UNIVERSITY OF ALBERTA

MUSCLE THICKNESS AND CROSS-SECTIONAL AREA OF SUPRASPINATUS AS MEASURED BY DIAGNOSTIC ULTRASOUND

BY

MASAKI KATAYOSE ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE.**

DEPARTMENT OF PHYSICAL THERAPY

EDMONTON, ALBERTA

FALL, 1999

0-612-47048-2

UNIVERSITY OF ALBERTA

LIBRARY RELEASE FORM

NAME OF AUTHOR: **MASAKI KATAYOSE**

TITLE OF THESIS: **MUSCLE THICKNESS AND CROSS-SECTIONAL AREA OF SUPRASPINATUS AS MEASURED BY DIAGNOSTIC ULTRASOUND**

DEGREE: **MASTER OF SCIENCE**

YEAR THIS DEGREE GRANTED: **1999**

Masaki Katayose

Miyanomori 4-2-1-1-407
Sapporo, Japan
064-095

Date: Sept 10 1999

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **MUSCLE THICKNESS AND CROSS-SECTIONAL AREA OF SUPRASPINATUS AS MEASURED BY DIAGNOSTIC ULTRASOUND** submitted by **MASAKI KATAYOSE** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE**.

Dr. David Magee - Supervisor

Mr. Sandy Rennie

Ms. Gail Amort-Larson

Dated : Sept 9 1999

DEDICATION

I would like to dedicate this work to my parents in thanks for all they have given and continue to give to me. Thank you for your continuing love and support in whatever I do. The love and support that you have always provided me has assisted me immensely in life.

ABSTRACT

The purpose of this study was to determine the normal standard of the cross-sectional area (CSA) and thickness of supraspinatus as measured by diagnostic ultrasound in male sedentary individuals. In addition, the influence of hand dominance and aging towards CSA and thickness of supraspinatus were determined. Seventy two subjects participated in the study, (six ten-year-block groups from 20 to 79 years of age). Normal standard values of CSA and thickness were demonstrated with a high measure of intrarater reliability. Both CSA and thickness on the dominant side were statistically larger than non-dominant side. From clinical and practical view points, it is hard to find a significant difference in CSA and thickness of supraspinatus between the dominant and non-dominant sides because of the standard deviation of the measurements and the actual small differences. The CSA and thickness of supraspinatus also significantly decreased with aging.

ACKNOWLEDGMENT

I would like to thank my advisor, Dr. David Magee, for his support. The completion of this project would not have been possible without his guidance and encouragement. Furthermore, he has taught me many important things in my life beyond this project. He has provided an example for me to strive to be as good as I can at whatever I do.

Very sincere thanks also my committee members, Mr. Sandy Rennie and Ms Gail Amort-Larson, for their assistance in the completion of this thesis and their thoughtful comments.

I would also like to thank very much the president; Dr. Toyoaki Akino, the dean; Dr. Tusyoshi Sato and the staff of School of Health Sciences, Sapporo Medical University, Japan for allowing me to study at the University of Alberta, and especially, the department chairs; Dr. Hidekatu Takeda and Dr. Shigenori Miyamoto, and staff of Department of Physical Therapy, for their support and encouragement.

I would also like to thank Dr. Seiichi Ishii, Dr. Toshihiko Ogino, Dr. Makoto Sugawara, Dr. Masanobu Mitani and Dr. Toshio Ohyanagi for their advice and support on many occasions during my academic and clinical career.

Thank you very much to Professor Masako Miyazaki and Dr. Lili Liu for their support to me and my family while in Edmonton which enabled me to concentrate on this project.

I would like to express my appreciation to the Aloka Company, Japan, for allowing me to use their equipment for this thesis.

Finally, I must thank my wife, Naoko, and my son, Lyousuke, who know the true meaning of family, love, support and encouragement. I truly could not have done this project without their deep understanding and emotional support. Thank you.

TABLE OF CONTENTS

I: CHAPTER ONE: THE PROBLEM
PAGE

II: CHAPTER TWO: LITERATURE REVIEW

III: CHAPTER THREE: METHODS AND PROCEDURES

IV: CHAPTER FOUR: RESULTS

APPENDICES **PAGE**

LIST OF TABLES

LIST OF FIGURES

I: CHAPTER ONE

INTRODUCTION

I-1. INTRODUCTION:

The shoulder joint is a ball and socket joint with a narrow socket surface in comparison to the humeral head (76). Therefore, most dynamic stability of the glenohumeral joint depends on the muscle activities around the shoulder joint, especially the rotator cuff muscles (5, 36, 71, 72). The rotator cuff consists of four muscles - subscapularis, teres minor, infraspinatus, and supraspinatus. These muscles act as stabilizers during shoulder movements when working in conjunction with each other and other shoulder muscles such as deltoid, trapezius, and rhomboids. Because of their important function, injury to the rotator cuff muscles and adjacent musculature is one of the major causes of shoulder dysfunction, and/or one of the results of shoulder dysfunction (33, 34, 37, 100).

Each of the rotator cuff muscles has a specific function according to electromyography studies. The precise and valid evaluation of each rotator cuff muscle is essential in the management of any shoulder problem. To evaluate the functions of an isolated rotator cuff muscle, two research method techniques, which are based on the general research methods of the study for muscle function, have been used primarily. The first is electro-physiological studies such as electromyography which demonstrates the electrical activity of muscle. Using this needle electrode method, which is an invasive technique, isolated rotator cuff muscle activity can be evaluated. Secondly, anatomical and morphological studies such as composition analysis of muscle fiber and cross-sectional area (CSA) analysis of muscle can be used. Because muscle force generation partly depends on the muscle CSA, as muscle CSA increases with muscle exercise, there is a positive relationship between muscle strength and muscle CSA (66, 83). Jones et al (43) stated that "about 50 percent of the variation in strength between people can be explained by differences in muscle size"(p105). Thus, although the angle of pennation of muscle fiber to tendon affects the relationship between CSA and force generation, the CSA of each muscle indicates the force generation capacity of each muscle. These two methods, electro-physiological and morphological studies, compensate for the limitation of each other. The electro-physiological studies explain how or when a muscle is active and the morphological studies explain how muscles have the capacity to generate force. In shoulder studies, several electromyography studies have been reported (36, 38, 46, 49, 69). Although anatomical and morphological studies for the shoulder have also been reported, most of these reports were related to the joint structure or the rotator cuff tendon, not the muscles which comprise the rotator cuff. The anatomical and morphological studies of rotator cuff muscle, especially CSA studies, have not been well studied (64, 65, 91).

The methods of acquiring a diagnostic image to perform anatomical and morphological studies for muscle are magnetic resonance imaging (MRI), computed tomography (CT), and diagnostic ultrasound. MRI is not an invasive technique and is reported to be the best way to get clear images of body soft tissue (56, 84). Many of the anatomical and morphological studies for muscle such as quadriceps have been done using MRI (2, 15, 21, 29, 31, 50, 66, 70, 91, 97). However, MRI is expensive and requires considerable time to accomplish the examination. Although CT requires less examination time than an MRI, it is an "invasive" technique in that potentially harmful x-rays are used. Thus, several considerations are required before use of these examination techniques as clinical evaluation tools for muscle morphology can be applied in repeatable and following-up situations. In contrast, diagnostic ultrasound is not invasive, expensive, or complicated in application. Furthermore, diagnostic ultrasound examination could be managed by a physical therapist. It would be a big advantage to have practical data such as the degree of muscle atrophy and effect of physical therapy treatment on muscle atrophy if this information could be acquired objectively and may affect the treatment given. These situations could lead to the accumulation of outcome data on the effectiveness of physical therapy in treating muscle injury and atrophy.

Diagnostic ultrasound does have some detractors and application difficulties: clearness of image, the reliability of understanding what is being seen which is affected by the skill of examiner, and the image limited by the size of the examination probe. Diagnostic ultrasound can not "see" the image behind high echo tissue such as bone. Therefore, the possible target areas are limited by a size of probe and echo level of the surrounding tissue. However, several recent studies have reported its usefulness in assisting clinical management in certain areas through technological innovation (6, 11, 12, 14, 20, 75, 89, 101). Other studies also demonstrated the clinical usage of diagnostic ultrasound for anatomical and morphological evaluation of muscle. In these studies, quadriceps femoris, tibialis anterior, and multifidus were selected as target muscles (28, 57, 85, 86, 88, 97, 102). All of these muscles are located in front of bone and close to skin. Of the rotator cuff muscles of the shoulder, supraspinatus can meet these characteristics as a target muscle. It has adequate muscle size for the diagnostic ultrasound probe, is in front of bone tissue, and is close to the skin.

Several researchers have observed supraspinatus muscle atrophy as the result of several clinical conditions, such as rotator cuff tears, neuropathy due to ganglions, overstress of the musclotendinosus unit from throwing and ischemic conditions in several specific positions, and exercises (64, 65, 91). Also, muscle atrophy of the supraspinatus has been shown to be induced by aging (65). All of these studies employed MRI and CT to evaluate supraspinatus atrophy. In most of these studies, the data of the "no symptom" side was regarded as the control in terms of supraspinatus to identify muscle atrophy, although it is not clear whether the "no symptom" side data was a normal standard. This method is not suitable for either the comparison of data between subjects or the identification of atrophy with aging, because it is a relative method for the detection of muscle atrophy in each subject. Normal standard data which may make it possible to compare inter-subjects' data is essential to accomplish muscle atrophy examinations. However, this standardized data with aging has not been elucidated in MRI, CT, or diagnostic ultrasound studies. In addition, muscle thickness is utilized to measure muscle atrophy as well as CSA in some studies since muscle thickness was assumed to reflect CSA. Hides et al (28) reported a high correlation between linear and area measurement in normal lumbar multifidus. However, Stokes et al (86) mentioned in a review paper in 1997 that the relationship between linear and area measurement may not be evident in atrophic muscle conditions. They also reported that the relationship between linear and area measurement may be different in different muscles. The relationship between CSA and muscle thickness of supraspinatus has to date not been elucidated.

I-2. STATEMENT OF THE PROBLEM:

The precise and valid evaluation of each rotator cuff muscle is essential in any shoulder problem because of its anatomical and functional characteristics. Diagnostic ultrasound may be one of the applicable tools for isolated measurement of muscle atrophy of supraspinatus because of the characteristics of diagnostic ultrasound and the location and characteristics of supraspinatus. Muscle atrophy has been indicated by the CSA and the muscle thickness based on the "no symptom" side data as a control in previous diagnostic ultrasound studies (21, 64, 91). However, it is not clear whether the "no symptom" side data are in reality a normal standard.

These values might be influenced by the lateralization of hand function, because muscles of upper extremity on the dominant side may be developed to a greater extent with dominant hand activities. In addition, dysfunction and/or decrease in activity on the injured side may influence the activity of "no symptom side". Thus, these influences mislead the interpretation of normal standard values for comparisons between subjects, and among changes with aging because they make use of intra-subject control data which is not a generalized standard. Normal standard data of CSA of supraspinatus as measured by diagnostic ultrasound has not been elucidated at this time. Furthermore, the obvious relationship between CSA and muscle thickness of supraspinatus has not been reported. Ideally, it should be demonstrated whether muscle thickness is adequate to measure atrophy of supraspinatus if muscle thickness is being selected as an indicator of muscle atrophy. The establishment of a normal standard of CSA and muscle thickness of supraspinatus may lead to the development of an effective clinical diagnostic ultrasound evaluation for supraspinatus, and it also gives the possibility of the accumulation of objective outcome data of physical therapy for the shoulder.

I-3. OBJECTIVES:

The purposes of this study were;

1. To demonstrate the normal standard value of CSA of supraspinatus as measured by diagnostic ultrasound in several age groups of a male Japanese sedentary population.
2. To demonstrate the normal standard value of muscle thickness of supraspinatus as measured by diagnostic ultrasound in several age groups of a male Japanese sedentary population.
3. To determine if there was a significant relationship between the CSA and muscle thickness of supraspinatus as measured by diagnostic ultrasound in a male Japanese sedentary population.
4. To demonstrate if CSA of supraspinatus as measured by diagnostic ultrasound in several age groups of a male Japanese sedentary population were different.
5. To demonstrate whether muscle thickness of supraspinatus as measured by diagnostic ultrasound in several age groups of a male Japanese sedentary population were different.
6. To determine if there was a significant difference in CSA of supraspinatus as measured by diagnostic ultrasound between dominant

hand side and non-dominant hand side in a male Japanese sedentary population.

7. To determine if there was a significant difference of muscle thickness of supraspinatus as measured by diagnostic ultrasound between dominant and non-dominant hand in a male Japanese sedentary population.

I-4. HYPOTHESES:

The research hypotheses were based on a review of the literature and author's clinical impression. The hypotheses were;

1. CSA and muscle thickness of supraspinatus as measured by diagnostic ultrasound in a male Japanese sedentary population will have a significant positive relationship.

2. CSA of supraspinatus as measured by diagnostic ultrasound of a male Japanese sedentary population will decrease with age.

3. Muscle thickness of supraspinatus as measured by diagnostic ultrasound of a male Japanese sedentary population will decrease with age.

4. There will be no significant difference in the CSA of supraspinatus as measured by diagnostic ultrasound between the dominant side and non-dominant side in a male Japanese sedentary population.

5. There will be no significant difference in the muscle thickness of supraspinatus as measured by diagnostic ultrasound between the dominant side and non-dominant side in a male Japanese sedentary population.

I-5. DEFINITIONS:

1: Muscle atrophy: The reduction in the cross-sectional area of individual muscle fiber (43). It may also be referred to as wasting.

2: Diagnostic ultrasound: A real-time image processor system. Although ultrasound is defined as the use of sound waves at a frequency over 2 MHz, frequency for diagnostic tools are utilized from 2 MHz to 10 MHz (86). Generally B mode is utilized to illustrate cross-sectional images of the tissue (Appendix A). This mode is utilized for musculoskeletal imaging. In this project, the diagnostic ultrasound images were acquired using the 7.5M Hz real time probe of Aloka Echo Camera SSD-1000. This system was borrowed for this research project from Aloka Co. Japan. The same probe and system were utilized in all measurements in this study after a pilot test to test the procedure of this project and to determine the measuring researcher's intra-rater reliability for measurements.

3: Muscle cross-sectional area (CSA) of supraspinatus: This is the cross-sectional area of the muscle in the slice image through the mid point of the scapular spine. The diagnostic ultrasound probe was put at a right angle to the line between posterior angle of acromion and medial edge of scapula spine. As a result, this probe angle was also at right angles to scapular spine. CSA was imaged with the B mode. See appendix A.

4: Muscle thickness of supraspinatus: This is the linear distance between inferior and superior boundary of supraspinatus in the slice image through the mid point of scapular spine. The superior boundary was the line between trapezius and supraspinatus. The inferior boundary was parallel to the superior line. This slice was the same as the image for CSA of the supraspinatus. Therefore, the image section was at right angles to scapular spine. The muscle thickness sometimes has been utilized for measurement of muscle size instead of CSA in certain muscles because it has been assumed that the relationship between CSA and muscle thickness had a high correlation in certain muscles such as the lumbar multifidus and the masseter muscle (28).

5: Dominant hand function side: This is also called lateral dominance of the hand. The criteria for dominance side was determined using the Edinburgh Handedness Inventory. This inventory involves 10 items in a questionnaire to determine the handedness (Appendix B) (67). Only right handed subjects were used in this study. Thus, subjects should have right hand dominance in all 10 items of the Edinburgh Handedness Inventory.

6: Sedentary : A level of physical activity. Sedentary people did not have regular based bilateral sports activity using the upper extremities more than four times a week and also did not have the regular based lateral sports activities of upper extremities. In addition, their work did not require heavy physical work.

I-6. LIMITATIONS:

This study was limited by the reliability of the examiner to measure CSA and muscle thickness of supraspinatus using diagnostic ultrasound. ICC of intra-rater reliability were demonstrated to be 0.83 between scans and 0.81 between days for CSA measurement and 0.98 between scans and 0.98 between days for thickness measurement (See Appendix C) In addition, this research was valid only in the following conditions:

1: The test probe was a linear probe with a frequency of 7.5 MHz.

2: The target muscle was supraspinatus.

3: Muscle thickness and muscle CSA were captured using B-mode and measured by a NIH image processor.

4: Subjects were male sedentary Japanese.

5: Subjects were right hand dominant.

I-7. DELIMITATIONS:

This study was delimited to:

1. test subjects having normal shoulders with no known pathology.
2. test subjects leading a sedentary lifestyle with no regular sports activity.

