Characterizing the Structural and Functional Anatomy Associated with Rotator Cuff Muscle Injury

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Rotator cuff muscle injuries are the most common cause of shoulder pain and dysfunction in industrialized countries and have a significant impact on the health care system and workforce. To date the natural history of RC pathology is not well understood. Muscle disuse and degeneration as well as de-innervation resulting from entrapment of the suprascapular nerve have all been implicated as possible causes for rotator cuff disease. Unfortunately, the mechanisms responsible for the changes in muscle structure and function are not well understood. The objectives of this research project are to 1. Characterize and document the structural anatomy of the supraspinatus muscle 2. Use MRI imaging to classify fatty degeneration using a widely accepted clinical classification system 3. Use isokinetic and handheld dynamometry to quantify rotator cuff muscle function in pathological based patient populations that have been diagnosed with a rotator cuff muscle injury. The results of this pilot project are expected to contribute to our understanding of the anatomical factors associated with rotator cuff injury and have the potential to offer significant insight into the structural and functional changes associated with rotator cuff muscle injury. It is than hoped that the findings associated with this project can launch further research that could provide surgeons with clinical guidelines on who should qualify for surgical versus conservative treatment of rotator cuff tears.

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Student's Signature

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Introduction

Rotator Cuff injuries are the most common cause of pain and dysfunction in the shoulder within industrialized nations (1). There are approximately 17 million people at risk of disability from these injuries in the United States and this has a significant impact on both the health care system as well as the work force (2). Unfortunately, according to the Canadian Institute of Health Information (CIHI), there is no data on the demographics or costs related to rotator cuff injury in Canada. This lack of data may under estimate the significance of such pathologies on our health care system, especially given the health care trends observed within Canada's aging population. Elderly patients are frequently affected by rotator cuff injuries due to age-related degenerative changes and/or injury (3). The frequency of such injuries coupled with an aging workforce and/or longer life expectancy underscores the need for research, which examines the pathogeneses associated with rotator cuff injury and dysfunction. This information would also greatly assist surgeons when selecting appropriate surgical/treatment interventions, as well as assist the health care system in saving substantial amounts of resources. Such research could help to reduce the reliance on expensive surgical procedures and reduce long wait times currently stressing the system.

The rotator cuff complex is composed of four muscles whose tendons attach on the greater and lesser tuberosities of the humerus. The muscles of the rotator cuff are the supraspinatus, infraspinatus, subscapularis and teres minor. The supraspinatus, located in the supraspinatus fossa, is part of the superior aspect of the scapula, and functions to enhance the intrinsic stability of the gleno-humeral joint as well as to power abduction of the humerus. The subscapularis, located in the subscapular fossa, is a medial rotator of the humerus. The infraspinatus, located in the infraspinatus fossa, is a lateral rotator of the humerus. Finally, the teres minor, which originates in the inferior aspect of the scapula, aids the infraspinatus in lateral rotation. All four muscles are the primary stabilizers of the gleno-humeral joint (4). The attachment points of the tendons of the rotator cuff muscles on the humerus are what are referred to as the footprints of each of these muscles (3). The majority of rotator cuff tears involve failure of the attachment of the tendon fibers near their insertion on the humerus (5). Knowing the dimensions of the footprint is important in successful repair of rotator cuff tears as function is better restored with the most accurate reattachment of the cuff to the original location on the tuberosities of the humerus.

The supraspinatus is the most commonly involved tendon in rotator cuff pathology with the infraspinatus also having a contribution in many tears (3). When the supraspinatus is injured or weakened, the balance of forces, which normally stabilizes the gleno-humeral joint are disrupted leading to dysfunction (6). Rotator cuff tears can be classified into partial-thickness or full-thickness tears irrespective of etiology (7). A full thickness tear leads to a communication space between the articular cavity and the sub-acromial-sub-deltoid space. A partial thickness tear does not completely penetrate the cuff and may be located on the articular or bursal side of the rotator cuff (7). Etiologies that can eventually lead to rotator cuff tears include muscle disuse and degeneration, de-innervation resulting from entrapment of the suprascapular nerve (8), diminished vascularization (9), overuse and contractile overload (10), as well as trauma (11). Regardless of the cause, patient's chief complaints include joint pain and dysfunction, but in many cases may include no symptoms at all. The natural history of rotator cuff disease is not well understood. Anatomically muscle atrophy and fatty replacement of muscle are often observed and significantly in proportion to each other (12). Unfortunately, because the symptoms range from pain and dysfunction to nothing at all and the amount of muscle atrophy and fatty degeneration vary from case to case, it is often impossible to relate the type of tear to the natural history or course of rotator cuff pathology. For this reason further anatomical and functional studies are needed in order to clarify and better understand the natural course of the pathology, as well as the most effective or appropriate treatment interventions.

To date, the vast majority of research on the rotator cuff complex has focused on the anatomical footprint of each of the four rotator cuff muscles, as well as the anatomical course of the suprascapular nerve. The current investigation is unique in that it examines three key aspects important for a clear understanding of the factors associated with rotator cuff pathology and treatment: 1. A critical examination of the anatomy of the rotator cuff complex, with a specific focus on characteristics of the supraspinatus muscle itself and its musculotendinous junction; 2. An imaging component looking at the amount of fatty degeneration based on a commonly accepted clinical classification system; 3. A functional component measuring strength reduction in patients with rotator cuff tears, which are than compared to normalized values.

