rates to allow the muscles to generate maximal output, relative to some objective for force, work or power, or relative to the dynamic conditions in some functional activity.[8]

Isokinetic measurements of the shoulder joint can be done in several positions, for example, sitting, standing, lying supine and with different angles of abduction and flexion of the shoulder. It is not known which is the most reliable position. The sitting and supine positions allow for greater stabilization of the trunk, and isolate the movement to the shoulder, unlike the standing position, where subjects may use the trunk muscles to assist the movement. Studies on 6 different positions for the rotational movement showed significant differences in the maximal torque measured.[1,5] The highest peak torque for the rotational movements (internal and external rotation) was seen in the neutral position, i.e sitting with no abduction and flexion of the shoulder. The influence of the position used on reliability of the measurements is not known; most studies have used only one position, either sitting, standing or supine lying. There is no consensus about the position to be used in the abduction and adduction movement.[1,5]

Literature reviews show that reliability coefficients for eccentric knee contractions seem to be higher than those of eccentric shoulder contractions. This leads one to hypothesize that because the knee is an easier joint to stabilize when using isokinetic equipment, less substitution or force oscillation may occur with the knee muscle contractions than with shoulder muscle contractions. The inability to completely stabilize the subject during isokinetic testing of the shoulder may lower the test-retest reliability, which is relevant when testing patients in the clinic. Trunk stability is important for preventing substitution around the shoulder and, therefore must be maintained to produce reliable isokinetic testing.[1,2,3,5,7,9] Several authors advocate the use of adequate stabilization using straps of relevant areas of the body to prevent instability.[1,2,3,5,9,11] Some positions may allow more effective stabilization, hence the need to determine a more reliable position for testing the shoulder internal and external rotators.

Several factors can influence the reliability of isokinetic measurements of the shoulder joint. First, in isokinetic dynamometry, the axis of the dynamometer has to be in line with the axis of the joint. The axis of the dynamometer is a fixed position, but there is no consensus about the localization of the functional joint axis of the shoulder. The glenohumeral joint has an extensive range of motion in several planes. The influence of this phenomenon on the reliability of the measurement is unknown.[1]

The choice of the preset angular velocity in isokinetic measurements of the shoulder is arbitrary rather than scientifically based. Low and high angular velocities are often used. The assumption is that a low angular velocity relates to maximal voluntary contraction, and a high angular velocity relates to muscular coordination, which is important in functional activities.[1]

The key to accurately determining the muscle strength of any muscle group in the body, for purposes of present treatment and for future evaluation depends on the test-retest reliability of the protocol chosen. It is therefore imperative that the test-retest reliabilities of the protocols chosen are known.

1.2. DEFINITION OF TERMS

1. CONCENTRIC CONTRACTION- if the joint motion is in a direction opposite the normal (gravitational) force and the tension produced by the muscle exceeds the external resistance encountered, the contraction is shortening (or concentric in nature.[17]

2. ECCENTRIC CONTRACTION- if the joint motion is in the direction of the normal force and the external resistance encountered exceeds the muscle's ability to generate tension, the contraction is lengthening (or eccentric) in nature.[17]

3. EXTERNAL ROTATION (lateral rotation)- When the anterior (front) surface of the shoulder rotates laterally (away from the midline of the body), or upwards. [18]

4. FORCE- push or pull produced by the action of one object on another. It is measured in pounds or Newtons. [16,17]

5. INTRACLASS CORRELATION COEFFICIENT- is a reliability coefficient, which reflects both correlation and agreement. [22]

6. INTERNAL ROTATION (medial rotation)- when the anterior surface of the shoulder rotates medially (towards the midline of the body), or downwards.[18]

7. ISOKINETIC EXERCISE- dynamic muscle activity performed at a constant angular velocity. The speed of the motion is preselected and controlled by an isokinetic dynamometer in which internal resistance is created to accommodate the force applied.[7,12,13,14,15,16,17]

8. MEAN/ AVERAGE PEAK TORQUE- the average of the peak torque over a number of repetitions.[14,16,17]

9. PEAK TORQUE- is a measure of the force generating capacity of the muscle, and is represented by the highest point on a patient's torque/angle curve.[12,14,16,17]

10. PLANE OF THE SCAPULA (SCAPTION)- elevation of the shoulder in a range between 30 degrees and 45 degrees anterior to the frontal plane.[19,20] Also described by Saha as a position where the humerus is 45 degrees in front of the coronal plane (frontal).

11. RELIABILITY- the consistency of a measurement when all conditions are thought to be held constant.[1,10]

12. SCAPULA STABILITY- ability to position and control movements of the scapula.[53] The lack of ligamentous restraints at the scapulothoracic joint requires the muscles that attach the scapula to the thorax have a major stabilizing role and hence these muscles need appropriate contractile and recruitment properties.[53]

13. TEST-RETEST RELIABILITY- reliability of a measurement over two sessions.[1] In a test-retest study, one sample of individuals is subjected to the identical test on two separate occasions, keeping all testing conditions as constant as possible.[22]

14. TORQUE- is the moment of a force applied during rotational motion. It is measured in foot-pounds or Newton-metres.[14,16,17]

Shoulder Position Protocols For The Study

1. Protocol A- The glenohumeral joint in 45 degrees of scaption.

2. Protoel B- The glenohumeral joint in 90 degrees of abduction and elbow in 90 degrees of flexion.

1.3. OBJECTIVES OF THE STUDY

The objectives of this study were:

1. In the ***sitting position*** to determine the test-retest reliability of concentric peak torque values for internal and external rotators at:

   a. 60°/sec for shoulder position protocol A.

   b. 180°/sec for shoulder position protocol A.

   c. 60°/sec for shoulder position protocol B.

   d. 180°/sec for shoulder position protocol B.

2. In the ***supine lying position*** to determine the test-retest reliability of concentric peak torque values for internal and external rotators at :

   a. 60°/sec for shoulder position protocol A.

   b. 180°/sec for shoulder position protocol A.

   c. 60°/sec for shoulder position protocol B.

   d. 180°/sec for shoulder position protocol B

1.4. RESEARCH HYPOTHESES

The following hypotheses were tested in this study for the 2 shoulder position protocols :

1. ***In sitting :***

a. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for protocol A would have an ICC value greater than 0.90.

b. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for protocol A would have an ICC value greater than 0.90.

c. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for protocol B would have an ICC value greater than 0.90.

d. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for protocol B would have an ICC value greater than 0.90.

2. ***In supine lying :***

a. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for protocol A would have an ICC value greater than 0.90.

b. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for protocol A would have an ICC value greater than 0.90.

c. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for Protocol B would have an ICC value greater than 0.90.

d. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for Protocol B would have an ICC value greater than 0.90.

1.5. LIMITATIONS OF THE STUDY

The following limitations applied to this study:

1. Standardized Protocol- a standardized protocol was used to minimize variables that could affect the reliability of this study. The chosen protocol may not reflect all the testing protocols used in clinical settings, however. The 2 shoulder position protocols were used – (a) the glenohumeral joint in 45 degrees of scaption and (b) the glenohumeral joint in 90 degrees of abduction and elbow in 90 degrees of flexion.

2. Subjects were between 18 and 32 years of age, to ensure that subjects are musculoskeletally mature, and also to reduce the risk of degenerative changes influencing the results.[72]

1.6. DELIMITATIONS OF THE STUDY

1. The test velocities used. There were several test velocities that could have been used for isokinetic testing. Low and high angular velocities are often used. The assumption is that a low angular velocity relates more to maximal vouluntary contraction, and a high angular velocity relates more to muscular coordination, which is important in functional activities.[1] Thus the two velocities of 60°/sec and 180°/sec, have been chosen for this study. This allowed an assessment of test-retest reliability at low and high angular velocities.

2. The test positions used. The test positions of sitting and supine were chosen, because they allowed for greater stabilization of the body, and limited the influence of other muscle groups such as the trunk being involved in the movement.

3. The study dealt with only internal and external rotation movement of the shoulder joint.

1.7. ETHICAL CONSIDERATIONS

Isokinetic exercises provide a safe alternative to other exercise modalities during the process of rehabilitation. This is because the dynamometer's resistance mechanism can be disengaged by the patient through the use of the dynamometer's stop control mechanism on the Kin Com when pain or discomfort is experienced by the patient (the Kin Com dynamometer has a stop control mechanism, which the subjects were asked to hold and to activate by pressing the control button when they felt pain or discomfort).[17] The primary risk associated with isokinetic muscle strength measurements was related to muscular soreness following the eccentric contraction efforts. To reduce this risk, only concentric contractions were used for this study. About 30% of the subjects reported experiencing mild discomfort after the test sessions, similar to that usually experienced after exercise one is not accustomed to doing, as a result of the high intensity contraction efforts (see appendix B).

This research was performed while maintaining total privacy of the patients. Before each subject was tested, a detailed verbal explanation of the test was given to each subject. Each subject was asked to sign a consent form, which also contained a detailed written explanation of the test protocol (see appendix B). Subjects were told that they could withdraw from the study at any time without prejudice (appendix B). Only one subject withdrew from the study, after she discovered she was pregnant. This was after the second test session.

The inclusion and exclusion criteria in this study allowed a proper screening of the study participants, so that only subjects who were fit participated in the study.

Approval was obtained from the Health Research Ethics Board: Panel B, of the University of Alberta (Appendix F).

CHAPTER 2

LITERATURE REVIEW

2.1. ANATOMY OF THE SHOULDER JOINT

The shoulder joint is a synovial joint of the ball and socket variety.[23] There is a four to one disproportion between the large round head of the humerus and the small shallow glenoid cavity. The glenoid labrum, a ring of fibrocartilage attached to the margins of the glenoid cavity deepens, slightly but effectively the depression of the glenoid fossa.[24,25]

Stability- The shoulder joint is an unstable structure. The head of the humerus is very much larger than the glenoid cavity, and the joint capsule, though strong, is very lax. These factors suggest that the glenohumeral joint is an unstable articulation.[24,25,26,27] The head of the humerus is maintained in the glenoid fossa by the combined action of rotator cuff and the capsule.[4,28]

Movement- The shoulder joint is a multiaxial joint with 3 degrees of freedom. The movements of the shoulder joints are- (1) flexion and extension
(2) adduction and abduction (3) medial and lateral rotation.

When the arm hangs at rest beside the body , the glenoid fossa faces forward as well as laterally. Flexion at the shoulder joint, without any associated scapula movement, brings the arm forwards and inwards across the front of the body. The clavicular head of pectoralis major and the anterior fibres of deltoid are assisted in this movement by coracobrachialis and the short head of biceps. The opposite movement of extension is The clavicular head of pectoralis major and the anterior fibres of deltoid are assisted in this movement by coracobrachialis and the short head of biceps. effected by latissimus dorsi, teres major and the posterior fibres of deltoid. .[23,24,25,27,28] The sternocostal part of pectoralis major is able to extend the fully flexed arm and flex the fully extended arm. The multipennate acromial fibres of deltoid are the principal abductors at the shoulder joint. Acting alone, deltoid would tend to raise the head of the humerus upwards, as in shrugging the shoulders, rather than abduct it. Supraspinatus, also active in abduction, holds the head of the humerus against the glenoid fossa, while subscapularis, infraspinatus and teres minor exert a downward and inward pull on the head. At approximately 90 degrees of abduction, the articular surface of the head of the humerus is fully utilized and lies edge to edge with that of the glenoid fossa. Lateral rotation of the humerus is required to bring additional articular surface into play and allow abduction to continue. No more than 120 degrees of abduction is usually possible at the glenohumeral articulation. Rotation is produced by the short scapular muscles- infraspinatus, and teres minor for lateral rotation, and subscapularis, teres major as well as latissimus dorsi, pectoralis major and anterior fibres of deltoid for medial rotation.[23,24,25,27,28]

2.2. MUSCLES WHICH CONTRIBUTE TO INTERNAL AND EXTERNAL ROTATION OF THE GLENOHUMERAL JOINT

Latissimus dorsi -arises from the spine of the lower six thoracic vertebrae and the posterior layer of the lumbar fascia, by which it is attached to the lumbar and sacral vertabral spines and to the posterior part of the crest of the ilium. Lateral to this, it also arises by muscular fibres from the outer lip of the iliac crest. The upper part of the flat sheet of muscle runs horizontally, covered by the lower triangular part of the trapezius, and passes over the inferior angle of the scapula, from which a few fibres may arise. The lateral part of the muscle runs vertically upwards, being reinforced by four slips from the lowest four ribs, whose fibres of origin interdigitate with those of the external oblique. This lateral border of the latissimus dorsi forms a boundary of the lumbar triangle. The muscles converge towards the posterior axillary fold, of which it forms the lower border. The fibres spiral around the lower border of teres major and are replaced by a flattened, shiny , white tendon about 3cm broad that inserts into the floor of the intertubercular sulcus of the humerus. As a result of the spiral turn around teres major , the surfaces of the muscles, anterior and posterior are reversed at the tendon , and the fibres that originate lowest at the midline insert highest at the humerus , while those that originate highest insert lowest.[24,25,26,28,29] The latissimus dorsi extends the shoulder and medially rotates the humerus (e.g folding the arms behind the back or scratching the opposite scapula. In combination with pectoralis major, it is a powerful adductor. [24,25,26,28,29]

Subscapularis- arises from the medial two thirds of the costal surface of the scapula and from the intermuscular septa. The tendon of the muscle is separated from a bare area at the lateral angle of the scapula by a bursa which communicates with the cavity of the shoulder joint. Lateral to this, the tendon fuses with the capsule of the shoulder joint and is inserted into the lesser tubercle of the humerus. [25,26,28,29]
With other rotator cuff muscles, the subscapularis gives stability to the shoulder joint assisting in fixation of the upper ends of the humerus during movements of elbow, wrist and handing. Acting as a prime mover, it is a medial rotator of the humerus.[23,25,26,28,29,30]