I-8. ETHICAL CONSIDERATIONS:

Diagnostic ultrasound has been demonstrated to be a non-invasive and safe diagnostic image processor (86). During diagnostic examination, subjects do not feel any unusual sensations. Although ultrasound is also utilized for therapeutic purposes in physical therapy and radiation therapy and attention must be paid to its administration, diagnostic ultrasound uses a different frequency and intensity than therapeutic ultrasound. Therapeutic ultrasound employs a relatively lower frequency than the diagnostic ultrasound.

Informed consent in Japanese was obtained from the subjects before enrollment in this study (Appendix D). Consent from the Joint University - Capital Health Authority Health Research Ethics Board was also obtained (Appendix E). The letter of support concerning subject consent form in Japan from dean of School of Health Sciences, Sapporo Medical Unversity, Japan (Appendix F). Subjects were told that they could withdraw from this study at any time without prejudice.

II: CHAPTER TWO
LITERATURE REVIEW

The literature has been reviewed in five sections: 1.) the function and injury of supraspinatus in the shoulder, 2.) the physiological basis of muscle atrophy, 3.) the atrophy of supraspinatus, 4.) measurement of muscle atrophy of supraspinatus, 5.) diagnostic ultrasound.

II-1. THE FUNCTION AND THE INJURY OF SUPRASPINATUS:

II-1-a. Function of Supraspinatus

The role of the supraspinatus muscle in the shoulder has been investigated from several points of view: biomechanical model analysis (34), cadaver dissection analysis (100), electromyographic movement analysis (41, 46, 49, 59), and muscle strength analysis (33, 37, 41, 46, 59). The supraspinatus and deltoid muscles are equally responsible through their force couple action for producing torque about the shoulder joint in the functional planes of motion (33). The supraspinatus probably works to compress the glenohumeral joint and initiates the movement of shoulder abduction (100). The supraspinatus has been defined as one of the synergistic muscles of shoulder abduction (33, 36, 71, 72). Recently, Hughes and An (34) stated that abduction may not produce the greatest loads on the supraspinatus tendon, and the force in the supraspinatus muscle is more significantly affected by external rotation when the arm is abducted. Itoi et al. (37) indicated, from isokinetic strength measurements following full-thickness tears of the supraspinatus tendon with local anesthetic for pain, that decreases in strength of 19% to 33% in abduction and 22% to 33% in external rotation appear to represent the contribution of supraspinatus to the strength of the shoulder. Furthermore, cadaver dissection studies revealed the partial insertion onto the lesser tubercle and stated that supraspinatus may act as an internal rotator (48, 95). Ihashi et al (35) also mentioned the internal rotator function of supraspinatus from EMG, MRI and cadaver dissection studies. They reported that when the humerus was relatively in internal rotation, shoulder internal rotation resulted and when the humerus was relatively in external rotation, shoulder external rotation resulted. The reason for these findings to be mentioned, from cadaver dissection and MRI examination, was because the relation between the running direction of the supraspinatus muscle and the center of rotation of the humeral head were dependent on the position of the shoulder joint. Thus, the supraspinatus appears to have a function not only in shoulder abduction but also in shoulder external and internal rotation. In addition, the supraspinatus works mainly as a dynamic stabilizer of the glenohumeral joint rather than as a mover in shoulder performance (4, 36, 69). Accordingly, the supraspinatus works for and is stressed by most shoulder activities.

II-1-b. Injury of Supraspinatus

Although many studies concerning supraspinatus tendon have been reported, only a few have mentioned specific injury to the supraspinatus muscle. Both injuries of the tendon and the muscle of supraspinatus have been reported to be associated with vascularization of this region (40, 52, 53). Most studies concerning the rotator cuff mentioned that the vascularization of supraspinatus tendon as a clue to supraspinatus tendon rupture (53, 62, 92). Ling et al (52) demonstrated the critical zone of the supraspinatus tendon. They also reported the critical zone tended to increase with age. Javholm et al

(38-40) investigated intramuscular pressure and muscle blood flow in supraspinatus. Intramuscular pressure which impeded local muscle blood flow was high in supraspinatus muscle compare with trapezius and deltoid muscles in the abducted arm position. Thus, sustained or repetitive high load contraction of supraspinatus could increase the hypovascularity period of supraspinatus.

Another factor that may affected the supraspinatus tendon is changes in the acromial morphology with age (98). Acromial morphology has been divided into three categories according to the shape of the acromion, which are Type I (Flat), Type II (smoothly curved), and Type III (hooked) (7). Epstein et al (19) reported no significant difference in the distribution of acromion type with respect to age or gender. However, recent studies demonstrated the incidence of the type III was significant greater in the above 50 age group as opposed to those below 50 years of age (98). MacGillvray et al (54) confirmed the anterior acromion slope becomes more hooked with age using three dimensional MRI (N= 111). Since type II and type III were associated with tears of the rotator cuff (68), aging might be one of the factors of the tears of the rotator cuff.

II-2. THE PHYSIOLOGICAL BASIS OF SKELETAL MUSCLE ATROPHY:

Skeletal muscle atrophy occurs in several clinical situations such as injury, pain, immobilization, weightlessness (16) and aging (58). Basically, the studies of skeletal muscle atrophy have been promoted by basic studies in space medicine (78). The mechanisms of the muscle atrophy are complex because of many related factors: 1.) biochemical and physiological factors; 2.) the neural system; and 3.) the influence of external and environmental factors (13). In this section, the literature is reviewed in the following three subsections: 1.) the effects of inactivity, immobilization, and weightlessness, 2.) the effects of pain, 3) the effects of aging.

II-2-a. The Effect of Inactivity, Immobilization, and Weightlessness

A review article in 1983 indicated that major changes occur in the mass of muscle during periods of disuse (9). Atrophic change in muscle occurs at a very early stage of immobilization. Booth et al (10) stated that the atrophy of skeletal muscle is caused by a decreased rate of protein synthesis and increased rate of protein degradation. They observed that during the first 6 hours of immobilization, when using rats, a significant decline of 3.6% per a day in the fractional rate of protein synthesis was found compared with the control value of 5.7% per day. It has also been reported that atrophy occurred earlier in slow-twitch muscle than fast twitch muscle after 5 weeks immobilization (25). However, when immobilization was continued, there are no different incidence in the two different types of muscle (79). In addition, it was reported that increased usage of atrophied muscle was followed by an increased rate of protein synthesis (60, 93). Therefore, muscle atrophy caused by inactivity and immobilization can be restored by proper exercise.

Muscle atrophy also occurred in weightless circumstances (17). Leblanc et al (50) demonstrated that a decrease in the cuff muscle volume (anterior cuff: -3.9%, soleus-gastrocunemius: -6.3%) and in the thigh muscle volume (quadriceps, -6%) after an 8-day shuttle flight to space. Edgerton et al (17) observed smaller fiber sizes (-16% for type I, -23% for type IIA and -36% for type IIB) in the vastus lateralis muscle of five astronauts after an 11-day flight. From this data, they demonstrated that the fast-twitch fibers showed more atrophic change than the slow twitch fibers. Bedrest studies and lower limb unloading model studies which simulate the weightlessness circumstances are currently utilized because of difficulty of acquiring weightlessness conditions. A review in 1997 summarizing bedrest studies indicated that thigh muscle atrophy seemed to occurred at the rate of two to three percent per week between one to six weeks (16). Hather et al (27) demonstrated a decrease in muscle cross-sectional area of the thigh and a different amount of atrophy between quadriceps (-16%) and hamstrings (-7%) after six weeks of lower limb suspension.

II-2-b. The Effect of Pain

The effects of pain on muscle atrophy has been described in several articles (3, 61, 87, 99). A review paper in 1989 summarized that pain is one of the major causes of thigh muscle reflex inhibition in knee injuries (61). Reflex inhibition is defined as a situation in which sensory stimuli decrease reflex activity. Although, even in the absence of pain, joint problems such as joint effusion could also stimulate reflex inhibition (87), pain is still the major factor causing reflex inhibition. Arvidsson et al (3) reported the influence of postoperative pain on muscle function. They demonstrated that pain relief as a result of epidural analgesia was significantly effective in causing normal activation of the quadriceps muscle after open knee surgery. Young et al (104) also demonstrated that pain relief using bupivacane could affect muscle extensor strength in the knee extensor strength in the post menisectomy knee. The control group, which did not receive the bupivacane, had the greatest decrease in rectus femoris strength.

II-2-c. The Effect of Aging

There is a general decline in certain muscle functions with aging. Even superbly trained world class athletes show similar trends and time courses of decline in structural and functional properties (80). Muscle atrophy and decreased muscle strength does occur with aging. Carmeli et al (13) mentioned that the extent of age-related changes varies from muscle to muscle, and some did not seem to be affected by age. Furthermore, Holloszy et al. (30) demonstrated that age-related muscle changes may be manifested differently in various muscle fiber types and may also depend on whether the muscles in question are weight-bearing or non-weight-bearing. The aging atrophy of the muscle begins around 25 years of age and thereafter accelerates (51). Generally, by 60-70 years of age, muscle mass of human beings decreases by 25-30% (23). Young et al (103) demonstrated that using diagnostic ultrasound to measure the cross-sectional area of the quadriceps muscle, a 25% decrease in cross sectional area in the 80s age group in comparison with the people in their 20s. Rice et al (74) demonstrated that decrease in 28-36% of muscle size of the leg muscles in people over age 65 years.

It has been reported that the atrophy occurring with aging is caused mainly by a loss of fibers (51). However, two studies have demonstrated no change in fiber number with aging (30, 82). A review article in 1994 stated that it is unclear whether or not the decrease of fiber size was accompanied by a decline in fiber number with age (13).

II-3. THE ATROPHY OF SUPRASPINATUS:

In this section, the literature has been reviewed in the following two subsections: 1.) the effects of clinical conditions, 2.) the effects of aging.

II-3-a. The Effect of Clinical Conditions

Atrophy of supraspinatus muscle has been observed in clinical conditions of the shoulder (65,105). Most investigations have focused on the relationship between rotator cuff pathology and the atrophy of the supraspinatus. Nakagaki et al (65) demonstrated that the diameter of supraspinatus muscle decreased with an increase in the length of the rotator cuff defect from cadaver dissection. Thomazeau et al (91), using MRI, demonstrated that the extent of the tear in both sagittal and coronal planes increased muscle atrophy, whereas a degenerative rotator cuff did not increase muscle atrophy.

Fatty degeneration in the supraspinatus muscle after a cuff tear has been found (63). Degeneration of the muscle has a stronger association with the degree of retraction of the tendon fibers than the reduction of muscle volume. That is, the extend of cuff tear size affects degeneration in the supraspinatus. The rotator cuff tear is not only one of the main related reasons for atrophy, but is also one of the related reasons for the degeneration of the muscle. Therefore, it is necessary to aware the degeneration of the muscle to identify the muscle fiber atrophy in the evaluation of muscle atrophy.

In addition, from the relationship between the morphologic changes of supraspinatus observed by magnetic resonance imaging and electromyography in torn cuff patients, Nakagaki et al (64) demonstrated that the muscle activity of supraspinatus muscle decreased more than what was expected from muscle atrophy when such morphologic changes were shown. The degeneration disguised the muscle fiber atrophy because the degeneration of muscle resulted in the exchange from muscle fibers to fibrous tissue.

Atrophy of supraspinatus has also been demonstrated in high school baseball pitchers who had some clinical symptoms without cuff tears, although hypertrophy of the supraspinatus of high school baseball pitchers who had no clinical symptoms and conditions was observed (44).

II-3-b. The Effect of Aging:

Nakagaki et al (65) reported that there was a negative correlation between age and the diameter of the slice of the supraspinatus muscle in the group with a normal cuff from cadaver dissection. They defined two types of diameter, because of the oval shape of CSA of supraspinatus, which are long diameter (L) and short diameter (W). (See Figure II-1.) There was a negative correlation between age and the short diameter but no significant correlation between age and the long diameter. The reason for the different influence between long and short diameter was not discussed. It has not been clear whether the degeneration of supraspinatus muscle with aging atrophy occurs in the same way as the degeneration of supraspinatus muscle with a cuff tear.

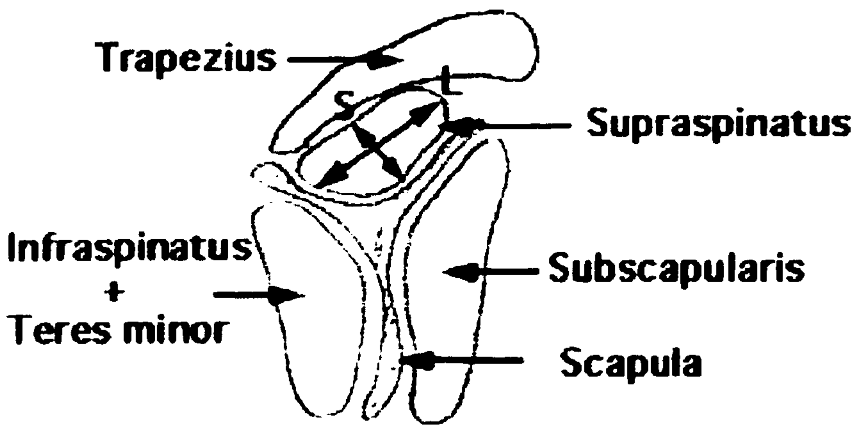


Figure II-1: Supraspinatus Muscle on Oblique-sagittal Slice

L: Long diameter, S: Short diameter

Vahlensieck et al (95) found the supraspinatus muscle to be composed of two distinct portions in cadaver dissections and MRIs. They observed the ventral part of the muscle, which originates from the anterior supraspinatus fossa and inserts onto the superior aspect of the greater tubercle and frequently also onto the lesser tubercle, and the dorsal portion, which originates from the posterior aspect of the supraspinatus fossa and the scapular spine and inserts onto the greater tubercle beside the ventral portion. Kolts (48) also stated a partial insertion onto the lesser tubercle of the ventral part of the muscle in a series of cadaver dissections. Gagey et al (21) observed that the ventral part of the supraspinatus muscle has a thicker and longer fibrous frame than the dorsal part. Therefore, characteristics of atrophy of supraspinatus with aging which is a negative correlation between age and the short diameter stated by Nakagaki (65) could be explained from these locations of two portions of supraspinatus.

II-4. MEASUREMENT TECHNIQUE OF MUSCLE ATROPHY OF SUPRASPINATUS:

Several methods for measurement of the muscle atrophy of supraspinatus have been tried. To observe the atrophy, direct measurements of cadaver specimens, MRI, CT, and ultrasound have been used in most of the investigations. The method of direct measurement of the cadaver specimen was used by a few investigations (65, 95). This method is very accurate but one is unable to use this method in clinical situations. MRI and CT were used in most investigations (21, 64, 91). However, these methods are very costly and in the case of CT scans, potentially dangerous because of x-ray use. The imaging time for MRI is quite long. Zanetti et al (105) described the imaging time for cuff muscles as three hours and twenty minutes per subject. Recently, ultrasound has been used by several researchers because of the cost factor, the image reliability, the short measurement time, and safety as mentioned previously (42, 44, 94). The relative small structure of supraspinatus and the tissue surrounded by bone tissue also supports using ultrasound. In addition, ultrasound can be used in repeatable and prompt examinations which are needed in some clinical situations such as checking the degree of muscle atrophy which, in turn, may indicate exercise efficacy during physical therapy sessions. It can be useful for judging rehabilitation outcome from a morphological view point in muscle exercise, because, the relationship between muscle exercise and atrophy could be confirmed promptly and frequently using diagnostic ultrasound.

Regardless of the method used, the problem of identification of muscle atrophy is the definition of the degree of the atrophy. Three methods of identifying muscle atrophy in supraspinatus have been reported in the literature. The first method is relative standardization based on the length of the supraspinatus. Nakagaki et al (65) measured the short and long diameter of a slice of the muscle belly in cadaver specimens directly. These diameters were standardized by the length of supraspinatus to consider the confounding of the body constitution. Nakagaki et al (64), using magnetic resonance imaging, also used the ratio of the largest width of the supraspinatus muscle belly to the long axis of the supraspinatus muscle which was the distance from the greater tubercle to the proximal end of the supraspinatus muscle. They termed this the supraspinatus muscle belly ratio.

The second method used the ratio between the surface of the cross-section of the muscle belly and that of the fossa. The observation slice was an oblique-sagittal plane which crossed the scapula through the medial border of the coracoid process (91).