Objectives

The main objective of this descriptive investigation was to supplement the existing information on the anatomical characteristics of the rotator cuff complex. By measuring the anatomical parameters of the supraspinatus muscle and its musculotendinous junction, it is our hope that the results from both normal and pathological shoulders with potential tears will increase the limited knowledge surrounding the natural history and course of progression of rotator cuff disease. Beyond this, by incorporating a combination of imaging and functional measurements, a further goal was to establish an assessment protocol for surgeons such that the results of imaging based on a person's size of tear, along with the amount of fatty degeneration, can be correlated with strength and range of motion decrements observed during isokinetic/isometric strength and range of motion testing. While current studies focus on normative strength values for normal shoulders (13), our aim was to conduct a pilot project for a much larger study that develops baseline functional data on pathological shoulders. This data, when evaluated in conjunction with results from both MRI and clinical examination, can then be used by surgeons to assist them in determining which particular cases would benefit most from surgical or conservative treatment.

Materials and Methods

The anatomical portion of our study consisted of 17 cadaveric shoulder dissections (9 male and 8 female) with a mean age of 77+/- 17 years at the University of Manitoba. The Health Research Ethics Board (HREB) at the University of Manitoba approved the study. A combination of sharp and blunt dissection techniques were employed to assure proper access to the supraspinatus muscle and to avoid damage to any significant structures that could potentially alter our results. A posterior approach was used to gain access to the rotator cuff muscles. The cadaver was laid flat on a dissection table in the prone position to allow access to the posterior aspect of the shoulder. Skin, superficial fatty and connective tissue were removed starting superiorly in the region of the neck, and progressing inferiorly to the lumbar region. The spinous processes of the thoracic vertebrae were used as a medial boundary and the skin was dissected away in a medial to lateral direction. This facilitated visualization of the muscles of the back including the trapezius and underlying rhomboid muscles. The trapezius was cut superiorly using sharp dissection to allow access to the rotator cuff muscles and free the arm, which allowed for a greater range of motion of the shoulder for easier access to the rotator cuff muscles. The rhomboids were then transected allowing unimpeded visualization of the scapula and infraspinatus muscle. This also allowed greater free movement of the scapula and humerus and greatly facilitated manipulation and visualization of the rotator cuff muscles. The arm was than rotated to expose the anterior portion of the cuff and allowing access to the superior aspect of the scapula where the supraspinatus was located. This dissection technique was used such that the arm could be manipulated and visualized from any direction without having to turn the cadaver over between supine and prone positions. The arm was secured with a rubber positioning block and dissection and measurements specific to the rotator cuff complex were initiated. Fatty and connective tissue were carefully removed using sharp dissection. The tissues were removed in layers such that the underlying fibers of the supraspinatus muscle would not be damaged. Fatty and connective tissue were also removed on the lateral aspect inferior to the spine of the scapula to allow visualization of the musculotendinous junctions of both the infraspinatus and teres minor muscles. When the supraspinatus muscle was in view, extra connective tissue was removed along the spine and anterior borders of the scapula, in order to delineate the boundaries of the supraspinatus muscle. An acromioplasty was performed using an orthopedic oscillating saw in order to expose the most superior aspect of the cuff tendons. Great care was taken not to damage the underlying cuff during this procedure. Blunt dissection was used to scrape the surface of the supraspinatus muscle removing thin layers of overlying connective tissue and thus exposing the fibers of the muscle. Preparation for our measurements than began. Colored strings were carefully pinned around the outer borders of the muscle to mark its scapular attachements, and then used to determine the length of the various structural parameters of the supraspinatus muscle. The strings were cut along the borders of the supraspinatus and measured with precision to the $1/100^{th}$ of a mm using digital calipers. Key anatomical measurements included: an anterior border (Z), a medial border (Y), a posterior border spilt into free floating (A) and fixed (X) portions, the musculotendinous junction (E) and the length of the supraspinatus muscle in vivo using the centers' of (E) and (Y) and connecting them (B). The widths of the musculotendinous junctions of the infraspinatus (F) and teres minor (G) were also measured. In order to insure proper delineation and hence accurate measurement of the widths of the musculotendinous junction, all three rotator cuff muscles were detached at their origins and folded back to view the musculotendinous junction from the underside of the muscle belly, which allowed for a clearer view between muscle and tendon (3). A different colored string was then placed over the most common muscle fiber in one of four designated quadrants of the supraspinatus muscle. These quadrants included a Superior Lateral (SL), Inferior Lateral (IL), Superior Medial (SM) and Inferior Medial (IM). A computer imaging program NIH ImageJ (14) was then used to calculate the mean angle fiber angle for each quadrant. The muscle was then harvested from the scapula using a combination of sharp and blunt dissection. The length of the muscle was measured in vitro (C) and compared to the length in vivo (B). Finally, the muscle was cut along its musculotendinous junction when harvested and submerged in a graduated cylinder in order to measure its volumetric displacement. (Fig. 1-8)