Infraspinatus- arises from the medial two thirds of the infraspinous fossa and from the deep surface of the infraspinous fascia, which covers the muscle and is attached to the scapula at its margins. A bursae which lies between the bare area of the scapula and the muscle, sometimes communicates with the shoulder joint. The tendon blends with the capsule of the shoulder joint and inserts into the smooth area on the central facet of the greater tubercle of the humerus, between supraspinatus above and teres minor below. [23,25,28,30]

Apart from acting to brace the head of the humerus against the glenoid cavity , giving stability to the joint, it is also a powerful lateral rotator of the humerus. [23,24,25,26,28,29,30]

Teres Minor- arises from an elongated oval area on the dorsal surface of the axillary border of the scapula . It passes upwards and laterally, edge to edge with the lower border of infraspinatus and behind the long head of triceps. The tendons blend with the capsule of the shoulder joint and attach to the lowest facet on the greater tubercle of the humerus. The lower part of the lateral border of this muscle lies edge to edge with teres major, but the latter muscle leaves it by passing forward in front of the long head of triceps. [23,25,28,29,30] This muscle assists the other rotator cuff muscles around the head of the humerus in steadying the shoulder joint. It is a lateral rotator and weak adductor of the humerus. With teres major, it holds down the head of the humerus against the upward pull of the deltoid during abduction of the shoulder. [23,24,25,26,28,29,30]

Teres Major- arises from an oval area on the dorsal surface of the inferior angle of the scapula. It is inserted into the medial lip of the intertubercular sulcus of the

humerus. The ribbon like tendon of lattissimus dorsi winds around its lower border and comes to lie in front of the upper part of the muscle at its insertion. [23,25,29,30]
Teres major assists the other rotator cuff muscles in steadying the upper part of the humerus in movement at the shoulder joint; acting alone, it is an adductor and medial rotator of the humerus and helps to extend the flexed arm. [23,25,26,29,30]

Deltoid- arises from the anterior border and upper surface of the lateral one third of the clavicle, from the whole of the lateral border of the acromion and from the inferior lip of the crest of spine of the scapula. From the ridge, and limbs of the V, three fibrous septa pass upwards between four septa to the acromion. The spaces between the septa are filled with a fleshy mass of muscle fibres which are attached to contiguous septa. The multipennate centre of the deltoid so formed has a diminished range of contraction, but a correspondingly increased force of pull. The anterior and posterior fibres, arising from the clavicle and the scapular spine, are not multipennate. They converge on the anterior and posterior margins of the deltoid tuberosity, and their range of movement is greater but the force of their pull is less.[24,25,26,28,29,30] Working with supraspinatus, deltoid abducts the arm by the multipennate acromial fibres. The anterior fibres assist pectoralis major in flexing and medially rotating the arm; the posterior fibres assist lattissimus dorsi in extending the arm and act as a lateral rotator. [24,25,26,29,30]

Pectoralis Major- is a thick triangular muscle. It originates from the medial half of the clavicle from the sternum, and from the upper 6 costal cartilages. Its fibres converge and are inserted by a bilaminar tendon into the lateral lip of the bicipital groove of the humerus.[23,26,27,29] Pectoralis major adducts the arm, medially rotates it and also flexes the arm(action of the fibres of the clavicular head of the pectorais major).[23,29,30]

2.3 SCAPULAR CONTROL MUSCLES

The scapula acts as a base for muscle attachment. The scapula performs five major roles in shoulder function. These include-

a. Acting as a stable part of the glenohumeral articulation.[51]

b. Retracting and protracting along the thoracic wall

c. Elevating the acromion

d. Acting as a stable base for muscle attachment

e. Acting as a link in the proximal to distal sequencing of velocity, energy, and forces that allows the most appropriate shoulder functions.

The scapular stabilizers attach to the medial, superior and inferior borders of the scapula and control the motion and position of the scapula to allow it accomplish all of its roles.[51] The scapulothoracic musculature plays a significant role in shoulder stability by providing a stable base of support for the glenohumeral muscles to fixate and function from.[52] These muscles position the glenoid beneath the humeral head, adjusting for the changing position of the arm. With periscapular dysfunction, there may be a failure to maintain a stable glenoid platform, an unlinking of scapulohumeral rhythm, and mild to severe winging of the scapula.[46]

The scapular control muscles includes:

a. trapezius

b. serratus anterior

c. levator scapulae

d. rhomboids

e. latissimus dorsi

f. pectoralis minor

Trapezius- is a large flat muscle, the most superficial of the upper part of the back. It arises in the middle line from skull to lower thorax and converges on the outer part of the pectoral girdle. Its origin extends from the medial third of the superior nuchal line to the spine of C7 vertebra, finding attachment to the ligamentum nuchae, between the external occipital protuberance and the vertebral spine. Below this, the origin extends along the spinous processes and supraspinous ligaments of all 12 thoracic vertebra. The upper fibres are inserted into the medial third of the clavicle at its posterior border; the middle fibres can be traced into their insertion along the medial border of the acromion and the superior lip of the crest of the scapula spine. The part of the muscle which arises from the lowest half dozen thoracic spines is inserted by a narrow recurved tendon into the medial end of the spine. All the fibres of trapezius help to retract the scapula, while the upper and lower fibres are important in scapular rotation. The upper fibres can elevate the whole scapula or prevent its depression. They can also produce lateral flexion of the neck.[25]

Serratus anterior- is a broad sheet of thick muscle which clothes the side wall of the thorax and forms the medial wall of the axilla. It arises by a series of digitations from the upper eight ribs. The muscle inserts into the costal inner surface of the scapula.

Serratus anterior protracts the scapula, and assists trapezius in rotating the scapula laterally and upwards in raising the arm above the level of the shoulder.[25]

Levator scapulae- is a strap like muscle which appears in the floor of the posterior triangle. It arises from the transverse process of the atlas and axis and from the posterior tubercules of the third and fourth cervical vertebra. It is inserted into the medial border of the scapula from the superior angle to the spine. Levator scapulae along with the upper part of trapezius, can elevate the scapula and laterally rotate the cervical spine.[25]

Rhomboids- Rhomboids consists of rhomboid major and rhomboid minor. The *rhomboid major* arises from four vertebral spines (T2-5) and the intervening supraspinous ligaments. It inserts into the medial border of the scapula between the root of the spine and inferior angle.

Rhomboid minor is a narrow ribbon of muscle parallel with rhomboids major, arising from 2 vertebral spines (C7, T1) and inserted into the medial border of the scapula at the root of the spine. Rhomboids draw the vertebral border of the scapula medially and upwards. With trapezius, they retract the scapula i.e. squaring the shoulders.[25]

Pectoralis minor – is a small triangular muscle which arises from the third, fourth and fifth ribs under cover of pectoralis major. The insertion is by a thick tendon into the medial border and upper surface of the coracoid process of the scapula (not to the tip of the process). It assists serratus anterior in protraction of the scapula, keeping the anterior (glenoid) angle in apposition with the chest wall as the vertebral border is drawn forwards by serratus anterior.[25]

2.4 RELIABILITY

Reliability refers to the extent to which a consistent score is obtained on different administrations of the instrument when all relevant conditions remain essentially constant [21,22] The need for test-retest reliability is clinically important, for long term follow up. When test-retest is good (ICC values of 0.75 and above)[22], unilateral comparison over a long period of time is possible.

2.4.1 Measurement of Reliability

Magnitude/ Strength of the Reliability Coefficient

According to Portney and Watkins,[22] reliability is hardly ever perfect, and reliability coefficients of 1.00 are rare. It is a property of an instrument that is attained to varying degrees. Most researchers establish limits that define acceptable levels of variability. Although such limits are essentially arbitrary, as a general guideline-

Below 0.50	Poor reliability
0.50 - 0.75	Moderate reliability
0.75 and above	Good reliability

According to Currier,[58] no universally accepted values have been established for reliability coefficients. The following criteria were suggested-

0.90 to 0.99	High reliability
0.80 to 0.89	Good reliability

0.70 to 0.79 Fair reliability

0.69 and below Poor reliability

The first way to interpret the coefficient is to examine the strength of the relationship, which is independent of the direction (direct or inverse) of the relationship.

The strength of the correlation coefficient by Domholdt[59] is given below-

0.00-0.25 little, if any correlation

0.26-0.49 low correlation

0.50-0.69 moderate correlation

0.70-0.89 high correlation

0.90-1.00 very high correlation

The above system of descriptors assumes that the meaningfulness of a correlation is the same regardless of the context in which it is used. This assumption is not necessarily valid. For example, if one is determining the reliability of a strength measure from one day to the other, an r (correlation) of 0.70 may be considered unacceptably low for the purposes of documenting day to day change in status. However, if one is determining the relationship between abstracts such as self esteem and motivation that are difficult to measure, then a correlation of 0.50 may be considered very strong.[35]

These limits must however be based on the precision of the measured variable and how the results of the reliability test will be applied. For example, researchers may be able to tolerate lower reliability for measurements that are used for description of groups, whereas those for decision making or diagnosis of individuals need to be higher, perhaps at least 0.90 to ensure valid interpretation of findings.

For the purpose of this study, however, the description by Currier was used for the interpretation of the results obtained from the study because, his guidelines best fit the purpose of this study. The results of this study will be used for clinical decision making and diagnosis of individuals. Thus, the value given to high reliability of 0.90-0.99, ensures valid interpretation of the results of this study which will be used for clinical diagnosis and decision making.

2.4.2 Factors Affecting Reliability of Isokinetic Torque Measurements

Test- retest reliability is important for long term follow up, however, data on the reliability of isokinetic dynamometry of the shoulder are scarce.[1,5] Accurate assessment of muscle strength is important in the prevention and treatment of shoulder injuries. Shoulder injuries are known to be frequent and often extensive in degree or number in athletics or occupations in which the arm is moved with high velocity, under load, or is stressed at end range.[31] Several factors can influence the reliability of isokinetic measurements of the shoulder joint.[1,6] They include the following:

(a) POSITIONING

A variety of test positions have been used in isokinetic measurements of the shoulder e.g. sitting, standing, lying supine and with different angles of abduction and flexion of the shoulder[16,32] The lack of data on shoulder muscle strength may be due in part to the difficulty in stabilization and evaluation of the multiaxial components. These limitations have, however, been reduced by introduction of isokinetic testing in scientific research.[31] The traditional isokinetic testing protocols documented for shoulder rotators during concentric activity places the subject supine with the shoulder at either 90 degrees abduction or 90 degrees flexion are potentially injurious to the rotator cuff by impingement of the supraspinatus tendon.[31] However, there have been no documented injuries.

Results of a test-retest reliability study performed by Hageman et al.,[33] of shoulder internal and external rotators performed with the subjects seated in a position of 45 degrees glenohumeral flexion and 45 degrees glenohumeral abduction, performed on 6 randomly selected subjects of the 20 who took part in the study, reported ranges from 0.83 for external rotators during eccentric contractions in mid abduction at 180°/sec to a high of 0.93 for internal rotators during concentric activity in midflexion position at 60°/sec. In this study, the 45 degrees forward flexed position placed the subject facing the dynamometer with the tested extremity at 45 degrees glenohumeral flexion from neutral (forearm in line with the acromion process) , and 90 degrees of elbow flexion. All the testing for this position was performed in a limited range for safety purposes with maximal shoulder external rotation at 15 degrees and maximal shoulder internal rotation at 60 degrees. For the 45 degrees glenohumeral abduction position, the subject sat beside the dynamometer with the tested extremity at 45 degrees glenohumeral abduction, zero degrees of glenohumeral flexion and 90 degrees of elbow flexion. The range of motion tested was limited to shoulder external rotation at 60 degrees and shoulder internal rotation at 30 degrees. This was for standardization of the test protocol. The reason for the different range of motions used was however not given. No gravity correction was reported in the study,[33] which could also have affected the results of the study. Isokinetic assessment involves movement of a limb through a gravity dependent position, gravity correction procedures should be employed to account for the weight of the dynamometer's lever arm and the limb being tested.[17] Regardless of muscle group, acceleration of the limb due to gravity erroneously adds to torque, in that direction. Conversely, additional force must be exerted to accelerate the limb against gravity, and this tends to reduce the torque output recorded.[17]

Other studies have highlighted the difference between isokinetic evaluation of shoulder rotational strength between the plane of the scapula and the frontal plane. Isokinetic testing and rehabilitation have previously been done in either the frontal or sagittal planes.[20,34,35,36] Glenohumeral movements in the scapula plane are less complex, than those in the frontal plane, providing more anatomical stability, more optimum muscle length-tension relationship, more congruous joint surfaces for movement and better approximation of joint surfaces.[10,19] Poppen and Walker[37] suggested that the true plane of movement in the shoulder joint occurs in the plane of the scapula. The plane of the scapula is clinically significant because the length-tension relationship of the shoulder abductors and rotators are optimum in this plane for elevation.[20,37,38] Specific muscles including the subscapularis, supraspinatus, infraspinatus and teres minor run from the scapula to the humerus.[20,25,26,28] Reorienting the humerus to the plane of the scapula places the humerus 30 to 45 degrees anterior to the frontal plane.[20,37] This change in position increases the distance from the humerus to the scapula, and lengthens the subscapularis, supraspinatus, infraspinatus and teres minor.[39] Research has demonstrated that the length of the muscle determines the amount of stretch applied to the individual sacromeres, enabling them to exert maximum tension. The length-tension curves obtained from normal muscles show that maximum tension is developed when the muscle length is approximately 90 percent of its maximum length.[20,39] Conversely, when the muscle is fully shortened, the tension developed is minimal.[20,39,40,41] Therefore, the optimal lengthened position of the muscle facilitates muscle contraction. In addition to optimal muscle length-tension relationships in the plane of the scapula, the capsular fibres of the glenohumeral joint are relaxed. [10,20]

Despite evidence to support activity in the scapular plane, most assessment occurs in the frontal plane, increasing the potential of impinging the rotator cuff tendons under the subacromial arch. [11,19,32] However, Soderberg and Blaschak[31] tested the internal and external rotators in six different shoulder positions and three different velocities (60,180,300°/sec). the tests were done in the sitting position. The positions of the shoulder were the neutral , midabduction, full abduction, midflexion, full flexion, and midposition. The results demonstrated that the external rotators muscles were optimally tested with the subject seated and with the arm of the subject in 90 degrees of shoulder abduction and in 90 degrees of elbow flexion. Although they found the internal rotator muscles to be strongest with the shoulder in neutral position , while the 90°/90° position yielded the third highest overall torque values.