The third method used the thickness of the supraspinatus, using ultrasound imaging instead of the cross-sectional area of the supraspinatus as was used in the former methods. Jensen et al. (42) performed ultrasound scanning at three sites above the fossa of supraspinatus on nine healthy subjects and five patients. They reported a coefficient of variation of the measurement of thickness as four percent. They also observed a 14 percent increase in the thickness of supraspinatus muscle during 30 degrees shoulder abduction in the health subjects, whereas the thickness of trapezius muscle remained constant. These findings indicate increasing muscle thickness when the muscle contracts. Katayose et al (44) reported that there was no difference between the right and left muscle thickness of the supraspinatus using this method. They also found a positive correlation between muscle thickness of supraspinatus and body height. The feasibility of establishing normative data in quantitative evaluation of muscle thickness of the supraspinatus was stated using this correlation although subjects were limited to the 20s age group.

II-5. DIAGNOSTIC ULTRASOUND:

In this section, the literature has been reviewed in following two sub sections: 1.) characteristics of ultrasound and ultrasound image, 2.) validity and reliability of ultrasound measurement

II-5-a. Characteristics of Ultrasound and Ultrasound Image

Ultrasound is very similar to acoustic sound except for its frequency. The frequency of ultrasound is between 2 and 10 MHz whereas the frequency of acoustic sound ranges between 20 and 20000 Hz. Since ultrasound is a longitudinal wave, as is acoustic sound, the characteristics of physics are the same for both. Ultrasound can be reflected, absorbed, or scattered (45). The speed of ultrasound , frequency, and wave length have a relation which is : speed of ultrasound = frequency x wavelength. The wave length is related to the resolution of the ultrasound image (90). Generally, since the average speed of ultrasound in soft biological tissues is assumed to be 1540m/s (86), wave length depends on frequency. Thus frequency in diagnostic ultrasound implies the level of image resolution (90). Stokes et al stated values of ultrasound wavelength for different ultrasonic frequencies assuming the speed of sound to be 1540m/s. See table II-1. In addition, the decision of the frequency used for ultrasound imaging depends on the depth of location of the target tissue, because low frequency loses the resolution with long wavelength and high frequency increases the attenuation with frequency (86). Therefore, 3 - 7.5 MHz is utilized in most studies of evaluation of muscle size when using diagnostic ultrasound (32, 44, 45, 88, 90, 103).

Table II-1
Values of Ultrasound Wavelength for Different Ultrasonic Frequencies
Assuming the Speed of Sound to Be 1540 m/s
< Adapted from (81, 86, 90) >

Frequency (MHz)	2	3	4	5	6	7	8	9	10
Wavelength (mm)	0.77	0.62	0.51	0.44	0.39	0.31	0.26	0.21	0.15

An ultrasound image is generated by the reflected waves occurring as echo from the boundary layers of tissue. Generally, continuous pulse mode and single pulse mode are used in the generation of an ultrasound image. Continuous pulse mode is utilized for Doppler imaging. This mode is adequate for the imaging of movement of the tissues. Recently analysis of the movement of tendon and muscle using Doppler imaging has been noted (24, 89). It has also been used in cardiac and blood flow studies (77). Single pulse mode is utilized for most imaging soft tissue. Generally, B-mode is based on a single pulse mode. A B-mode image provides location, position and shape of the tissues. Therefore, this mode is used for musculoskeletal imaging. The transducer generates pulsed ultrasound and also receives reflected ultrasound waves between pulsed ultrasound waves. Thus, 13-30 images per second pulses also can occur during a real time motion image.

II-5-b. Validity and Reliability of Ultrasound Measurements

Hide et al (28) demonstrated the validity of diagnostic ultrasound using the image of the lumbar multifidus with MRI. There were no significant differences between the CSA measurements made with the two techniques. Studies which involve comparison of diagnostic ultrasound with CT scan support this result (18, 83) .

The reliability of diagnostic ultrasound also has been shown in several studies (47, 57, 73). Martinson and Stokes (57) assessed intra-rater reliability for measurement of anterior tibial muscle CSA by analysis of the coefficient of variation. The coefficient of variation between measurements on two different days was 6.5 percent, and, that between the measurement of the two scans at same time was 3.6 percent. Kelly and Stokes (47) also reported the coefficient of variation of measurement of anterior tibial muscle CSA. They stated a coefficient of variation of 2.0 percent between days and 2.3 percent between scans. Recently, Rankin and Stokes (73) stated the intraclass correlation coefficients and Bland Altman test for real time ultrasound for measuring muscle CSA as an appropriate reliability study method. They also reported inter-rater and intra-rater reliability. The intraclass correlation coefficient for inter-rater reliability was 0.92. The intraclass correlation coefficients between measurement scans on day 1 and day 2 were 0.94 and 0.93 respectively. The intraclass correlation coefficients between days was 0.92.

III: CHAPTER THREE

METHODS AND PROCEDURES:

III-1. SUBJECTS:

Subjects were male sedentary volunteers. They were primarily recruited from 1) staff belonging to Sapporo Medical University and several related institutes in Sapporo, Japan; 2) students belonging to the Sapporo Medical University; and 3) elder people belonging to a seniors club in Sapporo, using verbal contact following a circular and project information letter (See Appendix G). The seniors club in Sapporo is a retired persons organization. The researcher informed the subjects of this study and set up an appointment if the subjects wished to participate. Once the subject agreed to participate in this study and had been examined to determine if he qualified, he was given an informed consent to read and sign (Appendix D). Qualifications of subjects were evaluated by the researcher based on set criteria (Appendix H). Subjects who did not have any clinical symptoms in their shoulder were considered for selection. All subjects were assured that they could drop out any time without consequence and that all information gained would be confidential. Finally, subjects were allocated one of six age groups; 20s (20-29), 30s (30-39), 40s (40-49), 50s (50-59), 60,s (60-69) and 70s (70-79).

III-2. SAMPLE SIZE:

For the comparison of CSA and muscle thickness among age groups , a sample size of 12 in each group was adequate from a sample size calculation (Appendix I) based on an expected standard deviation from a pilot study

(Appendix C). Twelve people in each 10 year category from 20 years old to 79 years old were examined (72 people in total were examined).

III-3. INCLUSION CRITERIA:

The subjects who participated in this study had normal shoulders. The criteria for normal shoulder was defined as follows: normal active range of motion, no pain in the neck or shoulder, no clinical symptoms in neck or shoulder, no history of any surgery to the shoulder or neck, no difficulty in using the upper extremity in daily activities. (See appendix H) The normal range of motion definition was based on a study by Boone et al (8). Mean ± 3SD acquired from the male population between 19 years of age and 54 years of age was used as normal range of motion since the subjects include elder people in this study. In addition, only males were used as subjects because muscle sizes might be different between the sexes. All subjects were right hand dominant to control the factor of hand dominance.

III-4. EXCLUSION CRITERIA:

Subjects who had a regular based bilateral sports activity using upper extremities, playing more than four times a week were excluded. In addition, subjects who had regular based lateral sports activity using upper extremities were also excluded. Subjects were excluded if they had any disease which could possibility affect muscle such as diabetes mellitus, neurological conditions, and/or collagen disease. In addition, subjects who were taking any medication such as steroids which could possibility affect muscle were excluded.

III-5. STUDY DESIGN:

This study was a cross-sectional survey design, partly correlational study, using a convenience sample. Measurement variables were CSA and muscle thickness of supraspinatus. These variables were measured using a ratio scale. Since the major purpose of this study was to determine if one could establish a normal standard of CSA and muscle thickness of supraspinatus, the characteristics of subjects had to be clearly defined. Population generalizability which refers to the degree to which a sample represents the population of interest and ecological generalizability which refers to the degree to which results of a study can be extended to other settings or conditions should be considered for a normal standard study. In this research project, characteristics of subjects which were not controlled were explained in particular since normal conditions may be varied from the several view points. These include several basic morphological data such as body height, body weight, shoulder ROM, and length of upper extremity (the length from acromion to the apex of the middle finger) and the length of upper arm (the length from acromion to lateral epicondyle of the humerus). See Appendix J for the data sheet for collection of the basic morphological data. In addition, active ROM of the shoulder which includes flexion, extension, external rotation, internal rotation, and abduction measured at the time of qualification for this study was used to explain the characteristics of the subjects. These variables were also all ratio scales. Furthermore, a questionnaire concerning daily activity level was performed in the interview style by the researcher. (See Appendix K for the questionnaire.) The interviews were used to ensure the eligibility of the subjects to participate. In addition, since age could be a strong factor in this study, the age factor was controlled through the allocation of subjects to several age groups. These processes gave the study better internal validity.

A pilot study which measured the intra-rater reliability of measurement muscle CSA and thickness of supraspinatus was done before the present research project began. In addition, these descriptive data were used to determine sampling size calculation.

III-6. DATA COLLECTION:

III-6-a. Place of Measurement

All measurements and interviews were done in the temporary laboratory of sports physical therapy at School of Health Sciences in Sapporo Medical University, Sapporo Japan. This temporary laboratory was arranged by the Department of Art and Science, School of Health Sciences, Sapporo Medical University (Chair, Dr. Norio Matushima) to utilize a high quality computer system for diagnostic ultrasound image analyzing.

III-6-b. Measurement of CSA and Muscle Thickness

The diagnostic ultrasound images were acquired using the 7.5MHz transducer (Aloka Echo Camera SSD-1000), which was borrowed from the Aloka Co. Japan for this research project. This system was maintained by professional service officers of Aloka Co. Japan. The same probe and system were utilized in all measurements in this study.

Subjects were asked to undress to the waist for measurement. Subjects were examined in the sitting position in a chair, and the shoulder was kept in neutral position, with the shoulder flexed and abducted at zero degrees (arm by the side) with palm facing inward. The section through the midpoint of scapular spine was observed. The midpoint of the scapula was determined using a metal tape measuring from the posterior edge of acromion to the medial edge of scapular spine at the medial border of the scapula. The probe was set on the surface of the skin over the supraspinatus at this midpoint of scapular spine at the appropriate angle (range 30 to 40 degrees) for observing the supraspinatus. Measurement of the image was observed with B-mode imaging to get the same slice angle for each subject based on the anatomical structure of the spine of the scapula. The B mode demonstrates the image of the sliced cross section of the muscle, and the thickness of a cross section of the supraspinatus was also measured with B mode (Appendix A). To get an identical slice and angle for each subject, the observed slice image was checked with B-mode image noting similar anatomical structures. Both shoulders were measured three times with the average being the selected value for each shoulder. The analog image data was converted to the digital image data as TIFF format, and stored in a Macintosh computer (Model G3 450MHz). Measurements of CSA and muscle thickness from these digital image data was analyzed on the Macintosh computer using the NIH Image program which is the public domain image processing and analysis program (developed at the U.S. National Institutes of Health and available on the internet at http://rsb.info.nih.gov/nih-image/). The measurement of CSA was taken using a square centimeter scale to two decimal points and the measurement of thickness was taken using a millimeter scale to one decimal point.

In the pilot study for measurement of CSA and muscle thickness of supraspinatus, the measuring researcher's intra-rater reliability of measurement of CSA and muscle thickness were ICC = 0.83 and ICC= 0.93 respectively.

Figure III-1 illustrates a cross-sectional image of supraspinatus. This image was acquired with the 7.5M Hz transducer using an Aloka Echo Camera SSD 1000. The subject was a 20 year old male university student who did not have any regular sports activity. Thickness of supraspinatus is the linear distance between the inferior and superior boundary of supraspinatus in the slice image through the mid point of the scapular spine. The superior boundary was the line between trapezius and supraspinatus. The inferior boundary was parallel to the superior line (Figure III-2).

Figure III- 1 : B-mode Image of Supraspinatus in Diagnostic Ultrasound

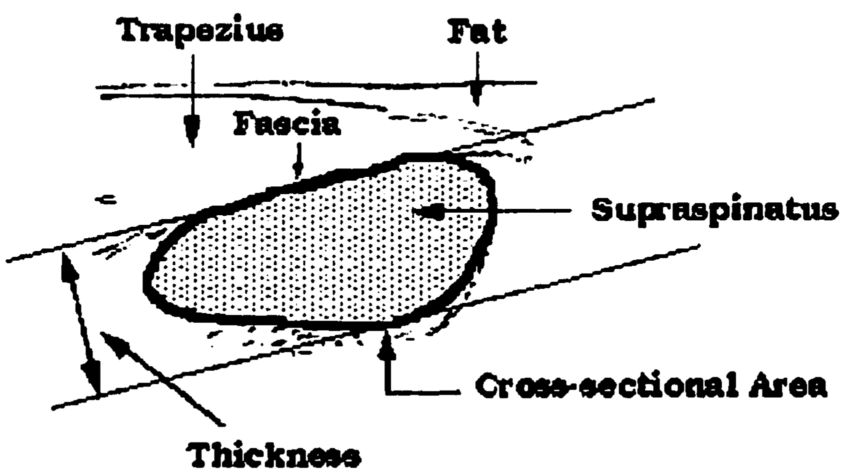


Figure III- 2 : Measurement Parameters; Cross-sectional Area and Thickness of Supraspinatus

III-6-c. Measurements of Body Characteristics of Subjects

III-6-c-1. Measurement of Body Height

The measurement for height was administrated using a body height meter. Subjects was asked to stand barefoot on the measurement step with the feet together. The ear lobe was in aligned with the acromion and the high point of the iliac crest (55). In addition, chin poking was corrected to avoid its influence on posture. The body height was measured in centimeters to one decimal point.

III-6-c-2. Measurement of Body Weight

The measurement of body weight was administrated using a digital body weight meter (TANITA TBF-501). Subjects were asked to stand on the meter table for measurement. The body weight was measured with the subject wearing just underwear. The body weight was measured in kilograms to one decimal place. The equipment was calibrated before measurements using calibration weights.

III-6-c-3. Measurement of Range of Motion

ROM was measured using a universal goniometer. Active shoulder ROM of extension, flexion, external rotation, internal rotation and abduction were measured. Appendix L shows the details of how the goniometer was placed on the bony land marks. Subjects were asked to sit on the chair when shoulder rotation was measured. The ROM of external rotation and internal rotation were measured with the arm in 90 degrees of shoulder abduction and 90 degrees of elbow flexion. The range between the horizontal line and ulna was measured. The axis of the goniometer was placed on the olecranon process. The ROM of shoulder flexion was measured in the standing position. The ROM of shoulder extension was measured in the standing position. All measurements were administrated by the researcher. Any cheating movement during the shoulder active movement was discouraged by advising the subject beforehand and the examiner watching for incorrect movement. Both sides were measured.

III-6-c-4. Measurement of Length of Upper Extremity and Upper Arm

The measurements for length of upper extremity and upper arm were administrated using a metal tape measure. Specifically, the length of the upper extremity was between the shoulder acromion and the apex of the middle finger when the subject was standing with his shoulder in the zero position (shoulder in zero degrees of flexion and abduction). Similarly, for upper arm length, the length between the acromion and lateral epicondyle of the humerus was measured. Both upper extremities were measured. The length was measured in centimeters to one decimal place.

III-6-d. Interview for Characteristics of Subject

A questionnaire concerning daily activities was conducted in the style of an interview (Appendix K). The same instrument was used at the interview for all subjects to avoid systematic errors in the interview. All examinations and interviews were done by the researcher.

III-7. STATISTICAL ANALYSIS

The following analytic methods were used to accommodate the study's goals. Appropriate descriptive statistics were used to characterize the subjects. The mean and standard deviation for CSA and muscle thickness in each group were described. The one-way ANOVAs were also used to determine if any significant difference in the characteristics of subjects existed among the six age groups. If ANOVA demonstrated a significant difference, Duncan post hoc analysis was employed to compare the differences between each group. These analysis demonstrated specifically the difference between each group. Furthermore, scatter plot graphs were used to summarize the values because they provided the trend of distribution with age. Since CSA and thickness were captured in three scans, the between-scans reliability was analyzed using intraclass correlation coefficients.

The one-way ANOVAs were conducted to demonstrate the difference of supraspinatus CSA and thickness among six age groups (20s, 30s, 40s, 50s, 60s, and 70s). If the ANOVA demonstrated significant difference, Duncan post hoc analysis was employed to compare the differences between each group. The difference between dominant and non-dominant hand side was determined with a Paired T-test. The correlation analysis was performed to demonstrate the relationship between CSA and muscle thickness of supraspinatus. All analyses employed the significant level of ≤ 0.05.

IV: CHAPTER FOUR

RESULTS

The present study examined the CSA and thickness of supraspinatus muscle of normal sedentary male subjects. Additionally, to describe specific characters of subjects, several body parameters such as weight, height, range of shoulder motion, and length of the upper extremity and upper arm, were obtained for each subject. The results are reported in the next two major subsections: 1) subject characteristics, 2) muscle CSA and thickness of supraspinatus.