The imaging component of the study consisted of analyzing MRI images from patients with partial or complete rotator cuff tears who met the inclusion criteria and a senior radiologist at the Pan Am clinic specializing in musculoskeletal diagnostics classified the fatty degeneration based on a common method of clinical classification, the Goutallier system (15). The MRI scanner at the Pan Am clinic is a Siemens Magnetom Avanto with a 1.5 Tesla magnet. Routine scan parameters of the shoulder include Axial 2D MEDIC, Coronal PD-T2, Sagittal PD-T2, and Sagittal TSE T1 images. The field of view is 160mm, slice thickness is 3mm, resolution ranges from 256-384 and the bandwidth 130-166 Hz/Px. The supraspinatus muscle is most easily visualized on a T1-weighted image (16). Fatty degeneration, which follows atrophy of the muscle following a rotator cuff tear, is also best visualized on a T1-weighted image. There is a strong correlation between the degree of atrophy and the amount of fatty degeneration (17). Furthermore a direct correlation exists between the size of the tendon rupture and the degree of atrophy (18). The Goutallier system comprises a five-stage classification system based on the ratio of fat to muscle: Stage 0 has absence of fat; Stage 1 consists of several fat lines; Stage 2 has fat content less than muscle; Stage 3 fat content is equivalent to muscle; and Stage 4 has fat greater than muscle. (Fig. 9-12) It is very important to note that although the Goutallier system is the most commonly used classification system in orthopedics, it is a highly subjective system based on the interpretation of the observer of the MRI scan and it has a relatively low reliability (19). An advantage of this system is that it may be used in both CT and MRI imaging. MRI is currently the gold standard in the diagnosis of rotator cuff tears. For complete tears it has a sensitivity of 80-97% and a specificity of 94%. It has a negative predictive value for diagnosis of over 90% (7). There is less reliability for partial thickness tears.

The third part of this rotator cuff study was comprised of a functional evaluation component which consisted of the development and piloting of empiric protocols designed to evaluate and quantify shoulder strength and range of motion within a rotator cuff pathological population. To date, there is an absence of functional data on this patient population within the literature, and through careful development and refinement of our testing protocol, we were able to develop an evaluation method which is expected to reliably measure the strength in patient populations with rotator cuff tears in both a safe and comfortable manner. The instrument of choice for strength testing was an isokinetic dynamometer (specifically the Biodex Systems 3 dynamometer). A critical aspect of the isokinetic testing is that it allowed testing to be conducted in a safe and patient friendly manner because of its ability to utilize fixed and comfortable shoulder positions while measuring strength at a single predetermined and controlled constant velocity. The testing protocol outlined below has received ethics approval from the University of Manitoba Research ethics board. Please note, that due to time constraints and difficulties associated with rotator cuff patient recruitment and scheduling the strength protocol was only tested and validated on healthy subjects. During this testing the protocol produced reliable test results and strength values in normal shoulders consistent with what has been previously reported in the literature.

1. Screening – patients with rotator cuff injuries
2. Verbal instructions of pre, test and post test procedures
3. Stretching/warm-up
4. Proper setup and optimal stabilization into the Biodex
5. Alignment of joint and dynamometer axes of rotation
6. Gravity correction when appropriate
7. Warm-up (3 sub maximal repetitions)
8. Rest (30sec-1min)
9. Maximal test (5 reps concentric/concentric) at velocity 90 deg/sec
10. Testing of contralateral side
11. Recording of test details to ensure replication on retest
12. Explain results to the patient

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Note: Non-pathologic*** side is tested first

Participant Inclusion / Exclusion Criteria??

Patient inclusion criteria:

1. Ages 45 – 75
2. Unilateral partial or full thickness rotator cuff tear in the shoulder confirmed via MRI diagnosis.
3. Awaiting surgical repair of a partial or full thickness rotator cuff of the shoulder.

Patient Exclusion Criteria:

1. Previous shoulder surgery
2. Radiographic evidence of severe gleno-humeral joint deterioration.
3. History of medical conditions that prevent the individual from performing physical activity.
4. Unable to provide consent due to language barrier or mental status
5. History of cardiovascular disease, or screen positive for ankylosing spondylitis, psoriatic arthritis, chronic reactive arthritis, or renal problems requiring peritoneal dialysis or hemodialysis.
6. Unwillingness or inability to return for follow-up appointments

Data Measured

1. Peak torque/force (point in range of motion which produces the greatest value)
2. Average torque (tension produced by muscle throughout entire range of motion)
3. Angle-Specific Torque (AST) (torque at any point throughout the motion)
4. Work – force X distance of muscle contraction (distance of rotation)
5. Power – work/time required to produce work

Mode of Testing

- Concentric external rotation / Concentric internal rotation (i.e. muscle is always shortening when being asked to produce force)

Things to look out for

- Obesity
- CV problems
- Other medical conditions which can cause problems for the patient
- Watch for those who are on anticoagulant therapy for cerebral, cardiac, or venous reasons (risk of hemorrhaging during isokinetic exercise)

Before Testing

- Warm-up
- Have patient go through movement they will experience in dynamometer before entering the machine

During Testing

- Gravity compensation (compensation requires some form of standardization)
- Damping/preload to avoid overshoot phenomenon - "0" for AST

Warm-up

- Upper body exercise bike
- 3 sub maximal repetitions on isokinetic dynamometer at 90 degrees/second

Rest

- 1 minute between warm-up and first maximal test
- Time it takes to setup for next testing position (at least 5 minutes)

Test Velocity

- 90deg/sec

Number of Repetitions

- 5 repetitions (4-6 to reach maximum torque)

Range

- Participant specific Maximum internal and external rotation minus 10 degrees
- Pain free ROM

Plane of Testing

- Scapular plane (30-45deg anterior to the frontal plane)

Shoulder Abduction

- 45deg and 80deg of abduction

Verbal Encouragement

- Patient is instructed before each test to produce maximum effort
- Tester should remain silent during the test

***Often patients will have rotator cuff tears on the contralateral side, which may be asymptomatic. The pathologic shoulder is symptomatic as the patient sought medical care and thus MRI was performed. We therefore consider the non-surgical side the non-pathologic side as no medical care was sought for this side and thus serves as our control.