During isokinetic testing, measurement error will increase if the axis of rotation of the limb is not congruent with the dynamometer axis.[10] Also, change in length tension relationship created by inaccurate positioning of the body or limb segment may influence muscle performance.[10] Therefore, adequate positioning is important if reliable readings are to be obtained.

(b) STABILIZATION

Stabilization of subjects on a dynamometer should be done in a way to isolate the target muscle group and to eliminate as much as possible, contribution from accessory contribute to the total force production. Hence the need for the use of straps for proper stabilization.

(c) GRAVITY CORRECTION

When isokinetic assessment involves movement of a limb through a gravity dependent position, gravity correction procedures should be employed to account for the weight of the dynamometer's lever arm and the limb being tested.[17,72] Regardless of muscle group, acceleration of the limb due to gravity erroneously adds to torque. Conversely, additional force must be exerted to accelerate the limb against gravity, and this tends to reduce the torque output recorded. The importance of gravity correction in obtaining valid strength measures, particularly of the quadriceps and the hamstrings has been established by research.[17] In the case of the thigh musculature, quadriceps force may be underpredicted by 4% to 43%, and hamstrings force maybe over predicted by 155 to 510%.[17] When shoulder internal and external rotation are assessed from a seated position, the internal rotators are assisted by gravity and the external rotators are opposed by gravity. Gravity correction tends to increase values obtained during shoulder external rotation and decrease values obtained during internal rotation.[17]

According to Perrin,[17] gravity correction appropriately increases shoulder external rotation values and decreases internal rotation values, thereby increasing the external / internal rotation reciprocal muscle group ratio. This correction allows an accurate determination of reciprocal muscle group ratios.

(d) ENVIRONMENT

It has been suggested that subject induced noises or room noises are psychological factors, or stressors that modify performance.[10] The use of a standardized test protocol is advocated to maximize performance , and clinicians should be aware that test score variability may be higher in a less controlled setting.[10]

(e) NEUROMOTOR LEARNING

Hislop[47] states that motor learning is the sum of all the changes in the nervous system wrought by repetitive activity and practice. It has been suggested that repeated muscle testing alone may provide sufficient perceptual training to influence motor performance.[10] In the cases of both concentric and eccentric contraction, an adequate familiarization period should be provided for each patient in the form of warm up repetitions prior to assessment at each test velocity, and should consist of first submaximal and then maximal efforts.[17] Three to four repetitions are recommended to achieve maximum torque. Perrin[17] advises adequate patient education and familiarization to obtain reliable and valid assessment.

(f) MOTIVATION

Cratty[48] suggests that motivation, is a broad term referring to a general level of arousal to action. It influences the initial attitude of the individual, his preparatory "set" and his state of readiness for action. Because quantitative assessment of muscle performance with isokinetic dynamometry relies on maximal subject effort, motivation may influence test results. Fatigue, pain or boredom during a task may act as a negative motivator. Also, the desire to excel at a task, especially if it is new or complex, and the need to exceed previous performance are critical variables in performance.[10] Hislop[47] observed higher increases in elbow flexor muscle strength when the subject's desire to achieve seemed great.

(g) VELOCITY

Isokinetic dynamometers enable assessment and exercise throughout a range of velocities. Depending on the instrumentation, this potential velocity spectrum may range from 1 to 500 deg/s.[17] The choice of the preset angular velocity in isokinetic measurements of the shoulder joint is arbitrary rather than scientifically based. Low and high angular velocities are often used; the assumption is that a low angular velocity relates to maximal voluntary contraction and a high angular velocity relates to muscle coordination which is important in functional activities. The motivation for the used angular velocities (often 60°/second, 180°/second and sometimes 300°/second) is not given.[1,4,42,43,44] For sportsmen using their arms, high angular velocities (> 180°/second) are often used.[1,4,42,43,44] For the purpose of this study, 60°/second, 180°/second was used to determine the test-reliability at both low and high angular velocities.

(h) MUSCLE FATIGUE

The rest interval separating test repetitions may influence force measurements. When a rest interval of 30 seconds interrupted reciprocal knee flexion and extension test repetitions, the torques produced were on the average 5% greater than when test repetitions were performed without rest.[49] Therefore, adequate rest intervals should be allowed between testing sessions.

(i) STARTING FORCES OR ACTIVATION FORCES

A pre-selected minimum force that must be applied to the load cell to initiate movement of the lever arm. The purpose is to prevent accidental initiation of the lever arm movement and to allow build up of force generated by the tested muscle so that maximum torque is achieved earlier in the test range of motion than under conditions of no preload. The same preload may be used for all subjects, for example, 20N, or the preload may be determined for each subject using a percentage of the maximum torque subject is capable of generating under the test conditions.[49]

(j) DAMP SETTINGS

Engaging an isokinetic dynamometer's resistance mechanism necessitates accelerating a limb to the predetermined test velocity. Deceleration of the overspeeding limb and lever arm produces a transient peak, or spike, in the isokinetic torque curve. This is the overshoot phenomenon. To compensate for this overshoot mechanism, various isokinetic manufacturers have incorporated a damp/ramp/preload feature into their instrumentation. Damping is intended to eliminate artifacts or peak torque overshoot.

(k) MUSCLE ACTION (single, reciprocal or continous, concentric or eccentric)

Isokinetic testing can be performed with concentric or eccentric contractions. Measurements for maximum concentric contractions of specified muscle groups differ from measurements of eccentric contractions, with eccentric peak torque being greater than concentric peak torque.[49,50]

(l) VERBAL ENCOURAGEMENT

The presence or absence of verbal encouragement can have a drastic effect on ability to produce maximum effort. Encouragement is proably more likely to stimulate a maximal effort during any kind of strength assessment or performance. But because encouragement can not be consistent among testers or between test sessions, subjects should be instructed before each series of repetitions to produce a maximum effort, and the tester should remain silent during the test.[17]

(m) CALIBRATION

Calibration is a process by which the measuring tool is compared with standard measures to determine its accuracy. If, inaccurate, some measuring tools can be adjusted until they are accurate.[55] Calibration is important to determine the correct position, value, capacity of an isokinetic dynamometer. It is important, so that readings taken from the isokinetic dynamometer are absolute rather than relative. The types of calibration usually done for dynamometers includes the angle calibration, velocity calibration, load cell and jog handle calibration, hydraulic system calibration.[54] The calibration on isokinetic dynamometers have already being done by the manufacturer. This involves both hardware and software calibration. The isokinetic dynamometer requires calibration once every year or two years. Thus, the isokinetic dynamometer rarely needs subsequent hardware calibration.[54]

2.4.3 Peak Torque and Average Torque

If the force or torque produced by a muscle has been assessed throughout the entire range of motion tested, the measurement may be reported as either peak or average value. The peak value would be from the point in the range of motion tested where the greatest force or torque was produced.[17] An average value would be calculated from the tension produced by the muscle throughout the entire range of motion tested. The use of average values necessitates careful standardization of the range of motion being tested when making pretest, posttest, or bilateral muscle group comparisons. In contrast, peak force or torque is likely to occur within the midrange of motion assessed. As such, standardization of the range of motion tested for measurements of peak values may not be as essential as when average values are of interest. Any of these values provide valid assessment of a muscle's ability to generate tension.[17]

For the purpose of this study, peak torque was used. The reason is that with a standardized protocol and the use of peak torque as the variable, the data was more stable, compared to the use of average torque. Another reason is that peak torque is the most widely parameter in isokinetic dynamometer.[1,7,10,19,20]

To ensure high intrarater reliability, a standardized protocol was strictly followed, as this also increased the test-retest reliability of the test measures of the test measures.

2.4.4. Reliability Reports From Previous Studies Of Isokinetic Measurement Of Shoulder

A variety of test positions have been used in isokinetic measurements of the shoulder e.g. sitting, standing, lying supine and with different angles of abduction and flexion of the shoulder.[6,32] However, it is not known which is the most reliable position.[1,6]

Meeteren et al.,[1] in their study, on test-retest reliability of isokinetic muscle strength measurements of the shoulder using low and high velocities for abduction and adduction (60°/second and 120°/second), and for internal and external rotation (60°/second and 180°/second), using twenty subjects in a sitting position), reported good to excellent reliability with intraclass correlation coefficient ranging from 0.69 to 0.92, using the Biodex Multi joint system.[1] However, the value of 0.69 should not be described as good according to Currier[58], since the values obtained for this type of study would be used for clinical diagnosis.

Another study by Frisiello et al.,[7] on test-retest reliability of eccentric peak torque values for shoulder medial and lateral rotation using the Biodex isokinetic dynamometer in standing reported an intraclass correlation coefficient ranging from 0.75 to 0.86. The reliability was fair to good. This study, demonstrated that the isokinetic mode of the Biodex dynamometer was reliable for the test-retest measure of peak torque.[7]

High test-retest reliability was also reported by Plotnikoff et al.,[5] using the KinCom isokinetic dynamometer in their study on test-retest reliability of glenohumeral internal and external rotator strength, using 14 subjects. The intraclass correlation coefficient values was described as high, with values ranging from 0.82 to 0.97. The subjects were tested in the seated position. According to Currier[58] this would be described as good to high reliability. The subjects were tested in the seated position.

Whitcomb et al.,[45] reported findings on the comparison of torque production, during dynamic strength testing of shoulder abduction in the coronal plane and the plane of the scapula, using the Cybex II isokinetic dynamometer. The results of the study showed there was no difference in torque production between the two planes. The intraclass correlation values ranged from 0.83-0.99. This revealed good to high relaibility. The subjects were seated during the testing period.[45]

Tis and Maxwell.,[19] in their study on the effect of positioning on shoulder isokinetic measures in females showed significant differences in peak torque, total work and average power between the dominant and non dominant extremities. The test position was supine. Peak torque, total work and average power were significantly greater in the scapular plane than in the frontal plane. Test-retest reliability revealed Pearson product moment correlation coefficients ranging from r= 0.86-0.99 for peak torque, r= 0.81-0.99 for total work, and r= 0.83-0.96 for average power. This study revealed good to high reliability.

Greenfield et al.,[20] in their study on isokinetic evaluation of shoulder rotational strength between the plane of scapula and the frontal plane in standing, showed statistically significant higher torque values for external rotational strength values in the plane of the scapula, than in the frontal plane. However, no difference in internal rotational strength values was found betweeen the two positions. The Pearson correlation coefficients ranged from 0.81-0.95 for all testing conditions. This revealed good to high relaibility. Their results suggested the clinical efficacy for shoulder strengthening in the plane of the scapula rather than the frontal plane.

Malerba et al.,[10] in their study on the reliability of dynamic and isometric testing of shoulder external and internal rotators, showed that isometric tests were generally most reliable with good to high reliability (intraclass correlation coefficient = 0.81-0.93), followed by concentric with poor to high reliability (intraclass correlation coefficient = 0.60-0.95) and eccentric tests with poor to high reliability (intraclass correlation coefficient = 0.44-0.92).[10] The results of the study also showed that isokinetic and isometric reliability were usually higher for involved than uninvolved shoulders. The measurements were done in a seated position.[10] However, isometric tests have certain disadvantages- Isometric exercises can produce a spike in systolic blood pressure that can result in potentially life threatening cardiovascular accidents.

Table 1
Reliability Studies on Isokinetic Muscle Strength Measurement for The Shoulder Internal and External Rotators.

Author	*Position/type of isokinetic dynamometer*	*Reliability*	*Velocity tested*	*(1) Variable measured (2) Type of Muscle Contraction*
Meeteren et. al.	Sitting/Biodex dynamometer	Int rot. =0.81-0.92, ext rot= =0.74-0.87 (ICC)	60°/sec, 120°/sec (add/ abd), AND 60°/sec, 180°/sec (int/ext rot)	(1) Peak Torques (2) Not specified
Frisiello et. al.	Standing/ Biodex dynamometer	Int/ext rot. =0.75-0.86 (pearson's r)	90°/sec and 120°/sec	(1) Peak Torque (2) Eccentric
Plotnikoff et. al.	Sitting/ Kincom dynamometer	Int rot. =0.87-0.91, ext rot= 0.89-0.94 (ICC)	30°/sec	(1) Average Torque (2) Concentric and eccentric
Tis and Maxwell	Supine/ Cybex 6000	Int/ext rot. = 0.86-0.99 (pearson's r)	1.047 rad.s^{-1}, 2.094 rad.s^{-1}	(1) Peak Torque, Total Work, Average Power (2) Concentric
Greenfield et. al.	Standing/Merac dynamometer	Int rot. =0.92 ext rot.= 0.80-0.94 (pearson's r)	60°/sec	(1) Peak Torque (2) Not specified
Malerba et. al.	Sitting /Biodex dynamometer	Int rot. = 0.60-0.95 ext rot =0.44-0.90 (ICC)	60°/sec, 120°/sec	(1) Total Work, Average Power (2) Concentric and eccentric

2.4.5 RELIABILITY COEFFICIENTS

Test-retest has traditionally been analyzed using the Pearson product-moment coefficient of correlation (for interval to ratio data), and Spearman's rho for ordinal data. As correlation coefficients however, they are limited as estimates of reliability, as it reflects only correlation.[22] The Intraclass correlation coefficient (to be used in this study) has become the preferred index because it reflects both correlation and agreement.[22]

Correlation reflects the degree of association between 2 sets of data, or the consistency of position within two distributions. For example, if the measurements of height and shoe size on a sample of adult men was taken, a correlation between the two variables would be found. That is, those with big feet tend to be tall, and those with small feet, short.[22]

Agreement means that the actual values obtained by two measurements are the same and not just proportional to each other. For example, range of motion is used to evaluate joint dysfunction on the basis of actual not just relative limitations. We need to know the true value of the limitation, not just that one patient is more limited than the other.[22]

For most research and clinical applications, the essence of reliability is agreement between the two tests. The goal is to know that the values obtained by the two measurements are the same, not just proportional to each other.[22]

2.4.6 CONTRIBUTION OF THIS STUDY TO THE BODY OF KNOWLEDGE

Several groups have used isokinetic dynamometer to study the strength characteristics of various muscle groups, in athletes, normal subjects and subjects with pathological conditions.[1,2,3,9,11,32,42,43] Few studies however address the issue of test-retest reliability of these measures, i.e the positioning, whether sitting, standing or lying. Several studies[1,6] use various protocols, particularly the knee joint. This may be due to the inherent stability of the knee joint, which makes it easier for testing.