IV-1. SUBJECTS CHARACTERISTICS

Seventy two subjects were utilized in this study with twelve subjects in 6 groups of ten year blocks. The demographic descriptive statistics for each subject are listed below. In addition, one-way ANOVAs were computed on the subject body parameters to determine if any significant difference existed among the six age groups. The results of one-way ANOVA for analysis of difference of subject body characteristics among six age groups are also listed below. If ANOVA demonstrated significant difference, a Duncan post hoc analysis was performed.

IV-1-a. Age

Table IV-1 presents the mean, standard deviation, and minimum and maximum age in each group.

Table IV-1

Descriptive Statistics for Subjects Age (in years)

Age Group	Number	Average ± SD	Minimum	Maximum
20s	12	23.4 ± 2.8	20	28
30S	12	34.3 ± 2.8	30	38
40S	12	45.3 ± 3.3	40	49
50S	12	53.8 ± 3.1	50	58
60S	12	64.0 ± 1.9	61	67
70S	12	73.8 ± 3.5	70	79

IV-1-b. Subject Height

Table IV-2 presents the mean, standard deviation, and minimum and maximum subject height in each group. As can be seen in Table IV-3, significant differences of height were found among the six age groups. The Duncan test demonstrated significant differences between 20's and all of the other groups (ie 30's, 40's, 50's, 60's, and 70's). It also demonstrated a difference between the 30's age group and 70's age group, as well as the 40's age group and 70's age group. These differences might have influenced this study's results. As will be discussed later in Section V-1, to determine the influence of this factor, height, and the correlation between height and CSA or thickness was analyzed in each group so that the age factor was not considered.

Table IV-2
Descriptive Statistics for Subjects Height (in cm)

Age Group	Number	Average ± SD	Minimum	Maximum
20s	12	173.5 ± 5.6	163.0	183.5
30S	12	168.5 ± 5.2	161.0	178.0
40S	12	168.8 ± 5.7	160.0	178.0
50S	12	166.4 ± 5.1	157.0	175.0
60S	12	166.7 ± 6.5	158.0	176.0
70S	12	163.2 ± 4.2	156.0	172.0
All groups	72	167.8 ± 6.1	156.0	183.5

Table IV-3
One-way ANOVA Result for Subjects Height among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	693.31	138.72	4.69	0.0010
Within Grp	66	1949.50	29.53		
Total	71	2643.11			

Table IV-4
Duncan Test as a Post Hoc Test of ANOVA for Subjects Height among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	173.3		*	*	*	*	*
30s	168.9						*
40s	169.4						*
50s	166.4						
60s	165.5						
70s	162.5						

*: significant difference

IV-1-c. Subject Weight

Table IV-5 presents the mean, standard deviation, and minimum and maximum of subject weight in each group. As can be seen in Table IV-6, significant differences in weight were not found among six age groups.

Table IV-5
Descriptive Statistics for Subjects Weight (in kg)

Age Group	Number	Average ± SD	Minimum	Maximum
20s	12	67.0 ± 6.9	59.3	83.8
30S	12	68.6 ± 7.4	56.4	83.6
40S	12	71.1 ± 8.5	61.3	92.2
50S	12	65.8 ± 7.6	54.9	79.7
60S	12	66.9 ± 8.3	54.4	82.9
70S	12	61.0 ± 8.5	41.6	82.3
All groups	72	66.7 ± 8.5	41.6	92.2

Table IV-6
One-way ANOVA Result for Subjects Weight among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	672.53	134.51	1.9848	0.0924
Within Grp	66	4472.77	67.77		
Total	71	5145.30			

IV-1-d. Shoulder ROM: Flexion and Extension

Table IV-7 presents the mean and standard deviation of subject shoulder ROM of flexion and extension in each group. As can be seen in Table IV-8, significant differences between right and left sides were not found. This finding means that there is no difference in the ROM of shoulder flexion and extension between dominant and non-dominant sides.

Table IV-7
Descriptive Statistics for Shoulder Range of Motion : Flexion and Extension (in degrees)

Age	Lt Flex.	Rt Flex.	Lt Ext	Rt Ext.
20s	176.3 ± 3.8	176.3 ± 3.8	59.6 ± 6.6	59.6 ± 6.6
30s	175.0 ± 6.0	175.0 ± 6.0	59.6 ± 7.2	59.6 ± 7.2
40s	168.8 ± 7.7	168.8 ± 7.7	56.7 ± 6.9	56.7 ± 6.9
50s	170.0 ± 3.0	170.0 ± 3.0	54.2 ± 4.5	54.6 ± 4.5
60s	165.0 ± 7.4	165.0 ± 7.4	53.3 ± 4.9	53.8 ± 4.8
70s	160.8 ± 6.7	161.3 ± 8.0	52.1 ± 3.3	52.5 ± 3.9
All groups	169.3 ± 7.9	169.4 ± 8.0	55.9 ± 6.3	56.1 ± 6.2

Lt: Left, Rt: Right, Flex: Flexion, Ext: Extension

Table IV-8
Paired T-test for Shoulder Flexion and Extension Range of Motion between Right and Left Sides

	Mean Difference.	DF	P-Value
Flexion Right - Left	0.07	71	0.658
Extension Right - Left	0.20	71	0.083

As can be seen in Tables IV-9 and IV-10, differences in shoulder flexion ROM were found among six age groups bilaterally. The Duncan test demonstrated the differences between the groups in Table IV-11 and Table IV-12. Shoulder flexion ROM tended to decrease with aging.

Table IV-9
One-way ANOVA Result for Right Shoulder Flexion Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	1978.13	395.63	9.97	0.0000
Within Grp	66	2618.75	39.68		
Total	71	4596.88			

Table IV-10
One-way ANOVA Result for Left Shoulder Flexion Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	2061.11	412.2	11.31	0.0000
Within Grp	66	2404.17	36.4		
Total	71	4465.28			

Table IV-11
Duncan Test as a Post Hoc Test of ANOVA for Right Shoulder Flexion Range of Motion among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	176.3			*	*	*	*
30s	175.0			*		*	*
40s	168.8						*
50s	170.0						*
60s	164.0						
70s	164.0						

*: significant difference

Table IV-12
Duncan Test as a Post Hoc Test of ANOVA for Left Shoulder Flexion Range of Motion among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	176.3			*	*	*	*
30s	175.0			*	*	*	*
40s	168.8						*
50s	170.0						*
60s	164.0						
70s	160.5						

*: significant difference

As can be seen in Tables IV-13 and IV-14, significant differences in shoulder extension ROM were found among six age groups bilaterally. The Duncan test demonstrated the significant differences between groups in Tables IV-15 and Table IV-16.

Table IV-13
One-way ANOVA Result for Right Shoulder Extension Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	544.44	108.89	3.24	0.0112
Within Grp	66	2216.66	33.59		
Total	71	2761.11			

Table IV-14
One-way ANOVA Result for Left Shoulder Extension Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	622.57	124.51	3.75	0.0048
Within Grp	66	2193.75	33.24		
Total	71	2816.32			

Table IV-15
Duncan Test as a Post Hoc Test of ANOVA for Right Shoulder Extension Range of Motion among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	59.6					*	*
30s	59.6					*	*
40s	56.7						
50s	54.6						
60s	52.5						
70s	52.5						

*: significant difference

Table IV-16
Duncan Test as a Post Hoc Test of ANOVA for Left Shoulder Extension Range of Motion among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	59.6				*	*	*
30s	59.6				*	*	*
40s	56.7						
50s	54.2						
60s	52.0						
70s	52.0						

*: significant difference

IV-1-e. Shoulder ROM : Rotation

Table IV-17 presents the mean and standard deviation of subject internal and external rotation shoulder ROM in each group. As can be seen in Table IV-18, significant differences between right and left sides were not found. This finding means that there was no difference in the ROM of shoulder internal and external rotation between dominant and non-dominant sides.

Table IV-17
Descriptive Statistics for Shoulder Range of Motion: Internal and External Rotation (in degrees)

Age	Lt IR	Rt IR	Lt ER	Rt ER
20s	69.2 ± 8.2	67.5 ± 7.8	87.9 ± 11.8	88.8 ± 14.6
30s	70.8 ± 7.0	70.4 ± 6.6	91.7 ± 5.8	92.5 ± 7.5
40s	67.1 ± 6.2	67.5 ± 5.8	88.3 ± 2.5	88.8 ± 3.1
50s	64.6 ± 3.3	64.6 ± 3.3	83.8 ± 3.8	83.8 ± 3.8
60s	71.6 ± 10.5	71.6 ± 10.5	87.5 ± 5.8	86.6 ± 4.4
70s	65.8 ± 7.3	65.8 ± 7.3	85.0 ± 5.6	85.0 ± 5.6
All groups	68.2 ± 7.6	67.9 ± 7.4	87.3 ± 6.8	87.6 ± 7.9

Lt: Left, Rt: Right, IR: Internal Rotation, ER: External Rotation

Table IV-18
Paired T-test for Shoulder Internal and External Rotation Range of Motion between Right and Left Sides

	Mean Difference.	DF	P-Value
IR: Right - Left	0.28	71	0.375
ER: Right -Left	0.20	71	0.567

IR: Internal Rotation, ER: External Rotation

As can be seen in Tables IV-19 and IV-20, significant differences in shoulder internal rotation ROM were not found among the six age groups bilaterally.

In addition, Tables IV-21 and IV-22 demonstrate significant differences in shoulder external rotation ROM among the six age groups bilaterally.

Table IV-19
One-way ANOVA Result for Right Shoulder Internal Rotation Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	433.33	86.67	1.66	0.1577
Within Grp	66	3454.17	52.34		
Total	71	3887.50			

Table IV-20
One-way ANOVA Result for Left Shoulder Internal Rotation Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	477.78	95.56	1.73	0.1391
Within Grp	66	3637.50	55.11		
Total	71	4115.28			

Table IV-21
One-way ANOVA Result for Right Shoulder External Rotation Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	589.24	117.85	2.04	0.0842
Within Grp	66	3810.42	57.73		
Total	71	4399.65			

Table IV-22
One-way ANOVA Result for Left Shoulder External Rotation Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	461.11	92.22	2.15	0.0708
Within Grp	66	2837.50	42.99		
Total	71	3298.61			

IV-1-f. Shoulder ROM: Abduction

Table IV-23 presents the mean and standard deviation of subject shoulder abduction ROM in each group. As can be seen in Table IV-24, significant differences between right and left sides were not found. This finding means that there was no difference in shoulder abduction ROM between dominant and non-dominant sides.

Table IV-23
Descriptive Statistics for Shoulder Range of Motion: Abduction (in degrees)

Age	Lt Abduction	Rt Abduction
20s	176.7 ± 3.9	176.7 ± 3.9
30s	175.4 ± 4.9	175.8 ± 4.2
40s	171.3 ± 5.7	171.3 ± 5.7
50s	171.3 ± 2.3	171.3 ± 2.3
60s	171.3 ± 4.3	170.8 ± 5.1
70s	167.5 ± 7.8	167.9 ± 7.8
All groups	172.2 ± 5.8	172.3 ± 5.8

Table IV-24
Paired T-test for Shoulder Abduction Range of Motion between Right and Left Sides

	Mean Difference.	DF	P-Value
Right - Left	0.07	71	0.567

As can be seen in Tables IV-25 and IV-26. significant differences in shoulder abduction ROM were found among the six age groups bilaterally. The Duncan test demonstrated the differences between the groups in Tables IV-27 and Table IV-28.

Table IV-25
One-way ANOVA Result for Right Shoulder Abduction Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	661.50	132.30	5.03	0.0006
Within Grp	66	1735.40	26.34		
Total	71	2396.90			

Table IV-26
One-way ANOVA Result for Left Shoulder Abduction Range of Motion among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	661.11	132.22	5.03	0.0006
Within Grp	66	1733.33	26.26		
Total	71	2394.44			

Table IV-27
Duncan Test as a Post Hoc Test of ANOVA for Right ShoulderAbduction Range of Motion among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	176.7			*	*	*	*
30s	175.8			*	*	*	*
40s	171.3						
50s	171.3						
60s	168.0						
70s	172.5						

*: significant difference

Table IV-28
Duncan Test as a Post Hoc test of ANOVA for Left Shoulder Abduction Range of Motion among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	176.7			*	*	*	*
30s	175.4						*
40s	171.3						
50s	171.3						
60s	171.5						
70s	167.5						

*: significant difference

IV-1-g. Length of Upper Extremity

Table IV-29 presents the mean and standard deviation of the length of upper extremity in each group. As can be seen in Table IV-30, significant differences between right and left sides were found. This finding means that there was a difference in the length of upper extremity between dominant and non-dominant sides.

Table IV-29
Descriptive Statistics for the Length of Upper Extremity (in cm)

Age Group	Lt U/E	Rt U/E
20s	74.2 ± 3.0	74.6 ± 3.3
30s	73.8 ± 3.7	74.3 ± 3.8
40s	73.7 ± 4.3	73.8 ± 4.4
50s	72.7 ± 3.4	73.5 ± 3.2
60s	72.3 ± 2.1	73.2 ± 2.1
70s	71.6 ± 2.0	72.4 ± 3.0
All groups	73.0 ± 3.2	73.6 ± 3.3

Lt: Left; Rt: Right; U/E: the length between the acromion and apex of middle finger

Table IV-30
Paired T-test for the Length of Upper Extremity between Left and Right Sides

	Mean Difference.	DF	P-Value
Left- Right	0.60	71	0.000

As can be seen in Tables IV-31 and IV-32, significant differences in the length of upper extremity were not found among the six age groups bilaterally.

Table IV-31
One-way ANOVA Result for the Length of Right Upper Extremity among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	39.53	7.90	0.70	0.6224
Within Grp	66	741.89	11.23		
Total	71	780.72			

Table IV-32
One-way ANOVA Result for the Length of Left Upper Extremity among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	61.00	12.20	1.19	0.3260
Within Grp	66	679.38	10.29		
Total	71	740.38			

IV-1-h. Length of Upper Arm

Table IV-33 presents the mean and standard deviation of the length of upper arm in each group. As can be seen in Table IV-34, significant differences between right and left sides were found. This finding means that there was a difference in the length of the upper arm between dominant and non-dominant sides.

Table IV-33
Descriptive Statistics for the Length of Upper Arm (in cm)

Age Group	Lt Upper Arm	Rt Upper Arm
20s	33.1 ± 5.1	33.3 ± 5.2
30s	31.5 ± 1.4	31.5 ± 1.3
40s	30.8 ± 2.2	30.9 ± 2.1
50s	30.2 ± 1.6	30.5 ± 1.4
60s	30.3 ± 1.5	30.8 ± 1.3
70s	29.6 ± 1.4	29.8 ± 1.5
All groups	30.9 ± 2.7	31.1 ± 2.7

Lt: Left; Rt: Right; Upper Arm: the length between acromion and lateral epicondyle.

Table IV-34
Paired T-test for the Length of Upper Arm between Right and Left Sides

	Mean Difference.	DF	P-Value
Right - Left	0.22	71	0.000

As can be seen in Tables IV-35 and IV-37, significant differences in the length of upper arms were found among six age groups bilaterally. The Duncan test demonstrated the significant differences between the groups in Tables IV-36 and Table IV-38.

Table IV-35
One-way ANOVA RESULT for the Length of Right Upper Arm among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	82.66	16.53	2.56	0.0352
Within Grp	66	425.71	6.45		
Total	71	508.38			

Table IV-36
Duncan Test as a Post Hoc Test of ANOVA for the Length of Right Upper Arm among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	33.3			*	*	*	*
30s	31.5						
40s	30.9						
50s	30.5						
60s	30.6						
70s	29.9						

*: significant difference

Table IV-37
One-way ANOVA Result for the Length of Left Upper Arm among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	93.98	18.80	2.84	0.0219
Within Grp	66	436.19	6.61		
Total	71	530.16			

Table IV-38
Duncan Test as a Post Hoc Test of ANOVA for the Length of Left Upper Arm among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	33.1			*	*	*	*
30s	31.5						
40s	30.8						
50s	30.2						
60s	30.1						
70s	29.6						

*: significant difference

IV-2. MUSCLE CSA AND THICKNESS OF SUPRASPINATUS

IV-2-a. Correlation Test Results between CSA and Thickness

The correlation between CSA and Thickness between right and left sides are listed in Table IV-39. There were significant correlations between CSA and thickness on both the right and left sides.

Table IV-39
Correlation Test Results between Cross-sectional Area and Thickness of Supraspinatus

	r	P-value
Rt	0.7039	0.000
Lt	0.6906	0.000

IV-2-b. Cross-sectional Area (CSA)

Cross-sectional area of supraspinatus was measured on each subject bilaterally. The measurement value of each subject was defined as the mean of three scan measurements.