The mode of concentric/concentric testing allows both internal and external rotation to be evaluated in a functional manner. This means as the lateral rotators shorten they produce force and the same applies to the internal rotators. A testing speed of 90 degrees per second was chosen because a basic principle of isokinetic testing is that when testing velocity increases, the peak torque decreases (21). While isokinetic testing can be done at speeds as high as 300 degrees per second and speeds as low as 60 degrees per second in common testing protocols, such speeds are simply impractical, unsafe and uncomfortable for a patient awaiting surgical repair of their rotator cuff tear. We therefore chose 90 degrees/second, which is both the safest and most comfortable and during pilot testing produced the most reliable data (20). We chose 5 repetitions (1 repetition consists of an internal and an external rotation) as literature supports 4-6 maximal repetitions for most reliable data (22). Testing was done in the scapular plane, which is defined as 30-45 degrees anterior to the frontal plane as this also produces the most reliable results (21). Shoulder abduction was done at 45 degrees (neutral position according to Biodex) and 80 degrees. These positions not only mimic positions and typical torque values observed in the shoulder during typical daily activities, but shoulder abduction of 80 degrees or less helps to avoid shoulder impingement which can further injure a patient. Thus, our protocol is within safe limits (21). A 5-minute warm-up on an upper body exercise bike is the recommended choice for this mode of testing (23).

Beyond isokinetic evaluation of concentric rotator cuff strength, an isometric strength evaluation protocol was also developed for participants who found the Biodex testing uncomfortable. This protocol was used to establish reliable strength data, which closely approximated that of Biodex isokinetic testing at 90 degrees/second (24). The handheld dynamometer is the most reliable instrument for measuring isometric strength of the rotator cuff (25). The protocol utilized the Lafayette Manual Muscle Tester Model 01163. The values were reported in Newtons for force and the torque is calculated by multiplying the force by the length of the lever arm. The lever arm is measured from the lateral epicondyle of the humerus to the point just proximal of the ulnar styloid where the dynamometer is placed on the patient's forearm.

Internal/External rotation isometric

- Patient was seated such that their back was supported to prevent movement of the torso
- The arm was placed in neutral position with the elbow tucked into the torso
- For external rotation the handheld dynamometer was placed just proximal to the ulnar styloid on the flat portion of the wrist for patient comfort
- Maximum torque was produced in the 30-60 degree range for both internal and external rotation from neutral***
- The angles were measured with a goniometer and isometric testing began in this range
- The patient was instructed to externally rotate with a constant increasing force while the tester stabilized themselves to provide resistance for accurate reading of the dynamometer
- The patient was shown and instructed not to abduct the shoulder or turn the torso so as to not involve other muscle groups
- For internal rotation the elbow was again tightly tucked against the torso
- The dynamometer was placed on the volar surface of the wrist with the tester stabilizing themselves such as to provide resistance for accurate measurement of the instrument
- Three readings were taken for both internal and external rotation and the average was used as the value for force produced. The torque was than calculated as described above

***Based on standardized values from previous studies, the maximum torque is produced anywhere from 30-60 degrees in either internal or external rotation (24). Our angle of testing was midway at 45 degrees so testing falls well within the range and can still be adjusted accordingly for patient comfort in either direction without compromising maximum torque

Abduction isometric

- Patient was seated such that the back is supported to prevent movement of the torso

- The patient's arm was placed in the scapular plane (45 degrees anterior to the coronal plane)
- With the arm fully extended the patient was instructed to apply force against the dynamometer abducting the shoulder
- The patient was shown and instructed not to produce other movements that would involve other muscle groups
- Three readings were taken and the average was used as the value for force. The torque was calculated as above

The final protocol was designed to measure the joint range of motion about the shoulder in patients with rotator cuff tears. A digital inclinometer, which consists of a small rectangular box that can be calibrated so any of the four sides can be used as a reference point to measure the joint angle, was used. It is placed flat on a surface such as the humerus for accurate reading. The instrument measures to 1/10 of a degree in accuracy. The patient's range of motion can then be compared to normal accepted values (26). For the current study, the motions of shoulder forward flexion, abduction and external rotation were selected. These single plane movements facilitated the easiest inclinometer readings against gravity and best mimicked the normal function of the rotator cuff complex and served as a reference point against which the ROM values from our study could be compared against normalized values previously reported in the literature (26).