Few studies, however, have addressed the issue of test-retest reliability of isokinetic muscle strength measurements in the shoulder.[1,5,6] A search of the literature has revealed no studies comparing the test-retest reliability of isokinetic muscle strength measurements of internal and external rotator muscles of the shoulder joint in sitting and supine lying. Hence, this study focussed on the of the test-retest reliability of isokinetic muscle strength measurements of internal and external rotator muscles of the shoulder joint in sitting and supine lying.

Thus, this study:

a. provided evidence that the clinician needs to know about which position (sitting or supine) and which protocol is more reliable in test-retest reliability of isokinetic muscle strength measurement of the shoulder internal and external rotators.
b. helped increase the database available on this subject, since only a few studies have addressed the issue of test-retest reliability of isokinetic muscle strength measurement of the shoulder internal and external rotators.
c. helped to validate some of the results obtained from previous studies.

DIFFERENCES FROM PREVIOUS STUDIES

1. Previous studies have only studied the test-retest reliability in one position, i.e sitting, standing, or supine. This study looked at the test-retest reliability in 2 positions (sitting

and supine) using the same subjects, hence increasing the strength of the study (same subject design).

2. Previous studies on test-retest reliability have used only one protocol. This study used two protocols, and from the results, it was hoped to be able to determine which of the protocols was more reliable.

3. Previous studies have only used 2 sessions for the test-retest reliability, making learning and fatigue an issue. It cannot be certain that in using the first session for familiarization and also testing, that sufficient learning has taken place. Slow learners may require more than the proposed number of familiarization contractions. Fatigue and familiarization (learning) are important factors which can affect the reliability of results.[49] This study addressed these issues by having 3 sessions, where the first session is devoted to familiarization, and the second and third sessions for testing.

SIMILARITIES WITH PREVIOUS STUDIES

1. Velocities (60°/sec and 180°/sec) used in this study have been used in previous studies.

2. The positions, that is sitting or supine, have been used in previous studies.

3. Proper stabilization of the subjects have been included in previous studies.

4. Warm ups have been in previous study and were used in this study.

5. The inclusion and exclusion criteria in this study was similar to those used in previous studies.

6. The age group used in this study was similar to that used in some previous studies.

CHAPTER 3

METHODOLOGY

3.1 Subject Selection-

Twenty healthy male and female subjects (see Appendix D for sample size calculation) between the ages of 18-32 years were drawn via a convenience sample of students and the general public. This age group was selected to ensure that subjects were musculoskeletally mature, and also to reduce the risk of degenerative changes being present in the shoulder joint.[71] This age group was also selected because other studies have also used similar age groups.

3.2 Inclusion Criteria-

1. Young adult between 18 and 32 years.
2. Subjects had no present or past history of cardiovascular or respiratory problems.

3.3 Exclusion Criteria-

1. History of shoulder pain, back or neck pain or within the past 8 months or having an unstable shoulder complex. This was determined by history of atraumatic or traumatic injury to the shoulder joint, presenting with subluxations and dislocations.
2. Previous history of injury to the shoulder joint.[5]
3. Utilization of anti-inflammatory medication at the time of the study.[5]
4. History of surgery to the shoulder joint.
5. Having an inability to understand consent.

6. Presence of abnormal shoulder range of motion. Any subject with shoulder internal rotation measurement greater than 70 degrees, and shoulder external rotation measurement greater than 90 degrees was excluded because of shoulder hypermobility.[56]

3.2 RECRUITMENT OF THE SUBJECTS

Subjects were recruited from the university community and the general public. Posters were displayed in Corbett Hall (Faculty of Rehabilitation Medicine) and other Faculties at the University of Alberta (see Appendix A).

3.3 INSTRUMENTATION

All testing was done on the Kin Com isokinetic dynamometer (Chattanooga, TN 37343). The Kin Com was used for the assessment of test-retest reliability of the shoulder internal and external rotators. All testing was be done at the orthopaedics laboratory of the Department of Physical Therapy, at the University of Alberta. The Kin Com isokinetic dynamometer measures torque, work, and power. The measure used for this study is peak torque. The peak value is the point in the range of motion tested where the greatest force or torque is produced.

3.4 CALIBRATION STATUS OF THE KIN-COM DYNAMOMETER

The Kin Com dynamometer requires calibration once in a year or two years according to the manufacturers. The Kin Com to be used in this study was last calibrated 6 months ago.

3.7 TYPE OF MUSCLE CONTRACTION

The concentric mode of contraction was used for this study, because of the minimized risk of subjects developing muscle injury and soreness which are selectively associated with eccentric contractions.[60]

3.8 PRELOAD/ACTIVATION FORCE AND CHOICE OF DAMP SETTINGS

Preload Force- The purpose of the preload was to prevent accidental initiation of lever arm movement and to allow buildup of force generated by the tested muscles so that maximum peak torque was achieved earlier in the test range of movement than under conditions of no preload.[49] Literature has shown that measurements of peak torque appear to be unaffected by the presence or absence of preload. The absolute value of the preload however affects average torque values.[49]

In addition, it has been noticed that the use of higher values on some subjects produced a torque curve that was not smooth at the initiation of the movement, because of the higher resistance. For this study, a preload of 5N was used for all subjects to standardize the value for all subjects.

Damp Setting- During the initial arc of motion tested, the lever arm of some electromechanical dynamometers accelerates to reach the preset speed. The point at which the preset speed is reached may show a bump in the torque curve, commonly referred to as "torque overshoot".[49] The Kin Com does not have damp settings, but the torque overshoot is modified by acceleration and deceleration rampings that can be set at low, medium, or high. These ramp settings put a ceiling on the amount of acceleration the lever arm is allowed by the instrument. A study examining the effects of different acceleration and deceleration rates on torques produced, found that the choice of ramp did not appear to have a meaningful effect on torque averaged over the whole curve nor did it affect peak torque.[49] For this study, a medium ramp setting was used to standardize the protocol.

3.9 HANDLE JOG PROCEDURE

The load cell reads forces in one direction, i.e internal rotation, external rotation, flexion, extension, concentric, eccentric. If one positions the load cell from one extremity, it will read force as if it were on the opposite side or inverted position. So whenever the load cell was repositioned e.g. for the left upper limb or the right, the hand jog procedure was performed.[54]

Procedure- one hand was placed on the load cell or pad attached to it, and the other hand on the lever arm. The load cell and the lever arm were pushed with both hands in the same direction as the direction of the movement to be performed. A gentle resistance was overcome, thus reversing the direction of force the load cell would read.[54]

3.10 GRAVITY CORRECTION

Gravity correction was done manually on all the measurements. The gravity effects calculated was added or subtracted from the force/torque at that position. In the gravity assisted position, they were subtracted, and at the gravity resisted position, the gravity effect was added. The weight of the limb was read off the Kin-Com dynamometer.

To calculate the gravity effects on the load cell, we used either of the following equations: sin x × weight of the limb or

cos y × weight of limb

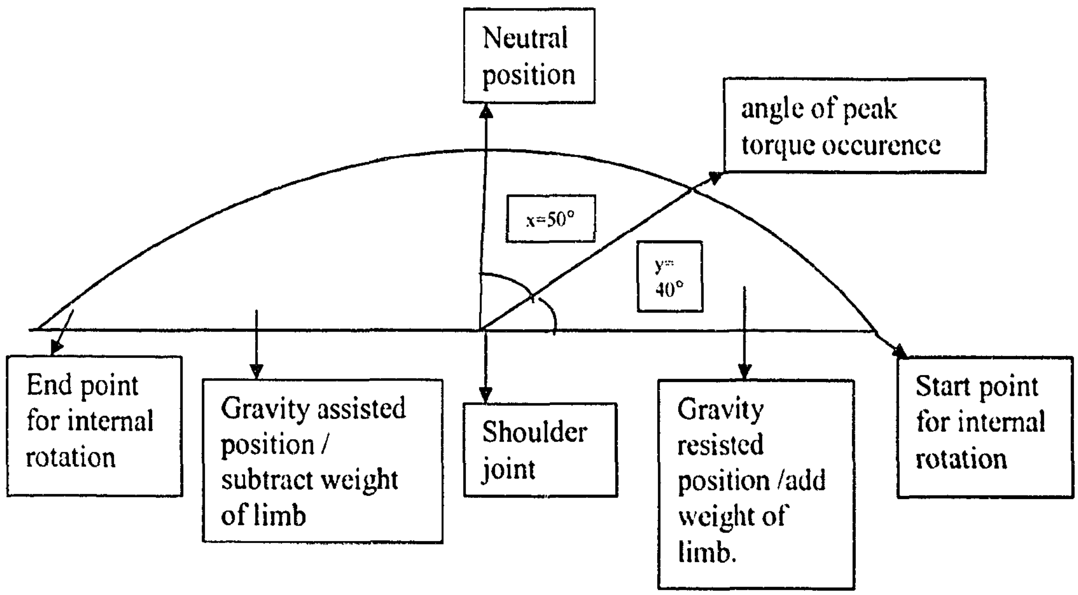

FIG 1- Illustration for gravity correction using internal rotation.

Example, when peak torque occurred at load cell position of 40° from the start point of internal rotation, and the weight of the limb was 20N, the gravity effects was:

Cos 40° × weight of the limb = cos 40° × 20N = 0.7660 × 20 = 15.32N

Sin 50° × weight of the limb = sin 50° × 20N = 0.7660 × 20 = 15.32N

This means that 15.32N was subtracted or added to the peak torque, depending on the angle at which peak torque occurred, to correct for gravity effects. This method of gravity correction was done for all the data collected.

3.11 RANDOMIZATION

Each subject was randomly assigned to the position order to be done either in sitting or supine lying. They had eight choices from which they drew one out of a hat (see below). This first session took approximately 60 minutes. For the position orders, 60°/sec was used first, followed by 180°/sec, so the subjects were adjusted to the increasing velocities.

Shoulder Position Protocols For The Study

1. Protocol A- The glenohumeral joint positioned in 45 degrees of scaption (scaption)

2. Protocol B- The glenohumeral joint is positioned in 90 degrees of abduction and elbow in 90 degrees of flexion (90/90).

Position order 1

The subject performed the first movements in sitting, and internal rotation was done first, followed by external rotation and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movements performed in supine with internal rotation also performed first, followed by external rotation and with the velocity of 60°/sec used first, followed by 180°/sec. Scaption (protocol A) was used first, followed by 90/90 (protocol B).

Sequence of position order 1:

Sitting: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec).

Supine: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec).

Scaption (protocol A), then 90/90 (protocol B).

Position order 2

The subject performed the first movements in sitting, and internal rotation was done first, followed by external rotation and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movements performed in supine with internal rotation performed first, followed by external rotation and with the velocity of 60°/sec used first, followed by 180°/sec. 90/90 (protocol B) was used first, followed by scaption (protocol A)

Sequence of position order 2:

Sitting: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec), Supine: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec). 90/90 (protocol B), then scaption (protocol A).

Position order 3

The subject performed the first movement in supine and external rotation was done first, followed by internal rotation and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movement in sitting with external rotation done first followed by internal rotation, and with the velocity of 60°/sec used first, followed by 180°/sec. Scaption (protocol A) was used first then 90/90 (protocol B).

Sequence of position order 3:

Supine: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec), Sitting: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec). Scaption (protocol A), then 90/90 (protocol B).

Position order 4

The subject performed the first movement in supine, and external rotation was done first, followed by internal rotation and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movement in sitting with external rotation done first followed by internal rotation, and with the velocity of 60°/sec used first, followed by 180°/sec. 90/90 (protocol B) was used first then scaption (protocol A).

Sequence of position order 4:

Supine: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec),

Sitting: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec).

90/90 (protocol B), then scaption (protocol A).

Position order 5

The subject performed the first movement in sitting, with external rotation done first, followed by internal rotation and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movement in supine with the external rotation done first, followed by internal rotation at the velocity of 60°/sec used first, followed by 180°/sec. Scaption (protocol A) was used first, then 90/90 (protocol B).

Sequence of position order 5:

Sitting: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec),

Supine: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec).

Scaption (protocol A), then 90/90 (protocol B).

Position order 6

The subject performed the first movement in sitting, with external rotation done first, followed by internal rotation and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movement in supine with the external rotation done first, followed by internal rotation at the velocity of 60°/sec used first, followed by 180°/sec. 90/90 (protocol B) was used first, then scaption (protocol A).

Sequence of position order 6:

Sitting: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec),

Supine: External rotation (60°/sec → 180°/sec) → Internal rotation (60°/sec → 180°/sec).

90/90 (protocol B), then scaption (protocol A).