IV-2-b-1. Measurement Reliability

Measurement intra-rater reliability of the three scans for CSA on the right and left sides is listed in Table IV-40.

Table IV-40
Measurement Reliability for Cross-sectional Area of Supraspinatus

	ICC
Rt among three scans	0.94
Lt among three scans	0.93

IV-2-b-2. Descriptive data of CSA

Table IV-41 presents the mean, standard deviation, and minimum and maximum of the cross-sectional area of supraspinatus in each group.

Table IV-41
Descriptive Statistics for Cross-sectional Area of Left and Right Supraspinatus (in square cm)

Age Group	CSA Ave. of Lt	Min/Max of Lt	CSA Ave. of Rt	Min/Max of Rt
20s	7.53 ± 0.95	6.36/9.65	7.66 ± 0.98	6.26/9.42
30s	7.32 ± 0.94	5.89/9.31	7.55 ± 1.13	6.05/10.23
40s	7.12 ± 0.81	5.55/8.40	7.43 ± 0.66	6.14/8.33
50s	6.73 ± 0.82	5.59/8.62	6.76 ± 0.88	5.53/8.89
60s	6.53 ± 0.61	5.50/7.37	6.62 ± 0.72	5.37/7.50
70s	6.22 ± 0.60	4.95/6.87	6.40 ± 0.48	5.67/7.14
All groups	6.91 ± 0.90	4.95/9.65	7.07 ± 0.95	5.37/10.23

Ave.: Average; Min: minimum value; Max: maximum value
Lt : Left Supraspinatus; Rt: Right Supraspinatus

IV-2-b-3. The Effect of Hand Dominance

As can be seen in Table IV-42, significant differences between right and left sides were found. This finding means that there was a significant difference in cross-sectional area of supraspinatus between dominant and non-dominant sides. Mean difference was 0.16 square centimetres.

Table IV-42
Paired T-test for Cross-sectional Area of Supraspinatus between Left and Right Sides

	Mean Difference	DF	P-Value
Left - Right	0.16	71	0.001

IV-2-b-4. The Effect of Aging

As can be seen in Tables IV-43 and IV-45, significant differences in cross-sectional area of supraspinatus were found among six age groups bilaterally. The Duncan test demonstrated the significant differences between groups in Table IV-44 and Table IV-46. There were significant correlations between CSA and age on both right and left side (Table IV- 47). Especially, the groups over 50 tended to show significant decreases in the CSA of supraspinatus in dominant side. The CSA of supraspinatus in non-dominant side tended to decrease constantly with aging. Figure IV-1 shows the bar graph of cross-sectional area in each age group.

Table IV-43
One-way ANOVA Result for Cross-sectional Area of Right Supraspinatus among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	17.42	3.48	4.94	0.0007
Within Grp	66	46.59	0.70		
Total	71	64.01			

Table IV-44
Duncan Test as a Post Hoc Test of ANOVA for Cross-sectional Area of Right Supraspinatus among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	7.66				*	*	*
30s	7.55				*	*	*
40s	7.43					*	*
50s	6.76						
60s	6.54						
70s	6.38						

*: significant difference

Table IV-45
One-way ANOVA Result for Cross-sectional Area of Left Supraspinatus among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	15.05	3.01	4.65	0.0011
Within Grp	66	42.78	0.6481		
Total	71	57.83			

Table IV-46
Duncan Test as a Post Hoc test of ANOVA for Average Cross-sectional Area of Left Supraspinatus among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	7.53				*	*	*
30s	7.32					*	*
40s	7.12						*
50s	6.73						
60s	6.44						
70s	6.22						

*: significant difference

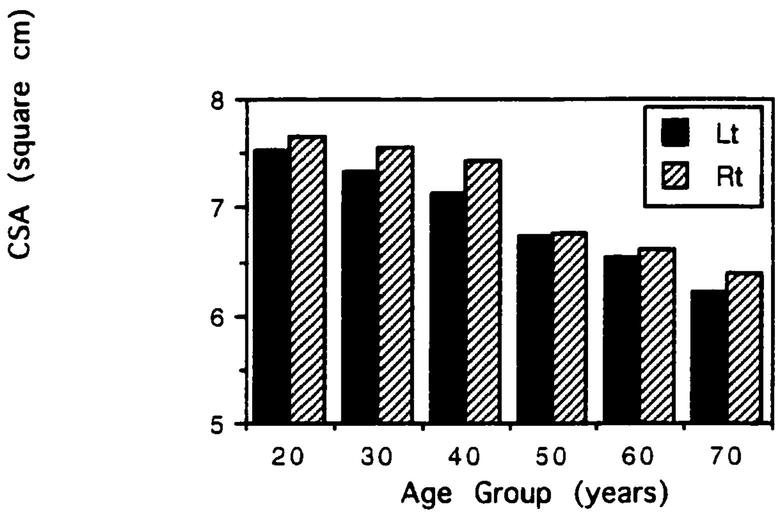


Figure VI-1: The Bar Graph of Average Cross-sectional Area in Each Age Group.

Note the greater drop between 40 and 50 years of age

Table IV-47
Correlation Test Results between Average Cross-sectional Area of Supraspinatus and Age

	r	P-value
Rt	0.4778	0.000
Lt	0.4825	0.000

From the results of the subject characteristics, significant differences existed in height among the six age groups, between the 20's and all the other groups (ie 30's, 40's, 50's, 60's, and 70's). It also demonstrated a difference between the 30's age group and 70's age group, as well as the 40's age group and 70's age group. To look at the influence of this height factor, the correlation between height and CSA was analyzed in each age group so that the age factor was not considered. Table IV-48 lists the correlations in each group. There were no significant correlations in any of the groups, though the correlation in the 40s was slightly high.

Table IV-48
Correlation Test Results between Cross-sectional Area of Supraspinatus and Height in Each Age Group

	r	P-value
20s	0.1093	0.710
30s	0.0893	0.782
40s	0.5453	0.067
50s	0.1746	0.608
60s	0.4296	0.143
70s	0.2868	0.342

IV-2-c. THICKNESS OF SUPRASPINATUS:

Thickness of supraspinatus was measured on each subject bilaterally using ultrasound imaging. The measurement values selected were the mean of three scan measurements.

IV-2-c-1. Measurement Reliability

Measurement intra-rater reliability of the three scans for thickness on right and left sides is listed in Table IV-49.

Table IV-49
Reliability of Thickness Measurement

	ICC
Rt among three scans	0.93
Lt among three scans	0.87

IV-2-c-2. Descriptive Data of Thickness

Table IV-50 presents the mean, standard deviation, and minimum, and maximum of thickness of supraspinatus in each group.

Table IV-50
Descriptive Statistics for Thickness of Supraspinatus (in mm)

Age Group	Ave. of Lt	Min/Max of Lt	Ave. of Rt	Min/Max of Rt
20s	20.3 ± 1.9	16.9/22.1	21.2 ± 2.4	16.9/24.3
30s	19.5 ± 1.5	16.8/21.7	21.0 ± 1.4	18.3/23.1
40s	18.9 ± 2.0	15.4/22.6	20.6 ± 2.4	16.3/25.2
50s	19.4 ± 1.5	15.9/21.1	19.7 ± 1.9	16.9/24.4
60s	18.5 ± 1.6	14.8/20.2	19.0 ± 1.8	16.4/21.3
70s	18.6 ± 1.6	15.6/21.2	19.1 ± 1.4	17.2/21.6
All groups	19.2 ± 1.8	14.8/22.6	20.1 ± 2.1	16.3/25.2

Ave.: Average; Min: minimum value; Max: maximum value
Lt: Left Supraspinatus; Rt: Right Supraspinatus

IV-2-c-3. The Effect of Hand Dominance

As can be seen in Table IV-51, significant differences between right and left sides were found. This finding means that there was a significant difference of thickness of supraspinatus between dominant and non-dominant sides. Mean difference was 0.89 millimeters.

Table IV-51
Paired T-test for Thickness of Supraspinatus between Right and Left Sides

	Mean Difference	DF	P-Value
Right - Left	0.89	71	0.000

IV-2-c-4. The Effect of Aging

As can be seen in Table IV-52 , significant differences in thickness of supraspinatus were found among the six age groups on the right side. The Duncan test demonstrated a significant difference between groups as shown in Table IV-57. The thickness of supraspinatus on the dominant side tended to decrease constantly with aging but the change was not as great as that seen with CSA. Significant differences in thickness of supraspinatus were not found among the six age groups on the non-dominant side (Table IV-54). Figure IV-2 shows the bar graph of thickness of supraspinatus in each age group. There were significant correlations between thickness and age on both right and left sides though their correlation ratios were low (Table IV-55).

Table IV-52
One-way ANOVA Result for Thickness of Right Supraspinatus among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	57.40	11.48	3.04	0.0156
Within Grp	66	248.94	3.77		
Total	71	306.35			

Table IV-53
Duncan Test As Post Hoc of ANOVA for Thickness of Right Supraspinatus among Six Age Groups

	Mean	20s	30s	40s	50s	60s	70s
20s	21.2					*	*
30s	21.0					*	*
40s	20.6						
50s	19.7						
60s	18.7						
70s	19.1						

*: significant difference

Table IV-54
One-way ANOVA Result for Thickness of Left Supraspinatus among Six Age Groups

Source	DF	SS	MS	F Ratio	F Prob.
Between Grp	5	26.85	5.37	1.80	0.1257
Within Grp	66	197.31	2.99		
Total	71	224.16			

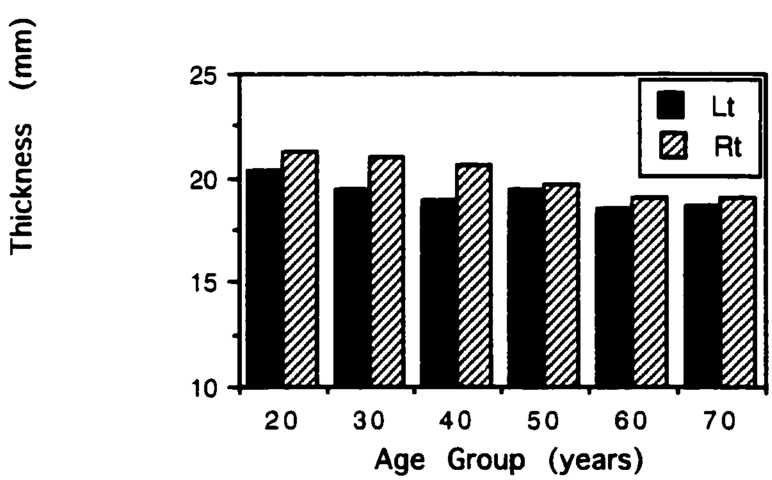


Figure IV-2: The Bar Graph of Average Thickness of Supraspinatus in Each Age Group

Table IV-55
Correlation Test Results between Thickness of Supraspinatus and Age

	r	P-value
Rt	0.4149	0.000
Lt	0.3068	0.009

From the results of subject characteristics, significant differences in height among the six age groups were found between 20's and the all other groups (ie 30's, 40's, 50's, 60's, and 70's). It also demonstrated a difference between the 30's age group and 70's age group, as well as the 40's age group and 70's age group. To ensure the influence of this height factor, the correlation between height and thickness was analyzed in each age group so that the age factor was not consider. Table IV-56 lists the correlations in each group. There were no significant correlations in any of the groups.

Table IV-56
Correlation Test Results between Thickness of Supraspinatus and Body Height

	r	P-value
20s	0.2110	0.469
30s	0.0319	0.922
40s	0.1491	0.627
50s	0.0465	0.880
60s	0.0218	0.944
70s	0.2493	0.411

V: CHAPTER FIVE
DISCUSSION

The purpose of this research project was to determine normal standard data for muscle CSA and muscle thickness of supraspinatus measured by diagnostic ultrasound in male sedentary individuals. This section will be discussed in the following three subsections: 1) CSA of supraspinatus using diagnostic ultrasound in sedentary males, 2) thickness of supraspinatus using diagnostic ultrasound in sedentary males, and 3) the relationship between CSA and thickness of supraspinatus.

V-1. CSA of Supraspinatus using Diagnostic Ultrasound in Sedentary Males

Previous studies have reported CSA of supraspinatus using direct cadaver measurement with a small sampling of subjects. These results are summarized in Table V-1. The average CSAs of the present study data on right and left sides in all subjects aged 20 to 79 were 7.07 ± 0.95 square centimetres and 6.91 ± 0.90 square centimetres respectively. Thus, the present study results were larger than the results from Veeger et al (96) and Poppen et al (71) in which the CSAs of supraspinatus were 5.21 ± 1.76 and 6.21 square centimetres respectively. These last two studies measured on cadaver did not differentiate between left and right sides. The primary reason for these differences between the previous and present study results were the different observation slices used in the previous studies. Ideally, a perpendicular slice to muscle fiber should be used for muscle CSA evaluation. The previous two studies slices were reported to be perpendicular slices to the muscle fiber on the largest CSA of the muscle belly using direct observation of the specimen. However, in the present study, because direct observation of the specimen in live subjects was not possible, it was decided to use slices perpendicular to the scapular spine which is the line between the posterior edge of the acromion and medial edge of the scapular spine. This position is easier to determine clinically. Therefore, in the present study, the slice might not be truly perpendicular to the muscle fibers which could explain the difference between the previous and present data. As CSA was greater in the present study, it is possible that the slice may have been at a slight deviation from the perpendicular which would lead to an enlargement of the CSA because any angle other than the perpendicular would lead to a larger value, In addition, the previous studies used fewer subjects, did not control for sex, activity or hand dominance, and did not look at the effect of height or age.

Table V-1
A Comparison of Cross-sectional Areas of Supraspinatus in Previous and Present Studies

	Poppen et al. (1978)	Veeger et al. (1991)	Present Study Lt Shoulder	Rt Shoulder
No. of shoulder specimens	2	14	72	72
Supraspinatus CSA (cm^2)	6.21	5.21 ± 1.76	6.91 ± 0.90	7.07 ± 0.95

No: Number; Lt: Left; Rt: Right

In this study, it could not be demonstrated how the measurement slice of this study was structurally different from the perpendicular slice of the supraspinatus muscle fibers as reported in the other two studies. The measurement slice in this study was defined by a clinically simple method, which tried to get as close to the perpendicular as possible. This technique allowed the researcher to have clearly palpable points such as the medial edge of the scapular spine and the posterior edge of scapular spine. Therefore, it was relatively easy to palpate the points used to determine the measurement position.

In the present study, the measurement reliability for CSA of supraspinatus using diagnostic ultrasound was high (ICC=0.93). Rankin et al (73) reported their measurement reliability (ICC between scans on the same day, as well ICC between scans on the different days for measurement), for CSA of tibialis anterior muscle. The ICC between scans on the same day was 0.94, and ICC between scans on the different days was 0.92. These data were similar to the present data for CSA measurement of supraspinatus (ICC of the three scans on the same day: 0.94 on the right, 0.93 on the left). Generally, the diagnostic ultrasound image does have the problem of unclear image and depends on the skill of the examiner as mentioned in the literature review. However, the reliability of measuring the CSA of supraspinatus using diagnostic ultrasound was high in this study. These findings support that the CSA of supraspinatus in the measurement method of this study can be used as an reliable clinical parameter if the examiner has sufficient experience in using diagnostic ultrasound and analyzing the data.

V-1-a The Effect of Hand Dominance on CSA of Supraspinatus

Veeger et al (96) and Poppen et al (71) demonstrated no significant difference of CSA of supraspinatus between left and right sides. However, in these studies, sample size was small and the definition of dominant side was not well described. On the other hand, in the present study, a significant difference between dominant and non-dominant sides was demonstrated. The CSA of dominant side was significantly larger than that of non-dominant side. The mean difference between right and left was 0.16 square centimetres. This trend was same in all six age groups (Table IV-41).

Furthermore, in this study, the Edinburgh Handedness Inventory was utilized to determine hand dominance, It did distinguished clearly and objectively between dominant and non-dominant hands. This process eliminated the confusion of hand dominance. In addition, subjects who had regular lateral activity were eliminated. These findings gave assurance that the influence of the hand dominance factor in normal sedentary individuals on the CSA of supraspinatus between dominant and non dominant sides could be determined.