Forward Flexion

- Patient stood in upright posture
- Inclinometer was placed on the humerus
- Arm flexed forward with elbow fully extended without side to side deviation

Abduction

Same steps as forward flexion except during abduction there should be no forward or backward deviation

External Rotation

- Patient lay on their side on examining table with knees in slight flexion for stability
- The humerus was aligned parallel to the torso with elbow tucked tightly against the torso
- The digital inclinometer was placed on the wrist near the ulnar styloid to provide a flat surface
- From the neutral position the patient externally rotated and the reading on the inclinometer was noted at the point of maximal external rotation

Results

Anatomical Study

Bony Attachments	Mean	Stand. Dev.	Range
Spine of scapula (X)	67 mm	7	56-79

Medial Border of Scapula (Y)	54 mm	10	30-68
Anterior Detached Border (Z)	77 mm	12	53-92
Free floating section (A)	48 mm	14	29-68
Mid Length of Muscle (B)	102 mm	15	78-128
Width of Humeral Attachment (E)	22 mm	5	14-29
Mid Length of Muscle Detached	113 mm	14	89-144
Volumic Displacement of Muscle (D)	27 ml	3	18-55
Width of Hum. Attach. Infra. (F)	22 mm	6	13-30
Width of Hum. Attach. Teres Minor (G)	20mm	4	13-26

Muscle Region	**Mean**	**SD**	**Range**
Antero-lateral (SL)	17 degrees	9	8-41
Postero-lateral (IL)	23 degrees	11	16-44
Antero-medial (SM)	16 degrees	7	4-29
Postero-medial (IM)	21 degrees	12	12-49

Functional Study

We tested six healthy students mean age 25.5 (3 males and 3 females) with no shoulder pathology due to time constraints associated with recruiting patients with rotator cuff tears. The mean for peak torque in males was 32.37 n-m with a standard deviation of 9.39, a min value of 25.2 n-m and a max value of 43.0 n-m. For females the mean for peak torque was 15.97 n-m with a standard deviation of 2.94, a min value of 12.7 n-m and a max value of 18.4 n-m.

Discussion

In clinical practice, physicians currently rely on results from a combination of special tests and advanced medical imaging when diagnosing rotator cuff tears. While the reliability and accuracy of many of these subjective clinical tests (such as the Hawking's impingement test for rotator cuff tears and Speed's test for biceps tendon/labral pathology) are unknown or influenced by a host of confounding variables, they currently represent the only clinical tools available to physicians when making treatment decisions regarding the management of rotator cuff pathologies (27)(28). Because of this, more objective and quantifiable data is needed regarding the natural course, progression and function associated with rotator cuff tears to better guide physicians when selecting conservative versus surgical treatment. The anatomical portion of this study contributed to our knowledge of the structural anatomy of the rotator cuff complex and the natural history of rotator cuff pathology. Our data revealed that 47% +/- 1% of the muscle was "free floating" with no direct bony attachment. If this percentage is larger in some patients does it increase the risk of tearing? The contribution of the supraspinatus tendon was also 36%+/- 1% similar to infraspinatus. Do these small contributions explain the larger involvement of supraspinatus pathology? Our development and refinement of functional testing protocols designed specifically for a rotator cuff injured patient population show promising results as they produced reliable and valid data for a normative population in both men and women (13). This functional assessment protocol, when used in conjunction with pathological imaging for a rotator cuff tear population, has the potential to provide surgeons with more complete and accurate information when making clinical management decisions that are best for both the rotator cuff injured patient and the health care system, in general.

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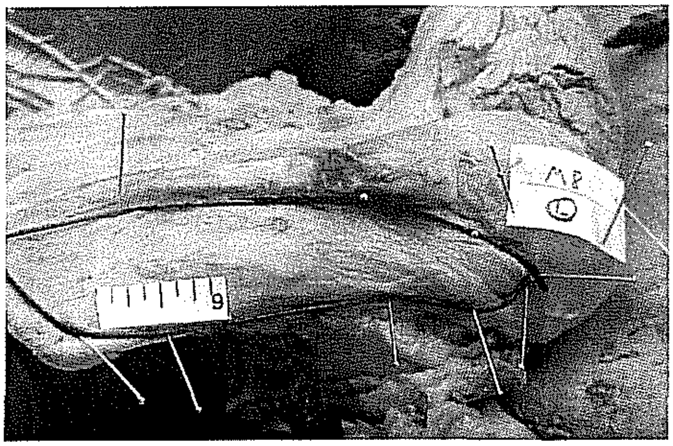