Position order 7

The subject performed the first movement in supine, and internal rotation was done first, followed by external rotation, and the velocity of 60°/sec was used first, followed by 180°/sec. This was followed by movement in sitting, with internal rotation done first followed by external rotation with the velocity of 60°/sec used first, followed by 180°/sec. Scaption (protocol A) was used first followed by 90/90 (protocol B).

Sequence of position order 7:

Supine: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec),

Sitting: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec)

Scaption (protocol A), then 90/90 (protocol B).

Position order 8

The subject performed the first movement in supine, and internal rotation was done first, followed by external rotation, and the velocity of 60°/sec used first, followed by 180°/sec. This was followed by movement in sitting with internal rotation done first followed by external rotation with the velocity of 60°/sec used first, followed by 180°/sec. 90/90 (protocol B) was used first followed by scaption (protocol A)

Sequence of position order 8:

Supine: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec),

Sitting: Internal rotation (60°/sec → 180°/sec) → External rotation (60°/sec → 180°/sec)

90/90 (protocol B), then scaption (protocol A).

3.12. TEST PROTOCOL

All measurements were be done according to a standardized protocol. This study consisted of three sessions, at least four days apart. Three sessions were used for this study, to avoid the effects of fatigue carrying over from the first test to the next.[22] The time frame between the tests was a minimum of four days. The scores for the second and third trials was used for the test-retest reliability study.

The test range for all measurements was between 50 degrees external rotation and 50 degrees internal rotation.[9] The neutral position for all the measurements was defined as the midway between full internal rotation and full external rotation, measured with a goniometer. All test sessions occured in a quiet setting, free from noise. It has been suggested that subject induced noises or room noises are psychological factors, or stressors that modify performance.[10]

The FIRST SESSION consisted of subject education and familiarization. Reliable and valid assessment is obtained only with adequate subject education and familiarization with the concept of isokinetic exercise.[6,10,17] On the first session, each subject read and signed the consent form. If they met the criteria for the study, the subjects were checked for abnormal range of motion by the co-investigator, who is a physical therapist.[56] The assessment included active and passive range of motion measurements, to ensure that the range was normal. After this, each subject was given a 10 minute explanation of how the isokinetic dynamometer functions, subjects were informed that an isokinetic dynamometer is set at a predetermined velocity, and that resistance would be encountered only when the subject attempted to move the body segment at an equal or greater velocity. Subjects were told that uniformed commands would be used to start each testing session (because encouragement cannot be consistent between test sessions, subjects were instructed before each series of repetitions to produce a maximum effort, and the tester remained silent during the test).[17]

The concentric (internal rotation) – concentric (external rotation) mode was used. Subjects were asked to "push and pull as hard and fast as you can".[17] Only the dominant upper limb was tested, because this study was a test-retest reliability study, and the testing of both upper limbs would influence the results. So, to reduce the number of contractions performed by each subject, and ultimately fatigue, the dominant upper limb only was chosen for this study.

On the first familiarization session, subjects were randomly assigned to the position order to be used in their familiarization session by drawing from a hat. After positioning (figure 2 to 4 below), a minimum of five submaximal and five maximal concentric internal and external rotation repetitions were performed by the subjects for each muscle group and position to be tested. This gave the subjects a chance to familiarize themselves with the equipment and test positions, and also it also allowed the muscles to warm up. There was a 60 second rest period between the tests. This was to prevent muscle fatigue. After completing the familiarization session, subjects were asked to come back for a test trial after at least 4 days.[49]

At the SECOND SESSION, subjects used the same position order picked from the hat on the first session. They were then positioned (see below, 3.9.1 and 3.9.2) accordingly. They performed three submaximal and three maximal concentric repetitions,[49] to familiarize themselves with the exercise velocity and testing position and also to warm up the muscles. They then rested for a period of 60 seconds to prevent muscle fatigue. Following the rest period, the subjects were asked to "push as hard and fast" as they could into external rotation from the start position of full internal rotation. They performed this concentric contraction 4 times as multiple contractions were necessary to obtain a true maximal value of force or torque, regardless of test velocity (maximum torque is typically evaluated from the first 2 to 6 contractions). The 2 highest peak torque values were recorded, and averaged and used as the force value. There was a rest period of 60 seconds between each trial in the various positions, to prevent muscle fatigue.[1,5] This second session took approximately 60 minutes.

At the THIRD SESSION, subjects followed the same position order as used for the second test session. They then followed the same procedure as outlined for the second test session. This session took approximately 60 minutes.

For the first session, a minimum of 80 submaximal and 80 maximal concentric repetitions were performed by the subjects, with 60 seconds rest period between trials. For the second session and third sessions, a minimum of 48 submaximal and 48 maximal warm up contractions were performed. A total of 64 contractions were perfomed for the actual test itself. There was a 60 second rest period between trials, and also the time required to reposition the patients took about 5-10 minutes. This time interval was enough to ease the effects of fatigue.

The same examiner positioned the subjects and performed all measurements on the subjects.

3.12.1 Test Protocol For Supine lying - subject were strapped down at the chest and pelvis for stability on the UBXT.

3.12.1.2 Glenohumeral joint at 90 degrees of abduction

In supine lying position, the subjects were asked to place the glenohumeral joint in 90 degrees of abduction, (it was measured with a goniometer). Previous research indicates that intraexaminer reliability for goniometer measurements for abduction in the shoulder is high (with ICC values ranging from = 0.87-0.99).[61,62,63] The elbow joint was placed in 90 degrees of flexion. This position is often chosen, because the subject can be well stabilized.[43] The dynamometer axis was placed at the same level as the shoulder joint axis. The arm was then be placed on the shoulder rotation support. The shoulder rotation support was set to firmly wedge the upper arm in a v-pad with the wrist in the neutral position. The U.B.X.T (a stabilization apparatus which allowed the patient to lie supine while being tested) floor locked mechanism was engaged. Subjects were stabilized at the chest and pelvis. Measurements were performed at 60°/sec and 180°/sec respectively. These two angular velocities were used to determine if there was any difference in the reliability of the positions at low and high speeds. Meeteren et al.,[1] suggested that low angular velocities relate to maximal voluntary contraction, and high angular velocities relate to muscular coordination, which is important for functional activities. The preload and damp setting were set at 5N and medium damp setting respectively.

Figure 2- Protocol B with subject in supine lying

3.12.1.2 The glenohumeral joint at 45 degrees of scaption

In the supine lying position, the subjects were asked to place the glenohumeral joint in 45 degrees of scaption, and the dynamometer axis aligned accordingly. The arm was then be placed on the shoulder rotation support. The shoulder rotation support was set to firmly wedge the upper arm in a v-pad with the wrist in the neutral position. The subjects were stabilized at the chest and the pelvis. The U.B.X.T floor locked mechanism was engaged. Measurements were performed at 60°/sec and 180°/sec respectively. The preload and damp setting were set at 5N and medium damp setting respectively.

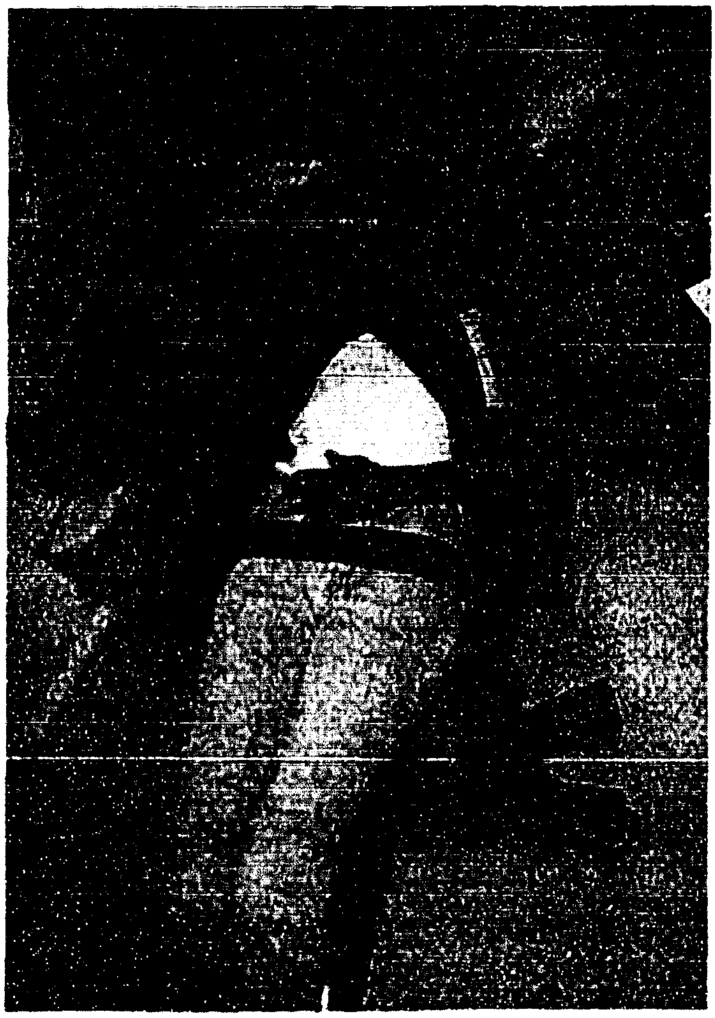

Figure 3- Protocol A with subject in supine lying

3.12.2 Test Protocol For Sitting-

Subjects were seated in a sturdy straight back chair. A torso stabilization strap was used around the chair back, and the pelvis was stabilized with a strap. The dynamometer axis was raised to the height of subject's shoulder height.

3.12.2.1 Glenohumeral joint at 90 degrees of abduction

In the sitting position, the subjects were asked to place the glenohumeral joint in 90 degrees of abduction (it was measured with a goniometer), and the elbow joint was placed in 90 degrees of flexion. The dynamometer axis was placed at the same level as the shoulder joint axis. The arm was then placed on the shoulder rotation support. The shoulder rotation support was set to firmly wedge the upper arm in a v-pad with the wrist in the neutral position. Measurements were performed at 60°/sec and 180°/sec respectively. The preload and damp setting were set at 5N and medium damp setting respectively.

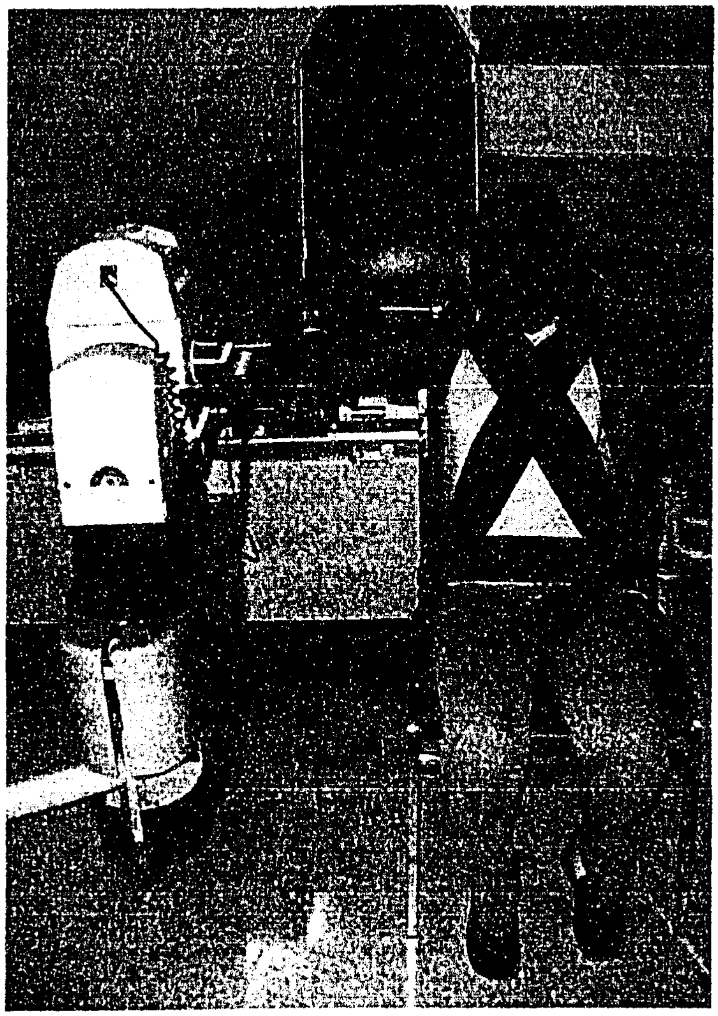

Figure 4- Protocol B with subject in sitting

3.12.2.2 The glenohumeral joint at 45 degrees of scaption

In the sitting position, the subjects were asked to place the glenohumeral joint in 45 degrees of scaption, and the dynamometer axis aligned accordingly. The arm was then placed on the shoulder rotation support . The shoulder rotation support was set to firmly wedge upper arm in a v-pad with the wrist in the neutral position. Measurements were performed at 60°/sec and 180°/sec respectively. The preload and damp setting were set at 5N and medium damp setting.