Statistically, the CSA of supraspinatus was not the same between dominant and non-dominant sides in sedentary male subjects, although there was a very small mean difference between dominant and non-dominant sides. Practically, the very small difference suggests that this amount of difference between right and left sides might be clinically insignificant because the difference falls within one standard deviation. Sometimes, even though there is a statistical significant difference, the difference is not clinically or practically significant. In this study, the amount of the average difference between dominant side and non-dominant side was 0.16 square centimetres. This amount is too small relative to the standard deviations of CSA in all age groups which were 1.8 square centimetres on the right side and 2.1 square centimetres on the left side. It would be very difficult to find a practical differences when performing a clinical evaluation of CSA of supraspinatus using this mean difference value (0.16 square cm).

In this study, inclusion and exclusion criteria tried to control subject activity level. Subjects in this study reported having no regular lateral sports activities using the upper extremities. In addition, subjects who had a regular bilateral sports activity using upper extremities, playing more than four times a week were excluded. These criteria were used in an attempt to eliminate activity level as an influencing factor for CSA. Thus, this finding helps contribute to the understanding of the isolated influence of hand dominance when measuring CSA using ultrasound imaging. In this study, left hand dominant subjects were not included, the dominant side was defined as the right side. To reinforce the present study results which demonstrate a significant difference between dominant and non-dominant sides, further study would be worth while for a left handed group of subjects.

From the findings of this study, one should realize that the influence of hand dominance for CSA of supraspinatus in sedentary males is very small and in fact may be insignificant clinically.

V-1-b. The Effect of Aging on CSA of Supraspinatus

The significant differences among the six age groups were demonstrated from ANOVA. Tables IV-43 and IV-45 show the significant differences between each group. Figure IV-1 also shows the bar graph of CSA in each age group. CSA of the supraspinatus muscle tended to decrease with aging. Although the significant correlation was 0.48 on both right and left sides, this correlation is not considered to be high. As previously mentioned in section IV-2-b-4, there were significant differences in height between some age groups such as between the 20's and all of the other groups (i.e. 30's, 40's, 50's, 60's, and 70's). It also demonstrated a difference between the 30's age group and 70's age group, as well as the 40's age group and 70's age group. This height difference between different age groups might influence the results of CSA. That is, the CSA of supraspinatus might be larger with increased body height of subject. Although correlation between height and CSA were demonstrated (Table IV-48), the correlations would be considered low in all age groups. Therefore, the CSA of supraspinatus is not influenced by the height of subject. These findings suggested that aging was a primary factor which influenced the CSA, with the CSA of supraspinatus decreasing with aging (See Figure IV-1). It is important to note however that this study was not a longitudinal study looking at changes in the supraspinatus muscle CSA in the same individuals over time but was a cohort study looking at different age groups at one period of time so the decrease may or may not be totally be related to aging but may have been related to different lifetime exposures of the different subjects.

The CSAs of supraspinatus in the 70s age group, in this study, were 83.6 percent and 82.6 percent of the CSA of 20s age group in right and left sides respectively. In the study of CSA of quadriceps muscle despite the different target muscle from this study, 25 percent decrease in cross-sectional area in the 80s age in comparison with the people in their 20s has been reported (103). The present study did not involve subjects greater than 79 years of age, which could be one of the reasons for this difference. Several other reasons could also be considered for the different results between the quadriceps study and present study such as muscle function, muscle fiber types, as well as the difference between lower limb and upper limb. The CSA of supraspinatus with aging from the 20s to 70s decreases about 17 percent.

Another finding observed in Figure IV-1 was the trend of decreasing CSA of supraspinatus with aging. Figure V-1 shows the line graph of CSA of supraspinatus on right side and left side respectively. From Figure V-1, there appears to be a greater "drop" in the line between subjects who were under 50 and those over 50 on the dominant side. On the non dominant side, the slope of the line is more consistent with a gradual constant decrease which is consistent throughout the different age groups. The Duncan Test suggested that the 50s, 60s and 70s groups were significantly different from the 20s and 30s groups on both sides and significant differences among the 20s, 30s and 40s groups were not demonstrated statistically on the both sides. That is, the decreasing value of CSA with aging appeared to be accelerated over 50 years of age on the dominant side statistically. However, it is hard to find the practical significant difference of acceleration of decreasing CSA in the three groups over 50 age of years on the Figure V-1 because the amount of the standard deviation on both the 40s age group and the 50s age group overlapped meaning the change is probably clinically small.

Therefore, these findings suggested that although statistically the CSA of supraspinatus primarily decreases with aging over 50 years of age, clinically it is adequate to realize that the decreasing CSA of supraspinatus occurs rather consistently with aging.

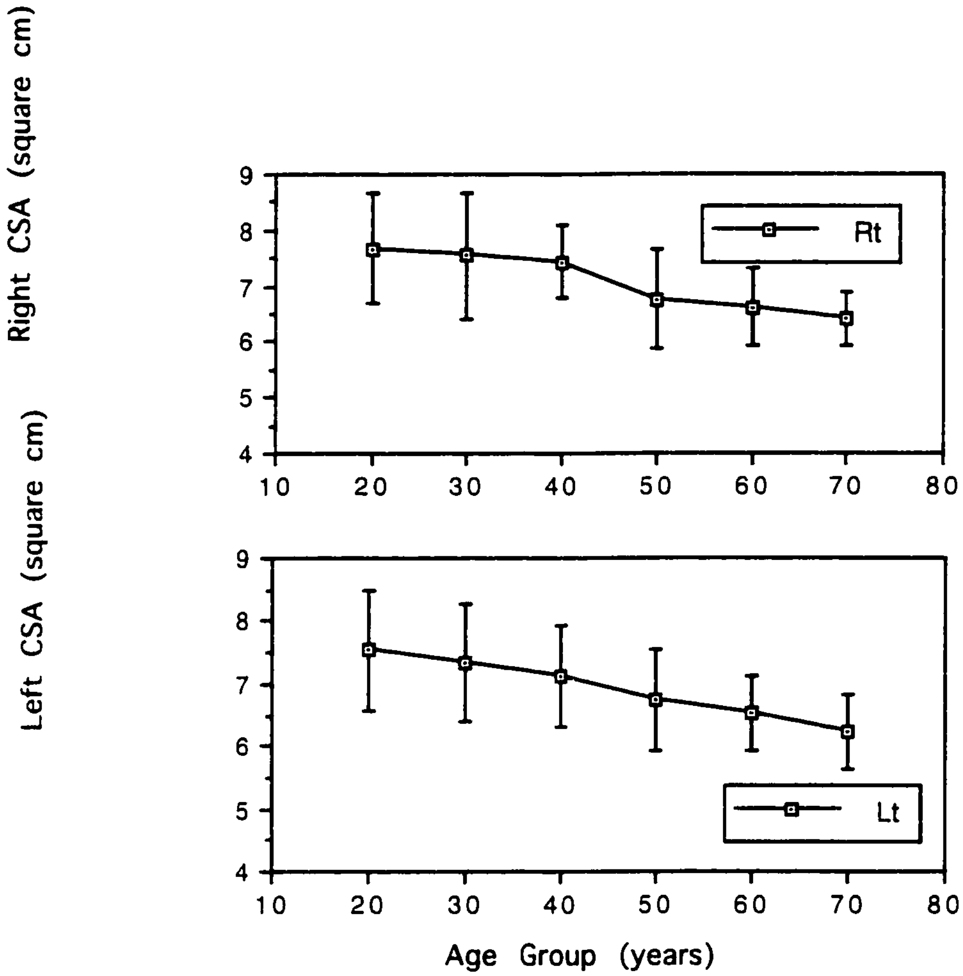


Figure V- I : The Line Graph of the Average Cross-sectional Area of Supraspinatus in Each Age Group

Certain shoulder pathologies such as rotator cuff rupture and frozen shoulder (so-called "fifty shoulder" in Japanese) have shown tendency to increase after about 50 years of age. These pathologies have been shown to be affected by degeneration of the shoulder structure. In addition, based on the function of supraspinatus and its anatomy, the decreasing supraspinatus function or use could be one of the influential factors in these shoulder pathologies. Further research will be required to confirm the apparent acceleration of decreasing CSA between 40 and 50 years of age on the dominant side.

V-2 THICKNESS OF SUPRASPINATUS USING DIAGNOSTIC ULTRASOUND IN SEDENTARY MALES

Previously, Katayose et al (44) reported on the thickness of supraspinatus using diagnostic ultrasound in younger subjects (mean age: 20.1 yrs.). They reported that the thickness of supraspinatus was 2.4 ± 0.2 centimetres. The resulting data of their study was larger than the present results (2.01 ± 0.21 centimetres in right side, 1.92 ± 0.18 centimetres in left side) because the location of the observation slice and the line measured were different. The previous Katayose study (44) used the perpendicular line to the ultrasound probe on the slice through the coracoid process and mid point of scapular spine, but the present study utilized the thickness between parallel lines, one of which was a line between supraspinatus and trapezius on the perpendicular slice through the mid point of scapular spine. The reasons the previous Katayose study used the perpendicular line to the ultrasound probe on the slice through the coracoid process and mid point of scapular spine were 1) to use a palpable landmark to get the observation slice, 2) to eliminate the effect of the deviation of the observation slice from that perpendicular to the muscle fibers if the perpendicular line to the ultrasound probe was kept. However, this observation slice is far from the perpendicular slice to the supraspinatus muscle fibers. In this study, in order to examine the relationship between CSA and thickness of supraspinatus, the same observation slice for both CSA and thickness was required. Therefore, the observation slice which was as close to the perpendicular to the supraspinatus muscle fibers as possible was selected for this study.

Vahlensieck et al (95) found the supraspinatus muscle to be composed of two distinct portions which include a ventral part and a dorsal portion. In addition, Gagey et al (21) reported that the ventral part of the supraspinatus muscle had a thicker and longer fibrous frame than the dorsal part. It is highly probable that the CSA of the fibrous portion would not change as much if muscle atrophy occurred. Therefore, thickness of supraspinatus could be dependent on the location of the observation slice. That is, thickness measurements through the ventral part and the other of the supraspinatus might indicate the different response of muscle atrophy of supraspinatus.

Nakagaki et al (65) utilized the short diameter and the long diameter of CSA of supraspinatus for evaluation of atrophy of supraspinatus (See Figure II-1). They stated that there was a significant negative correlation between the short diameter and age in normal subjects. In addition, there was no significant correlation between the long diameter and age. However, they also stated that the long diameter of supraspinatus was more efficient than the short diameter for evaluating muscle atrophy because of the observation of supraspinatus atrophy with a rotator cuff tear. These findings demonstrated that there are different responses of thickness for aging and/or clinical conditions in different sections of supraspinatus measured. The present study utilized the similar line for thickness measurement to the short diameter Nakagaki reported but not the same definition. There was a significant correlation between thickness and age in this study. It was similar to the results found for short diameter of CSA in Nakagaki's study.

However, the purpose of this study was to determine the base standard data of the supraspinatus muscle in normal sedentary male Japanese subjects, so that the data could be used as base data for further studies in situations such as clinical pathology and hypertrophy related sports activity. There is no evidence that the thickness line would be better than CSA. To demonstrate more clearly the clinical validity of this thickness measurement of supraspinatus, further study concerning the selection of the line of thickness of supraspinatus is required. It would be worthwhile to determine if there is a better way to measure thickness using diagnostic ultrasound. The reason one would prefer the thickness measure over CSA is that it is easier to measure. If a valid line of thickness can be determined, it might potentially be use for measuring characteristics of muscle atrophy.

V-2-a. The Effect of Hand Dominance on Thickness of Supraspinatus

The thickness of supraspinatus on the dominant side was significantly larger than the non-dominant side. The mean difference between right and left sides was 0.89 mm. This finding suggested that hand dominance influences the thickness of supraspinatus when measuring using this line of thickness of supraspinatus. However, clinically, the difference is so small (1mm) that it would be hard to detect, considering the value is an average and falls within individual differences.

V-2-b. The Effect of Aging on Thickness of Supraspinatus

The significant differences among the six age groups were demonstrated from ANOVA on only the right side which was the dominant side in this study. Figure V-2 shows the line graph of average thickness of supraspinatus in each age group. The correlations between thickness and age were 0.29 ($p=0.015$) for the right side and 0.40 ($p=0.001$) for the left side. The thickness of the supraspinatus muscle tended to decrease with aging although significant differences among the six age groups were demonstrated only on the dominant side. Even though the statistical analysis did not demonstrate the significant difference among the six age groups in non-dominant side, the trend of slightly decreasing thickness of supraspinatus was observed.

Significant differences between height and thickness in all age groups were not demonstrated in Table IV-56. Thus, the thickness of supraspinatus is not influenced by the height of the subject. This finding further supports the idea that aging has a major effect on supraspinatus muscles size, rather than body height or hand dominance.

The thickness of supraspinatus in 70s age group was 90.0 percent and 91.6 percent of the thickness of 20s age group on the right and left sides respectively. Thus there is about a 10 percent decrease in thickness of supraspinatus from age 20 to age 70. From the calculation of the mean change value from the 20s to the 70s, the thickness of supraspinatus decreased about 0.35 mm a year. Abe et al (1) stated the muscle thickness in several points of the body with aging from 20 to 80 years of age. Interestingly, they reported the decreasing value of thickness of anterior thigh muscle is constantly about 0.4 mm a year. This value is similar to that of supraspinatus although they are different muscles and have different functions. They also reported an interesting finding about the thicknesses of the anterior and posterior of upper arm, which were two of their five measurement points. Although a decrease in thickness of the anterior part of thigh started consistently from

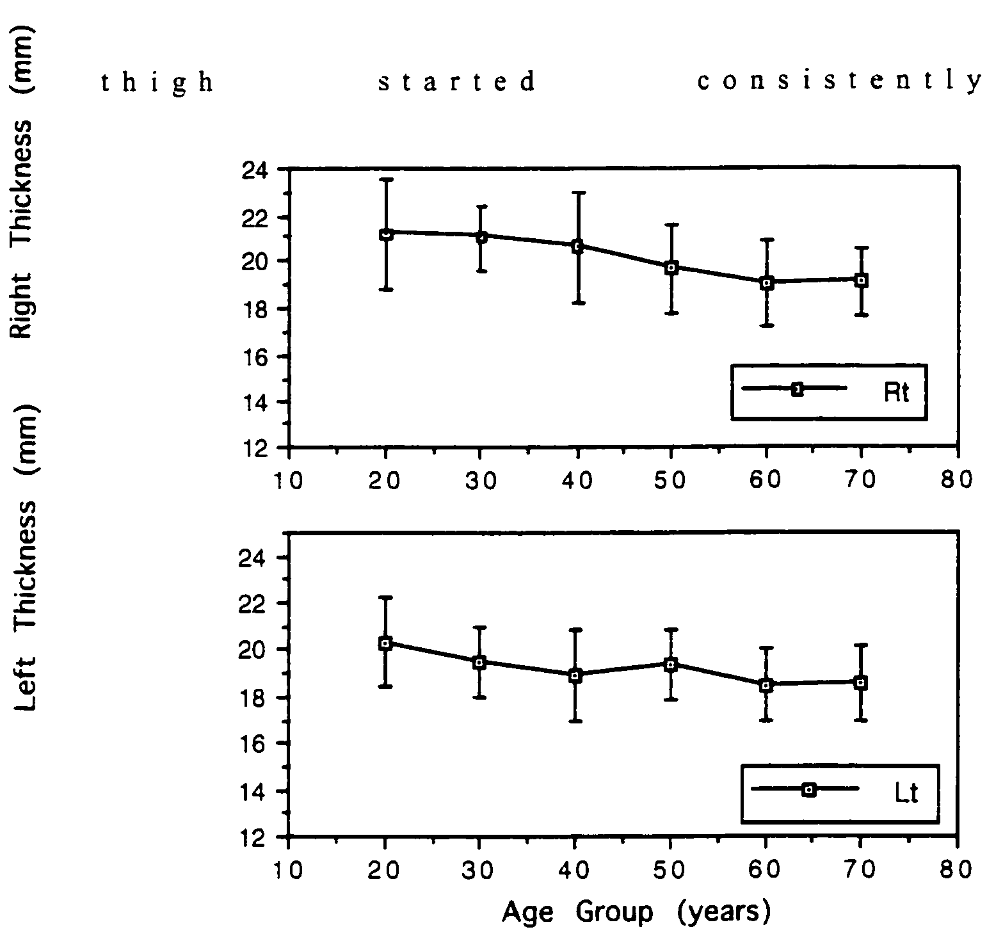


Figure V-2: The Line Graph of the Average Thickness of Supraspinatus in Each Age Group

age 30, the decreasing of thicknesses of anterior and posterior parts of upper arm started over 50 years of age. They found there was a significant difference in thickness of the anterior and posterior parts of upper arm between the age of 20 and 60. In other words, there was no significant change of thicknesses of anterior and posterior of upper arm until 50 years of age. In this present study, although the significant decrease of thickness was demonstrated on the only dominant side, there were no significant difference among 20s, 30s, and 40s on both sides. These findings suggest that aging is a factor in decreasing thickness especially after age 50. However, it is hard to find the practical significant difference of acceleration of decreasing of CSA in the three groups over 50 age of years (See Figure V-2) because of the degree of standard deviation of CSA measurement and subtle amount of change in thickness with aging. Most of the standard deviations for the different age groups overlapped, suggesting that the aging influence for thickness of supraspinatus muscle is hard to realize practically or clinically.