Figure 1 - Normal Supraspinatus

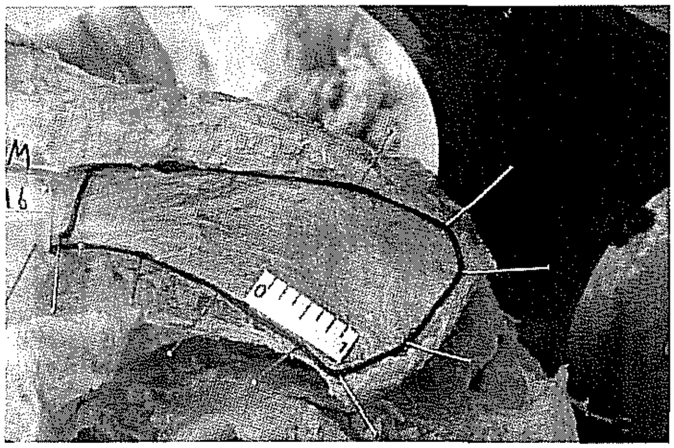

Figure 2 - Abnormal Supraspinatus –
Muscle atrophy and fatty degeneration

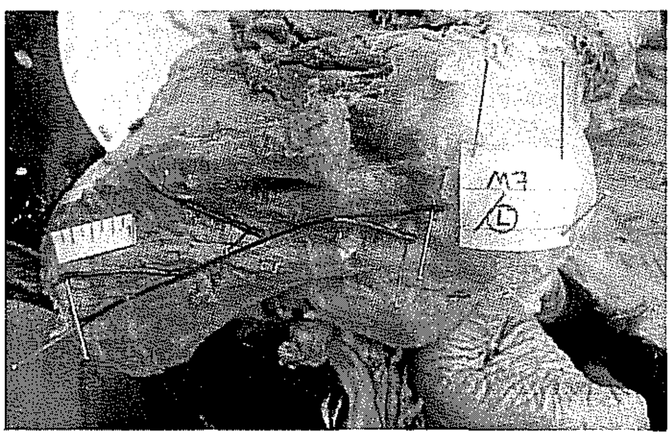

Figure 3 - Common Muscle Fibers

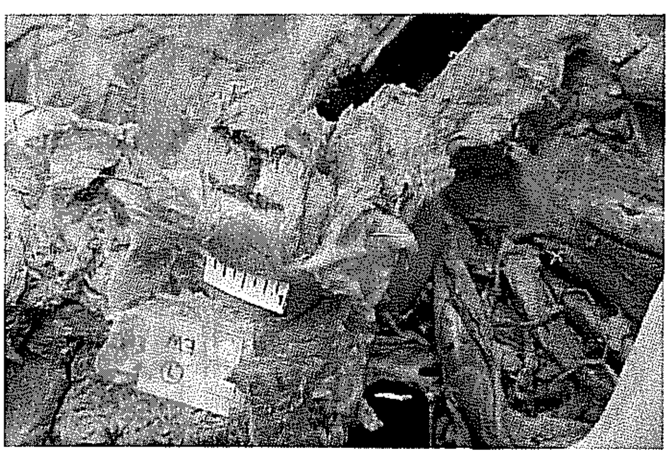

Figure 4 - Inferior Cuff View –
T = Teres Minor
I = Infraspinatus

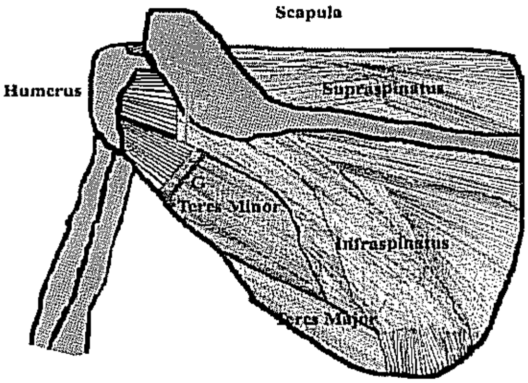

Figure 5

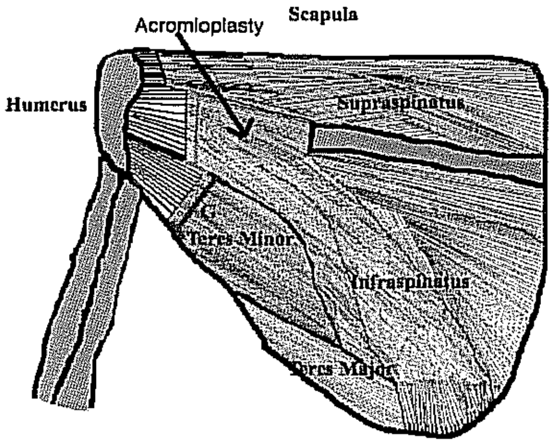

Figure 6

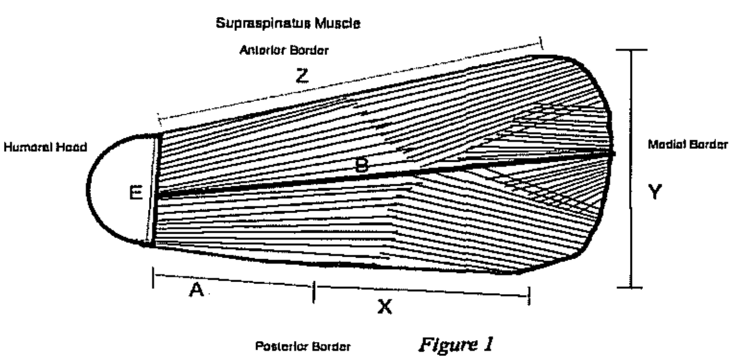

Figure 7 - Supraspinatus dissection parameters

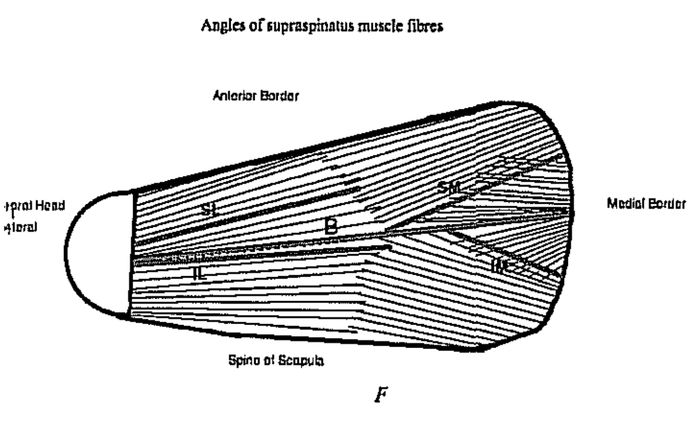