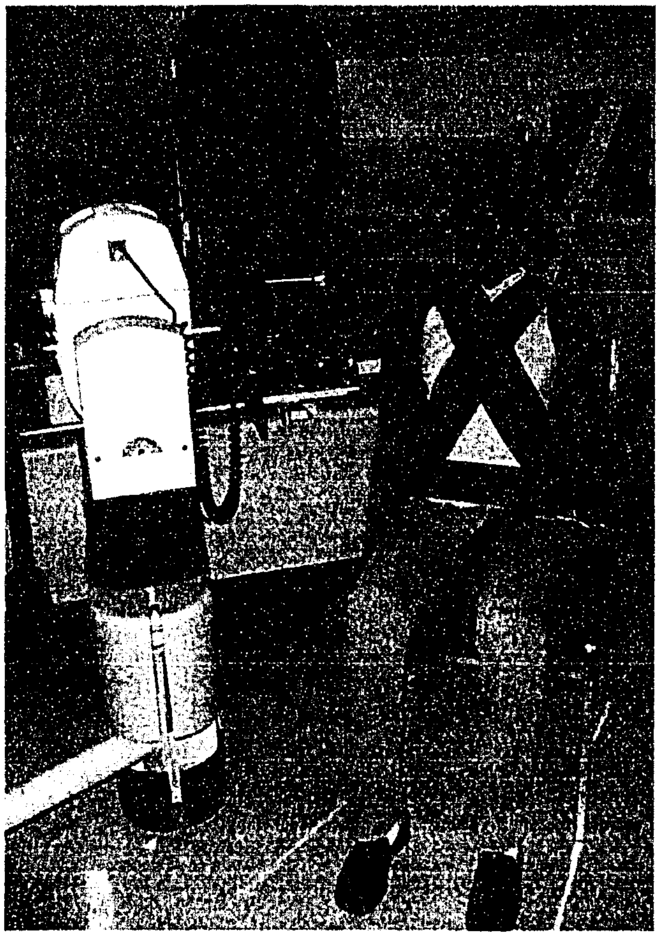

Figure 5- Protocol A with subject in sitting

3.13. COLLECTION OF DATA

Data collected were-

1. Descriptive (demographic) data- age, sex , height.

2. Peak torques at 60°/second and 180°/second were collected for supine and sitting for the 2 shoulder position protocols for the internal and external rotators. Two sets of data for each measurement were taken.[1,22]

3.14. STATISTICAL ANALYSIS

In this study, the following statistical analyses was performed –

STEP I

1. For the sitting position, SPSS was utilized to calculate the Intraclass correlation coefficient to get the test-retest reliability for the concentric peak torque values (time 1 and time 2):

a. internal rotators at 60°/sec for shoulder position protocol A.

b. external rotators at 60°/sec for shoulder position protocol A.

c. internal rotators at 180°/sec for shoulder position protocol A.

d. external rotators at 180°/sec for shoulder position protocol A.

e. internal rotators at 60°/sec for shoulder position protocol B.

f. external rotators at 60°/sec for shoulder position protocol B.

g. internal rotators at 180°/sec for shoulder position protocol B.

h. external rotators at 180°/sec for shoulder position protocol B.

2. For the supine lying position, SPSS was utilized to calculate the Intraclass correlation coefficient to get the test-retest reliability for the concentric peak torque values (time 1 and time 2):

a. internal rotators at 60°/sec for shoulder position protocol A.

b. external rotators at 60°/sec for shoulder position protocol A.

c. internal rotators at 180°/sec for shoulder position protocol A.

d. external rotators at 180°/sec for shoulder position protocol A.

e. internal rotators at 60°/sec for shoulder position protocol B.

f. external rotators at 60°/sec for shoulder position protocol B.

g. internal rotators at 180°/sec for shoulder position protocol B.

h. external rotators at 180°/sec for shoulder position protocol B.

STEP II

The ICC values obtained from SPSS in supine and sitting was then used to interpret the results according to the guideline of Currier[58] where-

0.90 to 0.99	-	High reliability
0.80 to 0.89	-	Good reliability
0.70 to 0.79	-	Fair reliability
0.69 and below	-	Poor reliability

CHAPTER FOUR

4.1 RESULTS AND DISCUSSION

Twenty subjects participated in the study consisting of 15 males and 5 females. The test sessions were performed at least four days apart.

Table 2. Descriptive statistics of age, height, weight of subjects who participated in the study

	Mean ± standard deviation	Range
Age (years)	26.85 ± 3.13	19.00 - 32.00
Height (metres)	1.75 ± 0.12	1.53 - 1.98
Weight (kilograms)	68.43 ± 12.50	47.00 - 91.00

Table 3. Descriptive statistics for protocols A and B in sitting and supine lying showing the means for day 1 and day 2, and the upper and lower limits (range) for day 1 and day 2 and the standard deviation for day 1 and day 2.

	Mean (Day 1) (Nm)	Mean (Day 2) (Nm)	Lower Range (day1/day 2) (Nm)	Upper Range (day 1/day 2) (Nm)	Standard Deviation (day1/day 2) (Nm)
Supine- Int 60°/sec (Protocol A)	22.22	20.84	D1- 10.34 D2- 8.94	D1- 40.23 D2- 47.03	D1- 8.81 D2- 9.48
Supine- Ext 60°/sec (Protocol A)	22.09	23.38	D1- 11.34 D2- 10.96	D1- 37.57 D2- 60.07	D1- 7.11 D2- 10.63
Supine –Int 180°/sec (Protocol A)	17.83	18.38	D1- 6.11 D2- 7.99	D1- 36.77 D2- 37.48	D1- 7.28 D1- 7.32
Supine- Ext 180°/sec (Protocol A)	20.66	20.95	D1- 7.07 D2- 11.63	D1- 48.20 D2- 53.94	D1- 9.34 D2- 9.57
Supine- Int 60°/sec (Protocol B)	19.84	19.98	D1- 8.79 D2- 10.59	D1- 37.23 D2- 37.98	D1- 7.15 D2- 7.68
Supine- Ext 60°/sec (Protocol B)	22.29	22.01	D1- 11.25 D2- 11.40	D1- 44.46 D2- 51.72	D1- 8.43 D2- 8.85

Supine –Int 180°/sec (Protocol B	16.95	16.26	D1- 7.04 D2-7.89	D1- 30.07 D2- 36.17	D1-6.25 D2- 6.31
Supine- Ext 180°/sec (Protocol B)	20.74	20.39	D1- 9.28 D2- 11.08	D1- 39.29 D2- 50.90	D1- 7.94 D2- 9.09
Sit- Int 60°/sec (Protocol A)	19.86	19.21	D1- 7.58 D2- 7.27	D1- 41.09 D2- 38.01	D1- 7.91 D2- 7.20
Sit- Ext 60°/sec (Protocol A)	24.17	22.88	D1- 12.50 D2- 2.41	D1- 58.70 D2- 58.01	D1-10.52 D2- 11.37
Sit –Int 180°/sec (Protocol A)	17.24	16.92	D1- 5.82 D2- 8.51	D1- 33.59 D2- 30.47	D1- 6.94 D2- 5.92
Sit- Ext 180°/sec (Protocol A)	21.94	20.57	D1- 8.63 D2- 2.12	D1- 47.88 D2- 45.30	D1- 9.30 D2- 9.71
Sit- Int 60°/sec (Protocol B)	18.84	17.47	D1- 5.43 D2- 6.12	D1- 36.37 D2- 36.37	D1- 8.17 D2- 7.53
Sit - Ext 60°/sec (Protocol B)	22.72	20.80	D1- 10.87 D2- 2.69	D1- 54.09 D2- 57.46	D1- 9.32 D2- 10.39
Sit –Int 180°/sec (Protocol B	17.40	15.95	D1- 5.35 D2- 5.99	D1- 33.94 D2- 30.80	D1- 7.84 D2- 6.43
Sit- Ext 180°/sec (Protocol B)	21.49	20.71	D1- 11.01 D2- 2.58	D1- 49.85 D2- 49.99	D1- 9.50 D2- 9.32

D1 = day1, D2 = day 2, Nm = Newton metres

Table 4. Intraclass correlation coefficient in supine with the glenohumeral joint in 45 degrees of scaption (protocol A)

	Intraclass Correlation Coefficient (ICC)	Standard Error of Measurement (SEM) (Newton metres/Nm)	Interpretation
60°/sec- Internal Rotation External Rotation	 0.929 0.858	 4.740 6.570	 High ICC Value Good ICC Value
180°/sec- Internal Rotation External Rotation	 0.868 0.949	 4.985 4.164	 Good ICC Value High ICC Value

The results for protocol A in supine (Table 4) show that at velocities of 60°/sec and 180°/sec, ICC was between 0.858 and 0.949 for internal and external rotation respectively. This shows good to high test-retest reliability. The standard error of measurement ranged from 0.4164 to 6.570. Tis et al.,[19] studied the reliability in this position, but it was at 40 degrees anterior to the frontal plane at velocities of 60°/sec (1.047 rad.s^{-1}) and 120°/sec (2.094 rad.s^{-1}). The results of their study (only seven subjects participated in the test-retest reliability) showed Pearson's moment correlation coefficients ranging from 0.86 to 0.99. These results, however, cannot be compared to this study because Pearson moment correlation coefficients and ICC (statistical method used in this study) measure different things. Tis et al. [19],did not study the reliability at 180°/sec velocity. The lowest ICC value obtained in the present study was in the supine position with the glenohumeral joint in 45 degrees of scaption and using a velocity of 60°/sec, and movement of external rotation.

Table 5. Intraclass correlation coefficient in supine position with 90 degrees of abduction and 90 degrees of elbow flexion(protocol B)

	Intraclass Correlation Coefficient (ICC)	Standard Error of Measurement (SEM) (Newton metres/Nm)	Interpretation
60°/sec-			
Internal Rotation	0.909	4.283	High ICC value
External Rotation	0.929	4.451	High ICC value
180°/sec-			
Internal Rotation	0.895	3.876	Good ICC value
External Rotation	0.918	4.696	High ICC value

In the supine position for protocol B, at velocities of 60°/sec and 180°/sec, good to high test-retest reliability was shown (Table 5). The standard error of measurement ranged from 3.876 to 4.969. Tis et al.,[19] studied the reliability in this position, with the glenohumeral joint placed in 90 degrees of shoulder abduction and 90 degrees of elbow flexion of 60°/sec (1.047 $rad.s^{-1}$) and 120°/sec (2.094 $rad.s^{-1}$). The results of their study showed the Pearson's moment correlation coefficients ranging from 0.86 to 0.99. However, the results of their study cannot be compared with that of this study because of the different statistical methods used. Pearson's moment correlation coefficients and ICC are not comparable. Tis et al., [19] did not study the test-retest reliability at velocity of 180°/sec.

Table 6. Intraclass correlation coefficient with the glenohumeral joint in 45 degrees of scaption (protocol A)

	Intraclass Correlation Coefficient (ICC)	Standard Error of Measurement (SEM) (Newton metres/Nm)	Interpretation
60°/sec-			
Internal Rotation	0.872	5.097	Good ICC value
External Rotation	0.912	6.229	High ICC value
180°/sec-			
Internal Rotation	0.964	2.403	High ICC value
External Rotation	0.885	6.106	Good ICC value

The result for protocol A in sitting revealed good to high intraclass correlation. The standard error of measurement ranged from 2.403 to 6.229 (Table 6). A previous study[5] for velocity of 30°/sec in sitting that placed the shoulder at 50 degrees of abduction and 30 degrees of flexion revealed ICC values ranging from 0.88 to 0.94. Another study[10] similar to this, but carried out on patients with shoulder dysfunction found an ICC value of 0.70 for the uninvolved extremity and 0.76 for the involved extremity at a velocity of 60°/sec for shoulder external rotation. For internal rotation at a velocity of 60°/sec, they found an ICC value of 0.86 for the uninvolved extremity and 0.82 for the involved extremity. They did not study the effects at 180 °/sec. The reason that the present study obtained a higher ICC value overall, may be due to subject education and the fact that the tests were done over three sessions, so the subjects were familiar with the protocol.

The highest ICC value obtained in this study was in the sitting position with the glenohumeral joint in 45 degrees of scaption and a velocity of 180°/sec and movement of internal rotation. The high values obtained in this study was probably due to the standardization of the protocol used.

Table 7 Intraclass correlation coefficient in sitting with 90 degrees of abduction and 90 degrees of elbow flexion (protocol B)

	Intraclass Correlation Coefficient (ICC)	Standard Error of Measurement (SEM) (Newton metres/Nm)	Interpretation
60°/sec-			
Internal Rotation	0.923	4.200	High ICC value
External Rotation	0.962	3.770	High ICC value
180°/sec-			
Internal Rotation	0.917	3.969	High ICC value
External Rotation	0.947	4.219	High ICC value

A previous study in sitting position revealed an ICC value similar to that obtained in the present study (Table 7), with values ranging from 0.74 to 0.92.[1] The study revealed ICC value for females for external rotation was 0.74. For males, for external rotation, the ICC value was 0.87. For internal rotation for females and males, the ICC values were 0.81 to 0.92 respectively. The standard error of measurement ranged from 3.770 to 4.219. They did not differentiate between the two velocities. The protocol chosen may have been responsible for some of the differences used. Also, the high values obtained in the present study maybe attributed to subject education, and the fact that one session was dedicated to educating subjects and familiarizing them with the machine and how it works. This ensured that the subjects did not perform too many muscle contractions on one day which helped reduce the effects of fatigue. Overall, the result for protocol B in sitting revealed high test-retest reliability.

Overall this study demonstrated that the position of 90 degrees of shoulder abduction and 90 degrees of elbow flexion was more reliable in both sitting and supine position than the position of scaption. The study also revealed that the velocity of 60°/sec was overall more reliable than that of 180°/sec. This may be due to the fact that at a lower velocity, it was easier to stabilize and there is more time for adequate recruitment of muscle fibres and therefore subjects were able to control the movements better.

The standard error of measurement (SEM) obtained in this study varied from 2.403 to 6.570. The standard error of measurement shows how much a score is likely to vary with repeated testing of a subject.[59] To determine the amount of measurement error, many repeated measurements of the same subject are taken and the standard deviation of the scores calculated. This standard deviation is known as the standard error of measurement.[59] In a case of perfect agreement (zero bias; ICC=1), the standard error of measurement is zero, and any change is a true one.[72] The standard error of measurement values (SEM) obtained in this study was not inversely proportional to the ICC value, that is, as the ICC value approaches one, the standard error of measurement did not approach zero. For there to be a conclusive clinical change or difference in measurements obtained on repeated testing of a patient, the difference in values from one day to the next would have to be beyond the upper and lower limits of the SEM obtained for the different positions respectively.

One major difference between this and other studies is the fact that the same subjects performed all the movements in the various positions and at various speeds. Search of the literature revealed that in most studies only one position was used.

Randomization of the test positions carried out in this study, reduced the probability that a particular position was always used first during the test sessions. This gave equal opportunity for all the test positions to be used first, thus reducing bias in the study.