V-3. The Relationship between Muscle CSA and Thickness

Stokes et al (88) reported a significant correlation between area and linear measurement of quadriceps as 0.7. However they also stated that the correlation was decreased in wasted muscle. Hide et al (28) reported similar findings using lumbar multifidus muscle. The correlation between linear and area measurements were high in normal muscle but less in the atrophic muscle of patients with low back pain. Thus, it appears that the relationship between CSA and thickness varies in different muscles and with different conditions.

In this study, there was a significant positive correlation between CSA and thickness of supraspinatus in both right and left sides. The correlations were 0.70 on the right and 0.69 in left side. However, it is doubtful if these correlations are sufficient to enable utilization of thickness of supraspinatus as a parameter of muscle atrophy base. In addition, the values of decrease in CSA and thickness with aging were different. The result of CSA of supraspinatus demonstrated the 17 percent decrease and the result of thickness of supraspinatus demonstrated the 10 percent decrease. Thus atrophic changes in muscle are more likely to be detected by CSA than muscle thickness. The supraspinatus muscle is a small muscle. Thus, even though the percent data of thickness described a 10 percent difference, its absolute value was 2.1 millimeters. On the other hand, CSA described a 17 percent difference which was 1.22 square centimetres as an absolute value. Clinically, it would be harder to recognize the difference of muscle atrophy using the thickness of supraspinatus than using CSA of supraspinatus because of the small differences seen when measuring thickness.

From these findings, the thickness of supraspinatus would not adequately indicate the size of supraspinatus. At this moment, especially if evaluating atrophy of the supraspinatus muscle, any advantage of thickness as a measurement of supraspinatus could not be found. It should be kept in mind however, that if thickness was measured at a different location of the muscle, different results may be obtained. The characteristics of supraspinatus atrophy could possibly be demonstrated using several different lines of thickness of supraspinatus for measurement. Further study will need to be carried out to determine the validity of using thickness of supraspinatus as a clinical measure.

VI: CHAPTER SIX
SUMMARY AND CONCLUSION

VI-1. SUMMARY

The purpose of this study was to determine normal standard data of the CSA and thickness of the supraspinatus muscle as measured by diagnostic ultrasound in male sedentary individuals. In addition, the influence of hand dominance and aging towards CSA and thickness of the supraspinatus muscle were demonstrated.

Seventy two subjects participated in the study, using six ten-year-block groups (20 to 79 years). All subjects underwent a clinical interview by the author to ensure all inclusion and exclusion criteria were met prior to participate in this study.

Appropriate descriptive statistics were used to characterize the subjects. One-way ANOVAs were also used to determine if any significant difference in the characteristics of subjects existed among the six age groups. To demonstrate the difference of CSA or thickness among the six age groups, a one-way ANOVA and a Duncan post hoc test were calculated. The difference between dominant and non-dominant hands was determined with a paired T-test. All analyses employed the significant level of 0.05.

Normal standard values of CSA and thickness in subjects controlled by the inclusion and exclusion criteria were demonstrated with high measurement intrarater reliability. Both CSA and thickness on the dominant side were statistically larger than non-dominant side. From clinical and practical view points, it is hard to find a significant difference of the CSA and thickness of supraspinatus between dominant and non-dominant sides because of the amount of the standard deviation and the subtle amount of actual difference. The CSA and thickness of supraspinatus significantly decreased with aging. The decreasing values of CSA and thickness of supraspinatus with aging were not the same. Although there were significant correlations between CSA and thickness of supraspinatus on both right and left sides, they were not high (0.70 on the right and 0.69 in left side). Because of the low correlation for thickness of supraspinatus, it is not advisable to utilize the thickness of suprapinatus as a parameter of muscle atrophy. The values of the decrease in CSA and thickness with aging were different. These findings suggest the thickness of supraspinatus would not indicate adequately the condition of CSA of supraspinatus. At this moment, the measurement of CSA using diagnostic ultrasound is the most reliable method to show supraspinatus muscle atrophy with aging.

VI-2. CLINICAL SIGNIFICANCE

Measurements of CSA and thickness of supraspinatus using diagnostic ultrasound have shown that reliable information regarding the morphological state of the supraspinatus muscle can be obtained. To establish this measurement technique as an objective measurement, normal standard data for these measurements is required. In addition, the consideration of several possible influencing factors on CSA and thickness of supraspinatus such as hand dominance, and aging is necessary and can be determined from normalized data. The findings in this study may be useful in developing applications for the objective evaluation of pathological supraspinatus muscle conditions. That is, these present data can be utilized as base data for further research and clinical evaluations.

In this study, several statistical significant results were found but on evaluation, these differences were very small and from a clinical or practical point of view are really too small to be considered clinically siginificant.

VI-3. SUGGESTIONS FOR FUTURE RESEARCH

This study was performed to establish normal standard base data in Japanese sedentary men for future study. Some directions for future research would be:

1). studying different normal groups (females, left handed, other cultures)

2). studying pathological shoulder conditions to determine the effect of atrophy and to compare the results with this standard base data.

3). studying active performance groups (e.g., athletes, workers using upper limbs primarily in their jobs).

4). studying the mechanism of acceleration of decreasing CSA in different muscles at different age groups.

5). studying the differences of validity of CSA and thickness of supraspinatus.

6). studying the selection of the line of thickness of supraspinatus. It would be worthwhile to determined whether there truly is a valid line of thickness for supraspinatus.

VI-4. CONCLUSIONS

Based on findings of this study, the following recommendations can be made:

1) The measurement of CSA using diagnostic ultrasound has been shown to be reliable and valid for the supraspinatus muscle. This measurement technique can be applied in repeatable and following-up situations. These situations could lead the accumulation of assessment and outcome data on the effectiveness of medical and paramedical intervention in the treatment of shoulder injuries.

2) The measurement of thickness using diagnostic ultrasound has been shown to be reliable. However, further studies will be needed for establishment of validity of measurement. This study did not demonstrate clear validity of the thickness of supraspinatus measure.

3) The CSA of supraspinatus in dominant and non-dominant hands are different, though the amount of difference is subtle. Practically, the very small difference suggests that this amount of difference between right and left sides might be clinically insignificant.

4) CSA and thickness of supraspinatus decrease with aging. The thickness of supraspinatus in 70s age group were 90.0 percent and 91.6 percent of the thickness of 20s age group in right and left sides respectively. The CSAs of supraspinatus in 70s age group, in this study, were 83.6 percent and 82.6 percent of the CSA of 20s age group in right and left sides respectively.

5) This study determined muscle thickness and CSA of supraspinatus in Japanese for the sedentary men using diagnostic ultrasound. Further clinical research based on these normal standard base data should be promoted.

REFERENCES

[1] Abe T, Fukunaga T: Fat and Muscle Thickness in Japanese. Tokyo: Kyo-rin Syoin Co., 1995.

[2] Arangio GA, Chen C, Kalady M, Reed JF, 3rd: Thigh muscle size and strength after anterior cruciate ligament reconstruction and rehabilitation. ***J Orthop Sports Phys Ther*** . **26(5) :238-43, 1997**

[3] Arvidsson I, Eriksson E, Knutsson E, Arner S: Reduction of pain inhibition on voluntary muscle activation by epidural analgesia. ***Orthopedics*** . **9(10) :1415-9, 1986**

[4] Basmajian JV, Bazant FJ: Factors preventing downward dislocation of the adducted shoulder joint. ***J Bone Joint Surg Am*** . **41 :1182, 1959**

[5] Bassett RW, Browne AO, Morrey BF, An KN: Glenohumeral muscle force and moment mechanics in a position of shoulder instability. ***J Biomech*** . **23(5) :405-15, 1990**

[6] Bertolotto M, Perrone R, Martinoli C, Rollandi GA, Patetta R, Derchi LE: High resolution ultrasound anatomy of normal Achilles tendon. ***Br J Radiol*** . **68(813) :986-91, 1995**

[7] Bigliani LU, Ticker JB, Flatow EL, Soslowsky LJ, Mow VC: The relationship of acromial architecture to rotator cuff disease. ***Clin Sports Med*** . **10(4) :823-38, 1991**

[8] Boone DC, Azen SP: Normal range of motion of joints in male subjects. ***J Bone Joint Surg [Am]*** . **61(5) :756-9, 1979**

[9] Booth FW, Gollnick PD: Effects of disuse on the structure and function of skeletal muscle. ***Med Sci Sports Exerc*** . **15(5) :415-20, 1983**

[10] Booth FW, Seider MJ: Early change in skeletal muscle protein synthesis after limb immobilization of rats. ***J Appl Physiol*** **. 47(5) :974-7, 1979**

[11] Breidahl WH, Newman JS, Taljanovic MS, Adler RS: Power Doppler sonography in the assessment of musculoskeletal fluid collections. ***AJR Am J Roentgenol*** **. 166(6) :1443-6, 1996**

[12] Campbell DG, Menz A, Isaacs J: Dynamic ankle ultrasonography. A new imaging technique for acute ankle ligament injuries. ***Am J Sports Med*** **. 22(6) :855-8, 1994**

[13] Carmeli E, Reznick AZ: The physiology and biochemistry of skeletal muscle atrophy as a function of age. ***Proc Soc Exp Biol Med*** **. 206(2) :103-13, 1994**

[14] Chhem RK, Sarazin L, Bonaldi VM, Fortin P: Detection of musculoskeletal infection using ultrasound. ***Applied Radiology*** **. 24(10) :29-30,33,, 1995**

[15] Conley MS, Stone MH, Nimmons M, Dudley GA: Specificity of resistance training responses in neck muscle size and strength. ***Eur J Appl Physiol*** **. 75(5) :443-8, 1997**

[16] Desplanches D: Structural and functional adaptations of skeletal muscle to weightlessness. ***Int J Sports Med*** **. 18 Suppl 4 :S259-64, 1997**

[17] Edgerton VR, Zhou MY, Ohira Y, Klitgaard H, Jiang B, Bell G, Harris B, Saltin B, Gollnick PD, Roy RR, Day MK, Greenisen M: Human fiber size and enzymatic properties after 5 and 11 days of spaceflight. ***J Appl Physiol*** **. 78(5) :1733-9, 1995**

[18] Engstrom CM, Loeb GE, Reid JG, Forrest WJ, Avruch L: Morphometry of the human thigh muscles. A comparison between anatomical sections and computer tomographic and magnetic resonance images. ***J Anat*** **. 176 :139-56, 1991**

[19] Epstein RE, Schweitzer ME, Frieman BG, Fenlin JM, Jr., Mitchell DG: Hooked acromion: prevalence on MR images of painful shoulders. ***Radiology*** **. 187(2) :479-81, 1993**

[20] Frost FS, Kelly CM, McCarthy W: High resolution real-time ultrasound for the diagnosis of venous thrombosis in the rehabilitation setting. ***Am J Phys Med Rehabil*** **. 70(1) :3-4, 1991**

[21] Gagey N, Gagey O, Bastian G, Lassau JP: The fibrous frame of the supraspinatus muscle. Correlations between anatomy and MRI findings. ***Surg Radiol Anat*** **. 12(4) :291-2, 1990**

[22] Greene WB, Heckman JD, American Academy of Orthopaedic Surgeons.: The Clinical Measurement of Joint Motion. 1st ed. Rosemount: American Academy of Orthopaedic Surgeons, 1994.

[23] Grimby G, Saltin B: The ageing muscle. ***Clin Physiol*** **. 3(3) :209-18, 1983**

[24] Grubb NR, Fleming A, Sutherland GR, Fox KA: Skeletal muscle contraction in healthy volunteers: assessment with Doppler tissue imaging. ***Radiology*** **. 194(3) :837-42, 1995**

[25] Haggmark T, Jansson E, Eriksson E: Fiber type area and metabolic potential of the thigh muscle in man after knee surgery and immobilization. ***Int J Sports Med*** **. 2(1) :12-7, 1981**

[26] Hassard TH: Understanding Biostatistics. St. Louis: Mosby Year Book. 1991.

[27] Hather BM, Adams GR, Tesch PA, Dudley GA: Skeletal muscle responses to lower limb suspension in humans. ***J Appl Physiol*** **. 72(4) :1493-8, 1992**

[28] Hides JA, Richardson CA, Jull GA: Magnetic resonance imaging and ultrasonography of the lumbar multifidus muscle. Comparison of two different modalities. ***Spine*** **. 20(1) :54-8, 1995**

[29] Higbie EJ, Cureton KJ, Warren GL, 3rd, Prior BM: Effects of concentric and eccentric training on muscle strength, cross- sectional area, and neural activation. ***J Appl Physiol* . 81(5) :2173-81, 1996**

[30] Holloszy JO, Chen M, Cartee GD, Young JC: Skeletal muscle atrophy in old rats: differential changes in the three fiber types. ***Mech Ageing Dev* . 60(2) :199-213, 1991**

[31] Housh DJ, Housh TJ, Weir JP, Weir LL, Johnson GO, Stout JR: Anthropometric estimation of thigh muscle cross-sectional area. ***Med Sci Sports Exerc* . 27(5) :784-91, 1995**

[32] Howe TE, Oldham JA: The reliability of measuring quadriceps cross-sectional area with compound B ultrasound scanning. ***Physiother Res Int* . 1(2) :112-26, 1996**

[33] Howell SM, Imobersteg AM, Seger DH, Marone PJ: Clarification of the role of the supraspinatus muscle in shoulder function. ***J Bone Joint Surg [Am]* . 68(3) :398-404, 1986**

[34] Hughes RE, An KN: Force analysis of rotator cuff muscles. ***Clin Orthop* . (330) :75-83, 1996**

[35] Ihashi K, Matsushita N, Yagi R, Handa Y: Rotational action of the supraspinatus muscle on the shoulder joint [In Process Citation]. ***J Electromyogr Kinesiol* . 8(5) :337-46, 1998**

[36] Inman VT, Saunders JB, Abott LC: Observations on the function of the shoulder joint. ***J Bone Joint Surg* . 26 :1-30, 1944**

[37] Itoi E, Minagawa H, Sato T, Sato K, Tabata S: Isokinetic strength after tears of the supraspinatus tendon. ***J Bone Joint Surg Br* . 79(1) :77-82, 1997**

[38] Jarvholm U, Palmerud G, Karlsson D, Herberts P, Kadefors R: Intramuscular pressure and electromyography in four shoulder muscles. ***J Orthop Res* . 9(4) :609-19, 1991**

[39] Jarvholm U, Palmerud G, Styf J, Herberts P, Kadefors R: Intramuscular pressure in the supraspinatus muscle. ***J Orthop Res*** . **6(2) :230-8, 1988**

[40] Jarvholm U, Styf J, Suurkula M, Herberts P: Intramuscular pressure and muscle blood flow in supraspinatus. ***Eur J Appl Physiol*** . **58(3) :219-24, 1988**

[41] Jenp YN, Malanga GA, Growney ES, An KN: Activation of the rotator cuff in generating isometric shoulder rotation torque. ***Am J Sports Med*** . **24(4) :477-85, 1996**

[42] Jensen BR, Jorgensen K, Sjogaard G: The effect of prolonged isometric contractions on muscle fluid balance. ***Eur J Appl Physiol*** . **69(5) :439-44, 1994**

[43] Jones DA, Round JM: Skeletal Muscle in Health and Disease : a Textbook of Muscle Physiology. New York: Manchester University Press, 1990.

[44] Katayose M, Ogino T, Miyamoto S, Sugawara M: Quantitative evaluation of muscle thickness of suprspinatus with ultrasonography. ***The Journal of The Japanese Society of Orthopedic Ultrasonics*** . **6(1) :175-177, 1994**

[45] Katthagen B-D: Ultrasonography of the Shoulder : Technique, Anatomy, Pathology. New York: Thieme Medical Publisher, 1990.