Figure 8 - Supraspinatous common muscle fibers

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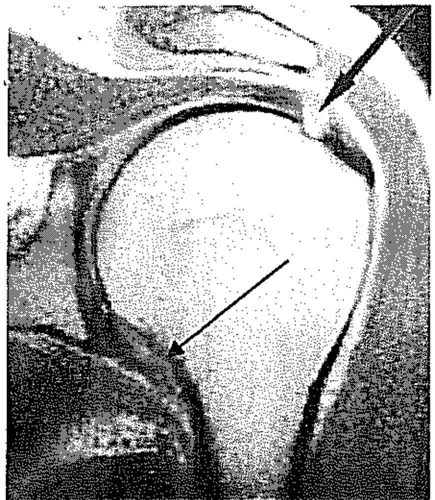

Figure 9 – Supraspinatus Tendon Tear

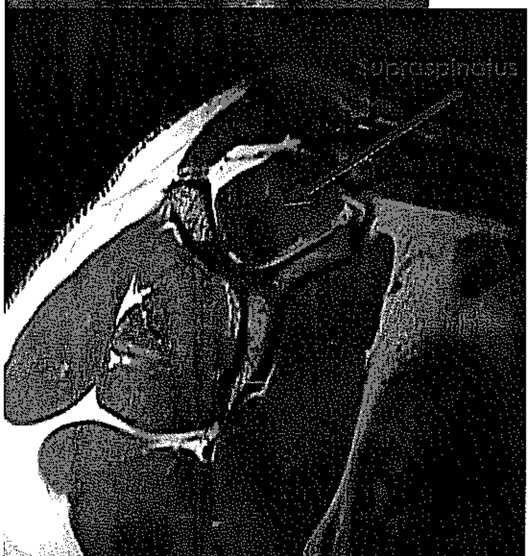

Figure 10 – Goutallier Stage 0 Supraspinatus

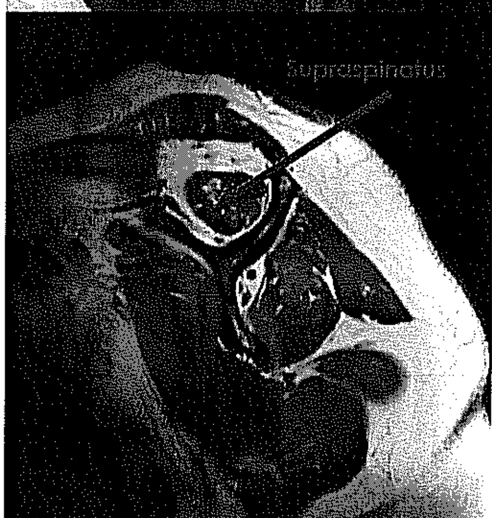

Figure 11 - Goutallier Stage 2 Supraspinatus

Figure 12 - Goutallier Stage 3 Supraspinatus, Stage 4 Infraspinatus

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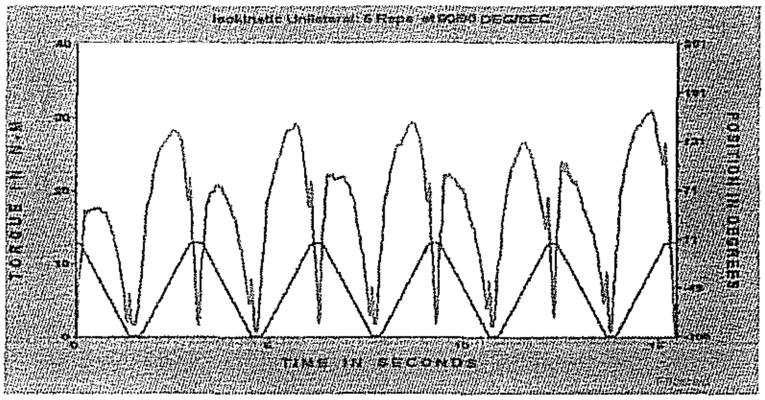
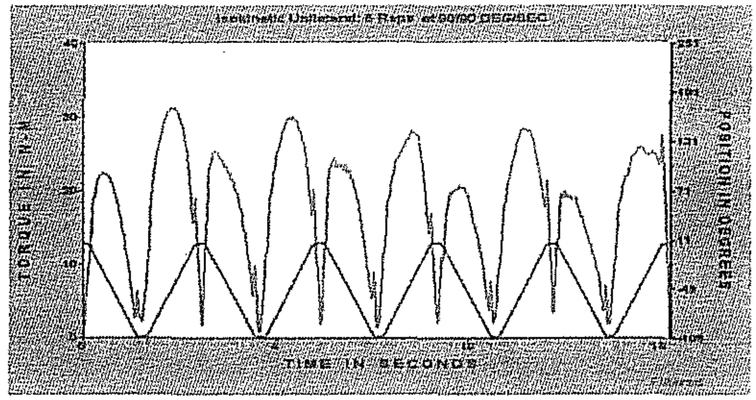
General Evaluation