The rotator cuff musculature has traditionally been assessed and rehabilitated by performing internal and external rotation movements in the frontal plane.[5,19] Significant differences in muscle performance have not been demonstrated between the frontal and scapular plane of testing, although the scapular plane of motion positions the glenohumeral joint near its loosed packed position, maximizing the potential for motion during rotation.[5] The position of scaption is advocated by some authors because of anatomical and biomechanical considerations.[1,16] Glenohumeral movements in the scapular plane are less complex, providing more anatomical stability, and have more congruous joint surfaces for movement.[19] It has been suggested that the true plane of movement in the shoulder occurs in the plane of the scapula.[1] For people with pathology at the shoulder complex, the use of the scapula plane has been advocated. It is in this position that the deltoid and supraspinatus are in optimal alignment during scapular plane abduction and maintain this alignment through the range since no humeral rotation is required. Whereas, abduction in the coronal plane requires humeral external rotation and some degree of horizontal abduction relative to the scapula, a twisting of the myotendinous unit results, thus altering an efficient origin to insertion pull. Also, the glenohumeral joint stability is improved during scapular plane abduction by maximizing glenohumeral articular contact and avoiding excessive tension of the static stabilizers. The obligatory external rotation and relative horizontal abduction that occurs in the frontal plane is avoided. This causes a decrease in the anterior shear force and reduced tension of the anterior-inferior capsuloligamentous complex.[45,1,5,19]

Gravity correction was done manually for all values obtained in this study. Most studies similar to this did not perform gravity correction. Gravity correction is important because the weight of the dynamometer's lever arm and the limb being tested should be accounted for.[17] This is because in dynamic contractions, the moment which has to be overcome (external moment) is generated by the weight of the distal segment (weight of limb), the load against which the limb acts (the dynamometer lever arm) and the inertia resistance of the segment. The inertia resistance becomes negligible as soon as the lever arm proceeds at a constant angular velocity. Thus, to determine the net muscle force, one must account for the effect of weight of the limb.[72] Regardless of the muscle group, acceleration of the limb due to gravity erroneously adds to torque. Conversely, additional force must be exerted to accelerate the limb against gravity, and this tends to reduce the torque output recorded. The importance of gravity correction in obtaining valid strength measures, particularly of the quadriceps and the hamstrings has been established by research. This correction allows an accurate determination of reciprocal muscle group ratios. [17]

Due to the age group used for this study, the results can only be generalized to individuals in this age group. Individuals between the aged of 18 and 32 years of age were chosen for this study to ensure that subjects are musculoskeletally mature, and also to reduce the risk of degenerative changes influencing the results.[71]

Test-retest reliability was clinically good to excellent for the positions used in this study. All measurements usually involve random and systematic errors.[72] Random errors are the inconsistent discrepancies that occur by chance, they do not exhibit any trend.[58] Systematic errors are constant errors that persist until discovered. [58] Practice effects or carryover effects which occur with repeated measurements are systematic errors.[22] Reproducibility of test findings can be affected by six potential sources of error[5]:

1. Instrument- the cumulative effect of the vast numbers of factors involved in strength testing ensures no two tests believed to be the product of identical conditions will yield exactly same findings. [72] Although it maybe argued that the detection of differences depends on the precision of the system, it has to be realized that some variations obtained in strength output measured by any instrument possess a random component of human motor behaviour. [72] For this study, the Kincom dynamometer was calibrated by the manufacturer's representative before commencement of the study.
2. Data processing- The kind of statistics used to analyze reproducibility determines the result. The intraclass correlation coefficient (ICC) was chosen to be used in this study, after considerations of the merits and demerits of other possible statistical methods. The t-test, Anova, and correlational indices (pearson's r and intraclass correlation coefficient) have been used to determine reliability. In the past, the t-test was commonly used to access the stability of findings.[72] T-tests indicate whether a difference exists between the mean scores of the test and the

retest. T-tests allow conclusions to be made based on the existence of systematic errors (a unidirectional change in scores, probably due to familiarization with the system). Situations where systematic increase is apparent do not constitute a special reproducibility problem.[72] The t-score is derived from a ratio whose numerator represents the difference between the means and the denominator (the variance). If the variance, which stands for the random error is relatively large, the ratio would indicate non significant differences and lead to a conclusion, that the test protocol yields a reproducible result. This conclusion may be unwarranted. [72] For more complex designs, the ANOVA maybe used. It as limited as the t-test, since it detects systematic errors. The main reason for using ANOVA is its ability to calculate ICC.

CORRELATIONAL INDICES - The two most widely used indices are the Pearson's r and the ICC. Pearson's r is a bivarate index. It measures the covariation of two sets of measurements derived from 2 independent variables. This means it is not supposed to be applied to two separate sets of measurements derived from the same variable.[72] Pearson's r measures the strength of the relation between 2 sets of measures, not their agreement. The strength of relation means the independent sets vary in the same way. This does not necessarily mean they reproduce each other. Pearson's r depends on the range of measurements within the sets, the larger the range, the higher correlation.[72] Highly correlated sets of findings can conceal considerable disagreement, so that exclusive reliance on r may lead to misinterpretation of reproducibility findings. [72] The Intraclass Correlation Coefficient (ICC) was chosen as the reliability index in this study, because it not only reflects the strength of association, but the actual agreement between scores.[72] The main strength of the ICC is in providing information about the ability of a given test to differentiate among subjects/ patients. Some studies have used the Pearson's r as the reliability index for the study. This could not have given a reliable picture because it does not measure agreement. For this reason, we did not used the Pearson's moment correlation coefficient.

3. Examiner - The introduction of the human element complicates the issue of reliability. Examiner variations in this study were reduced by adhering to the established protocol, and also having only one examiner position and instruct the subjects.

4. Subject-linked variations - This potential source of error is more complex. Subject willingness to produce a maximum effort and also tolerance of the discomfort of maximum muscle contraction may introduce variations in the data collected. One cannot control the mood or the willingness of the subject to produce a maximum contraction, subject reproducibility of similar performances is a major issue from one test session to next.[10,72] To account for subject linked variations in this study, all the subjects were educated about the purpose of this study and told they had to produce a maximum effort, in order that reliable readings maybe obtained. Also, the range of motion used in this study was 100 degrees, to minimize discomfort because the subjects did not move to the limit of their motion. However, fatigue, pain or boredom during a task may have acted as a negative motivator. Also, the desire to excel at a task, especially if it is new or complex, and the need to exceed previous performance are critical variables in performance.[10] Hislop[47] observed

higher increases in elbow flexor muscle strength when the subject's desire to achieve seemed great. Also, to ensure homogeneity among the subjects, only individuals between the ages of 18 and 32 years of age were chosen for this study to ensure that subjects were musculoskeletally mature, and also to reduce the risk of degenerative changes influencing the results.[71]

5. Test Procedure- To increase reproducibility of findings in this study, the test procedures were standardized and well organized. Also, the study procedures were adhered to, and uniform commands were used during the test procedures, to increase the reliability of the study. In this study, the instructions were standardized by telling the subjects to push as "hard and fast" as they could at the start of a test. The contribution of the standardized protocol and proper subject familiarization with the equipment used in this protocol cannot be overemphasized. In this study, each subject came for three different sessions, with the first session dedicated to subject education and familiarization. This ensured that test readings were not taken while subjects were fatigued and still getting used to the isokinetic dynamometer (none of the subjects who participated in this study had ever used this equipment before).
6. Protocol Linked Errors- At the shoulder complex, adequate stabilization becomes important because of the many muscles involved in simple movements.[5] If the trunk and pelvis are not properly stabilized due to unavoidable and unpredictable changes of slackness in the stabilizing belts, errors are introduced.[72] To account for this error, the subjects were properly stabilized and the stabilizing belts were checked regularly for slackness during the rest intervals.

4.2 STRENGTHS OF STUDY

1. The statistical method used helped to determine clinical significance/ relevance and not just statistical differences.
2. Standardized protocol was followed.
3. Subjects had enough time to be educated and to familiarize themselves with the equipment and protocol.
4. Previous studies have only studied the test-retest reliability in one position, i.e sitting, standing, or supine. This study looked at the test-retest reliability in 2 positions (sitting and supine) using the same subjects, hence increasing the strength of the study (same subject design).
5. Previous studies on test-retest reliability have used only one protocol. This study used two protocols, to be able to compare more readily with other studies and to compare protocols.

4.3 WEAKNESSES OF STUDY

1. Sampling method- sample of convenience was used.
2. This study can only be generalized for normal subjects aged 18-32 years.
3. This study did not account for differences between the dominant and non dominant upper limb.

CHAPTER 5

CONCLUSION

The results of this study revealed good to excellent reliability for concentric isokinetic muscle strength measurements of the shoulder internal and external rotators for all positions. However, the standard error of measurement (SEM) was not inversely proportional to the ICC value in all the positions. Based on this fact, it cannot be said conclusively that one position is clinically better than the other. For there to be a clinical change / difference, the difference in values obtained on repeated testing of a patient or subject from one day to the next would have to be beyond the upper and lower limits of the SEM obtained on the different positions.

From the hypotheses stated, the following hypotheses were confirmed with this study for the 2 shoulder position protocols :

1. ***In sitting :***

a. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for protocol A (scaption) would have an ICC value greater than 0.90. This hypotheses was confirmed for external rotation, but not for internal rotation.

b. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for protocol A (scaption) would have an ICC value greater than 0.90. This hypothesis was confirmed for internal rotation but not external rotation.

c. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for protocol B (90/90) would have an ICC value greater than 0.90. This hypothesis was confirmed for both internal and external rotation.

d. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for protocol B (90/90) would have an ICC value greater than 0.90. This was confirmed for both internal and external rotation.

2. ***In supine lying :***

a. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for protocol A (scaption) would have an ICC value greater than 0.90. This hypothesis was confirmed for internal rotation but not external rotation.

b. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for protocol A (scaption) would have an ICC value greater than 0.90. This hypothesis was confirmed for external rotation but not internal rotation.

c. Test-retest reliability of concentric peak torque values for both internal and external rotators at 60°/sec for Protocol B (90/90) would have an ICC value greater than 0.90. This hypothesis was confirmed for both internal and external rotation.

d. Test-retest reliability of concentric peak torque values for both internal and external rotators at 180°/sec for Protocol B (90/90) would have an ICC value greater than 0.90. This hypothesis was confirmed for external rotation but not internal rotation.

CLINICAL RELEVANCE

This study is relevant to clinicians because with the results of this study, it was determined which protocol/ position has good to high reliability of the shoulder internal and external rotators. It also helped to validate results previously obtained for some of the protocols. From this study, it was revealed that the most reliable position was that of 90 degrees of glenohumeral abduction and 90 degrees of elbow flexion in sitting (protocol B) which showed excellent reliability for all the velocities and for both internal and external rotation. The other positions also showed good to excellent reliability. However, in choosing a position to be used for evaluation, the clinician needs to consider the standard error of the measurement which was obtained for these measurements. It must be considered that for there to be a clinical change on repeated measurement of a subject or patient from one test session to the next, the difference in values obtained on the tests have to be beyond the upper and lower limits of the SEM obtained in this study for the various positions respectively. For example, if on testing a subject, the torque value obtained was 23 Nm on the first test session, and the standard error of measurement is 2.345 for that position, for there to be a conclusive clinical change, the values obtained on subsequent testing sessions have to be either below 20.655 or above 25.345.

The clinician also needs to consider the fact that for people with pathology at the shoulder complex, the use of the scapular plane may be preferred, because in this position the deltoid and supraspinatus are in optimal alignment during scapular plane abduction and maintain this alignment through the range since no humeral rotation is required.[45,1,5,19] This humeral rotation occurs when the shoulder is placed in 90 degrees abduction or 90 degrees flexion and leads to twisting of the myotendinous unit and thus impingement of the supraspinatus tendon.[31]

DIRECTIONS FOR FURTHER STUDIES

Further studies need to be done to determine the reliability of the shoulder internal and external rotators bilaterally using these protocols. Also the reliability of these protocols in a population with shoulder pathology should also be determined. In this case, the reliability of the affected and unaffected upper extremity should be considered. This study used subjects between the ages of 18 and 32 years, other studies should be done on individuals 32 years and above and individuals 18 years and below to determine the reliability of those groups.

REFERENCES

1. Meeteren VJ, Roebroeck ME, Stam HJ. Test-retest reliability in isokinetic muscle strength measurements of the shoulder. *J Rehabil Med* 2002;34: 91-95.

2. Ng YFG, Lam PCW. A study of antagonist/agonist isokinetic work ratios of shoulder rotators in men who play badminton. *J Orthop Sports Phys Ther* 2002;32; 399-404.

3.Sirota SC, Malanga GA, Eischen JJ, et al. An eccentric- and concentric-strength profile of shoulder external and internal rotator muscles in professional baseball pitchers. *Am J Sports Med* 1997;25: 59-64.

4. Wilk KE, Andrews JR, Arrigo CA, et al. The strength characteristics of internal and external rotator muscles in professional baseball pitchers. *Am J Sports Med* 1993;21: 61-66.

5. Plotnikoff NA, MacIntyre DL. Test-retest reliability of glenohumeral internal and external rotator strength. *Clin J Sports Med* 2002;12:367-372.

6. Nitschke JE. Reliability of isokinetic torque measurements: A review of the literature. *Aust J Physiother* 1992;38: 125-134.

7. Frisiello S, Gazaille A, O'Halloran J. Test-retest reliability of eccentric peak torque values for shoulder medial and lateral rotation using the Biodex isokinetic dynamometer. *J Orthop Sports Phys Ther* 1994;19: 341-400

8. Walmsley RP, Szybbo C. A comparative study of the torque generated by the shoulder internal and external rotator muscles in different positions and at varying speeds. *J Orthop Sports Phys Ther* 1987; 9: 217-222.

9. Wang H, Macfarlane A, Cochrane T. Isokinetic performance and shoulder mobility in elite volleyball athletes from the United Kingdom. *Br J Sports Med* 2000; 34:39-43.

10. Malerba JL, Adam ML, Harris BA et al. Reliability of dynamic and isometric testing of shoulder external and internal rotators. *J Orthop Sports Phys Ther* 1993; 18: 543-552.

11. Ellenbecker TS, Mattalino AJ. Concentric isokinetic shoulder internal and external rotation strength in professional baseball pitchers. *J Orthop Sports Phys Ther* 1997; 25: 323-328.

12. Hutson MA. Treatment and Rehabilitation. In: Hutson MA, ed. *Sports Injuries: Recognition and Management.* Second edition. Oxford: Oxford University Press, 1996.

13. Escamilla R, Wickham R. Exercise based conditioning and rehabilitation. In: Kolt GS, Mackler SL, eds. *Physical Therapies in Sport and Exercise.* Edinburgh: Churchill Livingstone, 2003.

14. Norris CM. *Sports Injuries: Diagnosis and Management.* Second edition. Oxford: Butterworth –Heinemann, 1998.

15. Hall SJ, Anderson MK. *Sports Injury Management.* Baltimore: William and Wilkins, 1995.

16. Prentice WE. *Rehabilitation Techniques for Sports Medicine and Athletic Training.* Fourth edition. Boston: McGraw Hill, 2004.

17. Perrin DH. *Isokinetic Exercise and Assessment.* Champaign: Human Kinetics Publishing,1993.

18. Behnke RS. *Kinetic Anatomy.* Champaign,IL: Human Kinetics Publishers, 2001

19. Tis LL, Maxwell Y. The effect of positioning on shoulder isokinetic measures in females. *Med Sci Sports Exerc* 1996; 28: 1188-1192.

20. Greenfield BH, Donatelli R, Wooden MJ, Wilkes J. Isokinetic evaluation of shoulder rotational strength between the plane of scapula and the frontal plane. *Am J Sports Med* 1990;18: 124-128.

21. Hays RD, Hadorn D. Responsiveness to change: an aspect of validity, not a separate dimension. *Quality of Life Research* 1992;1: 73-75.

22. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice.* Second edition. Upper Saddle River:Prentice Hall, 2000.

23. Whitaker RH, Borley NR. *Instant Anatomy.* Second edition. Oxford: Blackwell Sciences, 2000.

24. Marshall R. *Living Anatomy: Structure as the Mirror of Function.* Victoria: Melbourne University Press, 2001.

25. Sinnatamby CS. *Last's Anatomy: Regional and Applied.* Tenth edition. New York: Churchill Livingstone, 1999.

26. Monkhouse S. *Clinical Anatomy. A Core Text with Self Assessment.* Toronto: Harcourt Publishers, 2001.

27. Ger R, Abrahams P, Olson TR. *Essentials of Clinical Anatomy.* Second edition. New York: Parthenon Publishers, 1996.

28. Cailliet R. *The Illustrated Guide of Functional Anatomy of the Musculoskeletal System.* Chicago: AMA Press, 2004.

29. Snell RS. *Clinical Anatomy forMedical Students.* Fourth edition. Boston: Little Brown and Co. Publishers, 1992.

30. Muscolino JE. *The Muscular Systems Manual: The Skeletal Muscles of the Human Body.* Redding: JEM Publishers, 2002.

31. Soderberg GJ, Blaskhak MJ. Shoulder internal and external rotation peak torque production through a velocity spectrum in differing positions. *J Orthop Sports Phys Ther* 1987; 8: 518-524.

32. Newsham KR, Keith CS, Saunders JE, Goffinett SA. Isokinetic profile of baseball pitchers' internal/external rotation 180, 300, 450°·s⁻¹. *Med Sci Sports Exerc* 1998; 30: 1489-1495.

33. Hageman PA, Mason DK, Rydlund KW, Humpal SA. Effect of positioning and speed on eccentric and concentric isokinetic testing of the shoulder rotators. *J Orthop Sports Phys Ther* 1989; 11: 64-69.

34. Alderink GJ, Kuck DJ. Isokinetic shoulder strength of high school and college-aged pitchers. *J Orthop Sports Phys Ther* 1986;7: 163-172

35. Hinton RY. Isokinetic evaluation of shoulder rotational strength in high baseball pitchers. *Am J Sports Med* 1988; 16: 274-279

36. Ivey FM, Calhoun JH, Rusche K et al. Isokinetic testing of shoulder strength: Normal values. *Arch Phys Med Rehabil* 1985; 66: 384-386

37. Poppen NK, Walker PS. Normal and abnormal motion of the shoulder. *J Bone Joint Surg* 1976; 58A: 195-201.

38. Saha AK. Mechanism of shoulder movements and a plea for the recognition of "zero position" of glenohumeral joint. *Clin Orthop* 1983; 173: 3-10.

39. Williams PE, Goldspink G. Changes in sacromere length and physiological properties in immobilized muscle. *J Anat* 1978; 127: 459.

40. Tardieu C, Huet E, Bret MD. Muscle hypoextensibility in children with cerebral palsy:I. Clinical and experimental observations. *Arch Phys Med Rehabil* 1982; 63: 97-102

41. Thorstensson A, Grimby G, Karisson J. Force velocity relations and fiber composition in human knee extensor muscles. *J Appl Physiol* 1976; 40: 12-16

42. Wilk KE, Andrews JR, Arrigo CA. The abductor and adductor strength characteristics of professional baseball pitchers. *Am J Sports Med* 1995; 23: 307-311.

43. Brown LP, Niehues SL, Harrah A, Yavorsky P, Hirshman PH. Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. *Am J Sports Med* 1988;16: 577-585.

44. Noffal GJ. Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. *Am J Sports Med* 2003;31: 537-541.

45. Whitcomb LJ, Kelley MJ, Leiper CI. A comparison of torque production during dynamic strength testing of shoulder abduction in the coronal plane and the plane of the scapula. *J Orthop Sports Phys Ther* 1995;21: 227-232

46. Zachazewski JE, Magee DJ, Quillen WS(eds). *Athletic Injuries and Rehabilitation.* Philadelphia:Saunders,1996

47. Hislop HJ. Quantitative changes in human muscular strength during isometric exercise. *Phys Ther* 1963;43: 21-38

48. Cratty B. *Movement Behavior and Motor Learning.* Third edition. Philadelphia: Lea&Febiger, 1973

49. Keatings JL, Matyas TA. The influence of subject and test design on dynamometric measurements of extremity muscles. *Phys Ther* 1996;76: 866-889.

50. Hortobagyi T, Katch FL. Eccentric and concentric torque-velocity relationships during arm flexion and extension: influence of strength level. *Eur J Appl Physiol Occup* Physiol 1990;60: 395-401.

51. Kibler BW. Current concepts: The role of the scapula in athletic shoulder function. *Am J Sports Med* 1998; 26: 325-337.

52. Wilk KE, Arrigo CA, Andrews JR. Current concepts: The stabilizing structures of the glenohumeral joint. *J Orthop Sports Phys Ther* 1997;25: 364-379.

53. Mottram, SL. Dynamic stability of the scapula. *Manual Therapy* 1997;2: 123-131

54. Kin-Com II & III Muscle Testing and Training System:Clinical Desk Reference: Chattecx Corporation, Chattanooga,TN.

55. Domholdt E. *Physical Therapy Research: Principles and Applications.* Philadelphia:W.B. Saunders, 1993.

56. Clarkson HM, Gilewich GB. *Musculoskeletal Assessment: Joint Range of Motion and Manual Muscle Strength.* Baltimore: Williams & Wilkins, 1989.

57. Perrin DH. Reliability of isokinetic measures. *Athletic Training* 1986;10: 319-321.

58.Currier DP. *Elements of research in physical therapy. Baltimore*: William and Wilkins, 1979.

59. Domholdt E. *Physical therapy research: Principles and applications*. Philadelphia: W.B. Saunders,1993.

60. Lieber RL. *Skeletal muscle anatomy and physiology*. In Garrett (Jr) WE, Speer KP, Kirkendall DT, ed. Principles and Practice of Orthopaedic Sports Medicine. Philadelphia: Lipincott Williams and Wilkins, 2000.

61. Boone DC, Azen, SP, Lin CM, et al. Reliability of goniometric measurements. *Phys Ther* 58:1355-1360,1978.

62. Riddle DL, Rothstein JM, Lamb RL. Goniometric reliability in a clinical setting. Shoulder measurements. *Phys Ther* 67: 668-673,1987.

63. MacDermid JC, Chesworth BM, Patterson S, Roth JH. Intratester and intertester reliability of goniometric measurements of passive lateral shoulder rotation. *J Hand Ther* 12: 187-192,1999.

64. Hall SJ, Anderson MK. *Sport injury management*. Baltimore: William and Wilkins, 1995.

65. Prentice WE. *Rehabilitation techniques for sports medicine and athletic training*. Fourth Edition. Boston: McGraw Hill, 2004.

66. Norris CM. *Sports Injuries: Diagnosis and management*. Second edition. Oxford: Butterworth –Heinemann, 1998.

67. Perrin DH. *Isokinetic Exercise and Assessment*. Champaign: Human Kinetics Publishing, 1993.

68. Proske U, Morgan DL. Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications. *J Physiol* 537:333-345, 2001.

69. Brockett CL, Morgan DL, Proske U. Human hamstring muscles adapt to eccentric exercise by changing optimum length. *Med Sci Sports Exerc* 33: 783-790, 2001.

70. Gregory JE, Morgan DL, Proske U. Tendon organs as monitors of muscle damage from eccentric contractions. *Exp Brain Res* 151:346-355, 2003.

71. Cowan SM, Bennell KL, Hodges PW, Crossley KM, McConnel J. Delayed onset of EMG activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. *Arch Phys Med Rehabil* 82:183-189, 2001.

72. Dvir Z. *Isokinetics: MuscleTesting,Iinterpretation and Clinical Applications*. Second edition. New York: Churchill Livingstone, 2004.

73. Cohen J. *Statistical Power Analysis for the Behavioural Sciences*. New Jersey: Hillsdale, 1988.

Appendix B

PARTICIPANT INFORMATION LETTER

Title- Test-retest reliability of isokinetic muscle strength measurement of shoulder internal and external rotators in sitting and supine lying.

Researchers- *Principal Investigator-* Dr. D. Magee.
Co- Investigator- Abieyuwa Eboikpomwen, Master of Science Student.

This study is a part of the research requirement for a Master of Science in Physical Therapy Degree.

Background-

Many studies have been done on isokinetic (constant speed) muscle strength measurement. Only a few have addressed the issue of reliability. The few that addressed reliability have not considered the effect of positioning. Hence, the need for information on the reliability of isokinetic muscle strength measurements in different positions so that muscle strength can be accurately and reliably determined.

Purpose-

To determine the reliability of isokinetic muscle strength measurements of the shoulder muscles that turn the arm in and out. This will be done in sitting and lying face up. Only the dominant upper limb will be tested.

If you agree to take part in this study, you will be asked to come to room 1-26 in Corbett Hall for three sessions. Each of the 3 sessions will take about an hour of your time. For the sessions you will be required to wear clothing that exposes your arms. Each session will be at least four days apart.

If you meet the selection criteria, your height and weight will be measured during the first session. During this FAMILIARIZATION SESSION you will first draw a piece of paper out of the hat to determine whether you will be positioned in sitting first or lying first. This piece of paper will also determine whether internal rotation (rotating your arm in) or external rotation (rotating your arm out) movement would be performed first. Once your starting position has been chosen, your chest and pelvis will be strapped down to the chair or table to provide stability. Then you will be shown how the measuring device called an isokinetic dynamometer works. The co-investigator will then set a selected speed of the machine. You will then be asked to perform several submaximal and several maximal contractions by rotating your arm either in (internal rotation) and out (external rotation) or out (external rotation) and in (internal rotation) depending on what is written on the piece of paper. This will be done until you are comfortable with the movement. This will warm up your muscles and also prevent muscle soreness. A 60 second rest period will be allowed between the tests. Once you are familiar with the test procedures you will be allowed to leave.

On the SECOND AND THIRD SESSIONS, actual testing will occur. You will be positioned on the chair or table in the same order as the first session and the speeds

Appendix D

Sample Size calculation

This study is a [2 (60°/sec and 180°/sec) × 2 (supine lying and sitting)] × 2 (90 degrees glenohumeral and 45 degrees scaption) × 2 (internal and external rotation] . According to Cohen when using a one sided α to get a correlation coefficient of 0.60 with a power of 0.8 is 15, Adding 30 % for subject attrition, therefore gives a sample size of 20. See table 1 below.

Table 1 Sample size needed for the correlation coefficient, r

	r								
Power	.10	.20	.30	.40	.50	.60	.70	.80	.90
α_1= .05									
.70	470	117	52	28	18	12	8	6	4
.80	617	153	88	37	22	15	10	7	5
.90	654	211	92	50	31	20	13	9	6

Adapted from table 3.4.1 in Cohen j. Statistical power analysis for the behavioural sciences. Hillsdale, New Jersey , 1988

Appendix E

Data Collection Sheet
Subject no- ____
Age- ___
Sex- ___
Height-__
Weight- ____
Weight of Limb-___

Position Order- _______
External Rotation-_____
Internal Rotaion- ______

Supine Lying

	60°/sec				180°/sec			
	T1(1)	T1(2)	T2(1)	T2(2)	T1(1)	T1(2)	T2(1)	T2(2)
Protocol A: Int Rot								
Ext rot								
Protocol B: Int Rot								
Ext Rot								

Sitting

	60°/sec				180°/sec			
	T1(1)	T1(2)	T2(1)	T2(2)	T1(1)	T1(2)	T2(1)	T2(2)
Protocol A: Int Rot								
Ext rot								
Protocol B: Int Rot								
Ext Rot								