Name:		Session:	6/23/2011 2:15:03 PM	Windowing:	None
ID:		Involved:	None	Protocol:	Isokinetic Unilateral
Birth Date:	(M/d/yyyy)	Clinician:		Pattern:	Ext/Int Rotation 90 Abd
Ht:	183	Referral:		Mode:	Isokinetic
Wt:	78.0	Joint:	Shoulder	Contraction:	CON/CON
Gender:	Male	Diagnosis:		GET:	No Gravity Correction

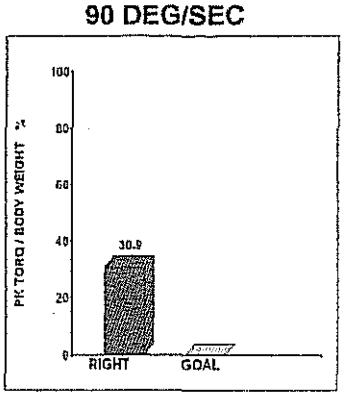




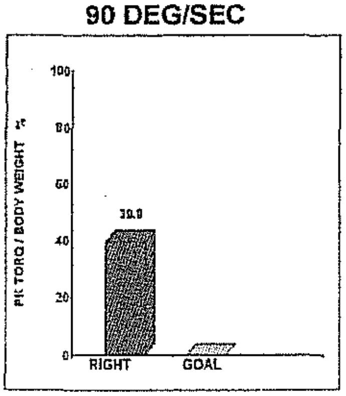
		'ÞAEXT ROTATION 90 DEG/SEC	¼ÞAINT ROTATION 90 DEG/SEC
Side: RIGHT			
# OF REPS: 5			
PEAK TORQUE	N-M	24.0	30.9
PEAK TQ/BW	%	30.9	39.9
MAX REP TOT WORK	J	33.8	52.3
COEFF. OF VAR.	%	11.5	5.5
AVG. POWER	WATTS	21.3	29.8
ACCELERATION TIME	MSEC	70.0	120.0
DECELERATION TIME	MSEC	200.0	310.0
ROM	DEG	114.6	
AVG PEAK TQ	N-M	21.4	28.9
AGON/ANTAG RATIO	%	77.6	G: 61.0

		'ÞAEXT ROTATION 90 DEG/SEC	¼ÞAINT ROTATION 90 DEG/SEC
Side: RIGHT			
# OF REPS: 5			
PEAK TORQUE	N-M	25.3	31.3
PEAK TQ/BW	%	32.6	40.4
MAX REP TOT WORK	J	37.7	50.7
COEFF. OF VAR.	%	9.0	4.3
AVG. POWER	WATTS	22.5	30.5
ACCELERATION TIME	MSEC	80.0	180.0
DECELERATION TIME	MSEC	200.0	220.0
ROM	DEG	114.5	
AVG PEAK TQ	N-M	22.6	29.1
AGON/ANTAG RATIO	%	80.7	G: 72.0

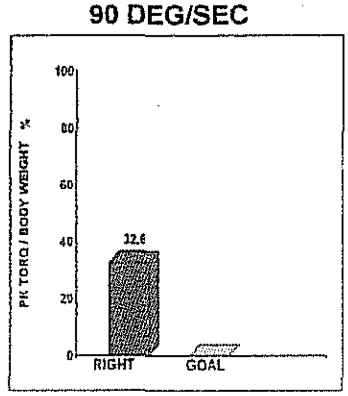
'ÞAEXT ROTATION
90 DEG/SEC



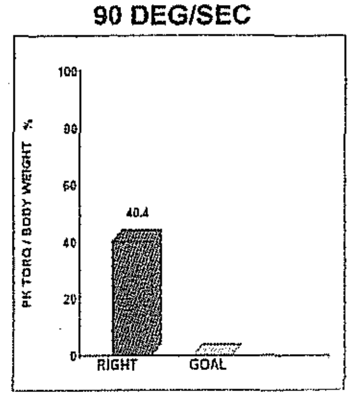
¼ÞAINT ROTATION
90 DEG/SEC



'ÞAEXT ROTATION
90 DEG/SEC



¼ÞAINT ROTATION
90 DEG/SEC



AK TORQUE:	Highest muscular force output at any moment during a repetition. Indicative of a muscle's strength capabilities.
AK TQ/BW :	Represented as a percentage normalized to bodyweight and compared to an established goal
X REP TOT WORK:	Total muscular force output for the repetition with greatest amount of work. Work is indicative of a muscle's capability to produce force throughout the range of motion
EFF. OF VAR.:	Statistical representation of test validity based on reproducibility of preformance. Lower values demonstrate higher reproducibility.
3. POWER:	Total work divided by time. Power represents how quickly a muscle can produce force.
CELERATION TIME:	Total time to reach Isokinetic speed. Indicative of a muscle's neuromuscular capabilities to move the limb at the beginning of the range of motion
CELERATION TIME:	Total time to go from Isokinetic speed to zero speed. Indicative of a muscle's neuromuscular capability to eccentrically control the limb at the end of the range of motion.
ON/ANTAG RATIO:	The Reciprocal muscle group ratio. Excessive imbalances may predispose a joint to injury

Figure 13 – Isokinetic Dynamometer Report

[redacted]

[redacted]