[46] Kelly BT, Kadrmas WR, Speer KP: The manual muscle examination for rotator cuff strength. An electromyographic investigation. ***Am J Sports Med*** . **24(5) :581-8, 1996**

[47] Kelly SJ, Stokes MJ: Symmetry of anterior tibial muscle size measured by real-time ultrasound imaging in young females. ***Clin Rehabil*** . **7 :222-228, 1993**

[48] Kolts I: A note on the anatomy of the supraspinatus muscle. ***Arch Orthop Trauma Surg*** . **111(5) :247-9, 1992**

[49] Kronberg M, Nemeth G, Brostrom LA: Muscle activity and coordination in the normal shoulder. An electromyographic study. ***Clin Orthop*** . **(257) :76-85, 1990**

[50] LeBlanc A, Rowe R, Schneider V, Evans H, Hedrick T: Regional muscle loss after short duration spaceflight. ***Aviat Space Environ Med*** . **66(12) :1151-4, 1995**

[51] Lexell J, Taylor CC, Sjostrom M: What is the cause of the ageing atrophy? Total number, size and proportion of different fiber types studied in whole vastus lateralis muscle from 15- to 83-year-old men. ***J Neurol Sci*** . **84(2-3) :275-94, 1988**

[52] Ling SC, Chen CF, Wan RX: A study on the vascular supply of the supraspinatus tendon. ***Surg Radiol Anat*** . **12(3) :161-5, 1990**

[53] Lohr JF, Uhthoff HK: The microvascular pattern of the supraspinatus tendon. ***Clin Orthop*** . **(254) :35-8, 1990**

[54] MacGillivray JD, Fealy S, Potter HG, O'Brien SJ: Multiplanar analysis of acromion morphology [In Process Citation]. ***Am J Sports Med*** . **26(6) :836-40, 1998**

[55] Magee D: Orthopedic Physical Assessment. 3rd edition, Philadelphia: W.B. Saunders,1997.

[56] Marcantonio DR, Weatherall PT, Berrey BH, Jr.: Practical considerations in the imaging of soft tissue tumors. ***Orthop Clin North Am*** . **29(1) :1-17, 1998**

[57] Martinson H, Stokes MJ: Measurement of anterior tibial muscle size using real-time ultrasound imaging. ***Eur J Appl Physiol*** . **63(3-4) :250-4, 1991**

[58] McComas AJ: Skeletal muscle : form and function. Champaign: Human Kinetics, 1996.

[59] McMahon PJ, Jobe FW, Pink MM, Brault JR, Perry J: Comparative electromyographic analysis of shoulder muscles during planar motions: anterior glenohumeral instability versus normal. ***J Shoulder Elbow Surg*** **. 5(2 Pt 1) :118-23, 1996**

[60] Morrison PR, Muller GW, Booth FW: Actin synthesis rate and mRNA level increase during early recovery of atrophied muscle. ***Am J Physiol*** **. 253(2 Pt 1) :C205-9, 1987**

[61] Morrissey MC: Reflex inhibition of thigh muscles in knee injury. Causes and treatment. ***Sports Med*** **. 7(4) :263-76, 1989**

[62] Moseley HF, Goldie E: The arterial pattern of the rotator cuff and shoulder. ***J Bone Joint Surg Br*** **. 45 :780, 1973**

[63] Nakagaki K, Ozaki J, Tomita Y, Tamai S: Fatty degeneration in the supraspinatus muscle after rotator cuff tear. ***J Shoulder Elbow Surg*** **. 5(3) :194-200, 1996**

[64] Nakagaki K, Ozaki J, Tomita Y, Tamai S: Function of supraspinatus muscle with torn cuff evaluated by magnetic resonance imaging. ***Clin Orthop*** **. (318) :144-51, 1995**

[65] Nakagaki K, Tomita Y, Sakurai G, Oshiro O, Tamai S, Ozaki J: [Anatomical study on the atrophy of supraspinatus muscle belly with cuff tear]. ***Nippon Seikeigeka Gakkai Zasshi*** **. 68(7) :516-21, 1994**

[66] Narici MV, Hoppeler H, Kayser B, Landoni L, Claassen H, Gavardi C, Conti M, Cerretelli P: Human quadriceps cross-sectional area, torque and neural activation during 6 months strength training. ***Acta Physiol Scand*** **. 157(2) :175-86, 1996**

[67] Oldfield RC: The assessment and analysis of handedness: the Edinburgh inventory. ***Neuropsychologia*** **. 9(1) :97-113, 1971**

[68] Ozaki J, Fujimoto S, Nakagawa Y, Masuhara K, Tamai S: Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. A study in cadavera. ***J Bone Joint Surg [Am]*** **. 70(8) :1224-30, 1988**

[69] Pearl ML, Perry J, Torburn L, Gordon LH: An electromyographic analysis of the shoulder during cones and planes of arm motion. ***Clin Orthop*** **. (284) :116-27, 1992**

[70] Ploutz-Snyder LL, Tesch PA, Crittenden DJ, Dudley GA: Effect of unweighting on skeletal muscle use during exercise. ***J Appl Physiol*** **. 79(1) :168-75, 1995**

[71] Poppen NK, Walker PS: Forces at the glenohumeral joint in abduction. ***Clin Orthop*** **. (135) :165-70, 1978**

[72] Poppen NK, Walker PS: Normal and abnormal motion of the shoulder. ***J Bone Joint Surg [Am]*** **. 58(2) :195-201, 1976**

[73] Rankin G, Stokes M: Reliability of assessment tools in rehabilitation: an illustration of appropriate statistical analyses. ***Clin Rehabil*** **. 12(3) :187-99, 1998**

[74] Rice CL, Cunningham DA, Paterson DH, Lefcoe MS: Arm and leg composition determined by computed tomography in young and elderly men. ***Clin Physiol*** **. 9(3) :207-20, 1989**

[75] Robertson VJ, Ward AR: Subaqueous ultrasound: 45kHz and 1MHz machines compared. ***Arch Phys Med Rehabil*** **. 76(6) :569-75, 1995**

[76] Saha AK: Dynamic stability of the glenohumeral joint. ***Acta Orthop Scand*** **. 42(6) :491-505, 1971**

[77] Saltin B, Radegran G, Koskolou MD, Roach RC: Skeletal muscle blood flow in humans and its regulation during exercise. ***Acta Physiol Scand*** **. 162(3) :421-36, 1998**

[78] Sandler H, Vernikos J, ed. Inactivity: Physiological Effects. Orlando: Academic Press, 1986.

[79] Sargeant AJ, Young CTM, Davies C, Maunder, Edwards RHT: Functional and structiral changes following disease of human muscle. ***Clin Sci*** **. 52 :337-342, 1977**

[80] Schulz R, Curnow C: Peak performance and age among superathletes: track and field, swimming, baseball, tennis, and golf. ***J Gerontol*** **. 43(5) :113-20, 1988**

[81] Shiroishi S: Ultrasonic Diagnosis in Orthopaedic Surgery. Tokyo: Medical Core, 1995.

[82] Silbermann M, Finkelbrand S, Weiss A, Gershon D, Reznick A: Morphometric analysis of aging skeletal muscle following endurance training. ***Muscle Nerve*** **. 6(2) :136-42, 1983**

[83] Sipila S, Suominen H: Quantitative ultrasonography of muscle: detection of adaptations to training in elderly women. ***Arch Phys Med Rehabil*** **. 77(11) :1173-8, 1996**

[84] Steinbach LS, Fritz RC, Tirman PF, Uffman M: Magnetic resonance imaging of the elbow. ***Eur J Radiol*** **. 25(3) :223-41, 1997**

[85] Stokes M: Reliability and repeatability of methods for measuring muscle in physiotherapy. ***Physio. Pract.*** **1(2) :71-6, 1985**

[86] Stokes M, Hides J, Nassiri DK: Musculoskeletal ultrasound imaging: diagnostic and treatment aid in rehabilitation. ***Physio. Ther. Rev*** **. 2(2) :73-92, 1997**

[87] Stokes M, Young A: The contribution of reflex inhibition to arthrogenous muscle weakness. ***Clin Sci*** **. 67(1) :7-14, 1984**

[88] Stokes M, Young A: Measurement of quadriceps cross-sectional area by ultrasonography: a description of the technique and its applications in physiotherapy. ***Physiotherapy Practice* . 2(1) :31-6, 1986**

[89] Sugamoto K, Ochi T: Colour Doppler analysis of tendon and muscle movements. ***J Hand Surg [Br]* . 23(2) :237-9, 1998**

[90] The Japanese Society of Orthopedic Ultrasonics, ed. *Ultrasonographic Diagnosis of Orthopedic Diseases*. Tokyo: Nankou-dou, 1995.

[91] Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F: Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. ***Acta Orthop Scand* . 67(3) :264-8, 1996**

[92] Tsustui H: Anatomical investigation of arterial distribution and clinical application of selective angiography of shoulder joint. ***Nippon Seikeigeka Gakkai Zasshi* . 60(4) :401-414, 1986**

[93] Tucker KR, Seider MJ, Booth FW: Protein synthesis rates in atrophied gastrocnemius muscles after limb immobilization. ***J Appl Physiol* . 51(1) :73-7, 1981**

[94] Turrin A, Cappello A: Sonographic anatomy of the supraspinatus tendon and adjacent structures. ***Skeletal Radiol* . 26(2) :89-93, 1997**

[95] Vahlensieck M, an Haack K, Schmidt HM: Two portions of the supraspinatus muscle: a new finding about the muscles macroscopy by dissection and magnetic resonance imaging. ***Surg Radiol Anat* . 16(1) :101-4, 1994**

[96] Veeger HE, Van der Helm FC, Van der Woude LH, Pronk GM, Rozendal RH: Inertia and muscle contraction parameters for musculoskeletal modelling of the shoulder mechanism. ***J Biomech* . 24(7) :615-29, 1991**

[97] Walton JM, Roberts N, Whitehouse GH: Measurement of the quadriceps femoris muscle using magnetic resonance and ultrasound imaging. ***Br J Sports Med*** **. 31(1) :59-64, 1997**

[98] Wang JC, Shapiro MS: Changes in acromial morphology with age. ***J Shoulder Elbow Surg*** **. 6(1) :55-9, 1997**

[99] Wild JJ, Jr., Franklin TD, Woods GW: Patellar pain and quadriceps rehabilitation. An EMG study. ***Am J Sports Med*** **. 10(1) :12-5, 1982**

[100] Wuelker N, Plitz W, Roetman B, Wirth CJ: Function of the supraspinatus muscle. Abduction of the humerus studied in cadavers. ***Acta Orthop Scand*** **. 65(4) :442-6, 1994**

[101] Yokosawa K, Shinomura R, Sano S, Ito Y, Ishikawa S, Sato Y: A 120-MHz ultrasound probe for tissue imaging. ***Ultrason Imaging*** **. 18(4) :231-9, 1996**

[102] Young A, Hughes I, Russell P, Parkers MJ, Nichols PJ: Measurement of quadriceps muscle wasting by ultrasonography. ***Rheumatol Rehabil*** **. 19(3) :141-8, 1980**

[103] Young A, Stokes M, Crowe M: The size and strength of the quadriceps muscles of old and young men. ***Clin Physiol*** **. 5(2) :145-54, 1985**

[104] Young A, Stokes M, Shakerspeare D: The effect of intra-articular bupivacaine on quadriceps inhibition after menisectomy. ***Med Sci Sports Exerc*** **. 15 :154, 1983**

[105] Zanetti M, Gerber C, Hodler J: Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. ***Invest Radiol*** **. 33(3) :163-70, 1998**

APPENDIX A:

B-MODE IMAGE OF SUPRASPINATUS IN DIAGNOSTIC ULTRASOUND

B MODE

B mode image illustrates a cross-sectional image of supraspinatus. This image was acquired with the 7.5M Hz using an Aloka Echo Camera SSD 1000. The subject was a 20 year old male university student who did not have any regular sports activity.

Thickness of supraspinatus is the linear distance between inferior and superior boundary of supraspinatus in the slice image through the mid point of scapular spine. Superior boundary was the line between trapezius and supraspinatus. Inferior boundary was parallel to superior line.

APPENDIX B:

EDINBURGH HANDEDNESS INVENTORY

EDINBURGH HANDEDNESS INVENTORY

Surname.. Given Names..

Date of Birth.. Sex........................

Please indicate your preferences in the use of hands in the following activities *by putting + in the appropriate column*. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, *put* ++. If in any case you are really indifferent *put + in both columns*.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

		LEFT	RIGHT
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Toothbrush		
6	Knife (without fork)		
7	Spoon		
8	Broom (upper hand)		
9	Striking Match (match)		
10	Opening box (lid)		
i	Which foot do you prefer to kick with?		
ii	Which eye do you use when using only one?		

L.Q.		Leave these spaces blank	DECILE	

<Cited from Oldfield, 1971 p112>

APPENDIX C:

PILOT STUDY
INTRA-RATER RELIABILITY OF MEASUREMENTS

CSA of supraspinatus

ICC= 0.83

Between Day1 Scan1 and Day 2 Scan 1: ICC=0.81

Subject	Day 1* + Scan 1	Day 1* Scan 2	Day 1* Scan 3	Day 2+ Scan 1
1	6.84	6.58	6.49	6.50
2	7.74	7.22	7.53	7.35
3	6.70	6.37	6.94	7.00
4	6.55	6.44	6.16	6.70
5	6.90	6.11	6.96	6.50

Muscle thickness of supraspinatus

Among Day 1: ICC = 0.98

Between Day1 Scan1 and Day 2 Scan 1: ICC= 0.98

Subject	Day 1* + Scan 1	Day 1* Scan 2	Day 1 * Scan 3	Day 2+ Scan 1
1	16.8	16.9	17.0	16.6
2	20.7	20.6	20.3	20.2
3	20.0	19.3	20.0	20.5
4	17.5	17.0	17.6	16.8
5	23.1	23.0	22.5	22.8

* : Day 1 scans done to demonstrate interater reliability between scans on same day

\+ : Day 1 Scan 1 and Day 2 Scan 2 done to demonstrate interater reliability between scans on different days.

APPENDIX D

APPENDIX D-1:
Consent Form - English Version-

APPENDIX D-2:
Consent Form - Japanese Version -

Project Title: Muscle thickness and cross-sectional area of supraspinatus as measured by diagnostic ultrasound

Investigators:

Mr. Masaki Katayose,
Instructor, School of Health Sciences,
Sapporo Medical University
Dr. David Magee,
Professor, University of Alberta, Canada
Professor, School of Health Sciences,
Sapporo Medical University
S1-W17, Sapporo Japan
Tel (011)-611-2111 ext. 2972

Do you understand that you have been asked to be in a research study?	Yes	No
Have you read and received a copy of the Information Sheet?	Yes	No
Do you understand the benefits and risks involved in taking part in this research study?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Do you understand that you are free to refuse to participate or withdraw from the study at any time? You do not have to give a reason and it will not affect your situation.	Yes	No
Has the issue of confidentiality been explained to you? Do you understand who will have access to your records?	Yes	No

This study was explained to me by: ______________________

I agree to take part in this study.

______________________ ______________

Signature of Research Participant Date

____

Printed Name

______________________ ______________

Signature of Witness Date

____

Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

______________________ ______________

Signature of Investigator Date

研究被検者　同意書

研究課題：　超音波診断による健常成人男性の肩棘上筋の筋厚，筋横断面積

研究者：　片寄正樹（カタヨセ　マサキ）
札幌医科大学保健医療学部　助手，理学療法士
（電話：011-611-2111，内線2972）
David Magee（デーヴィト　マギー）
札幌医科大学保健医療学部　教授，博士，理学療法士
アルバータ大学リハビリテーション医学部　教授

- 本研究で，被検者としておこなわれる内容は理解できましたか　　はい　いいえ

- 添付した研究計画書は読まれましたか？　　はい　いいえ

- 本研究における被検者の利益および危険性は理解できましたか？　　はい　いいえ

- この研究に関する質問や討議をする機会が与えられましたか？　　はい　いいえ

- いつでもこの研究の被検者を辞退できることは理解できましたか？　　はい　いいえ
  辞退するための理由を申し出る必要性はなく，なんらかの制約を受けることもありません。

- 研究に関わる情報の守秘に関して説明を受けましたか？
  誰がこの研究に関わる情報に接触するか理解できましたか？　　はい　いいえ

この研究については ________________ から説明を受けました。

私はこの研究に参加することを同意します。

被検者署名 ________________________　　年月日

立会い人署名 ________________________　　年月日

私は上記に同意し，署名した被検者が研究の内容を理解し，参加に同意したことを確認します。

研究者署名 ________________________　　年月日

APPENDIX E:

Health Research Ethics Approval

University of Alberta Health Sciences Faculties, Capital Health Authority, and Caritus Health Group

Health Research Ethics Board

biomedical research
212.11 Walter Mackenzie Centre
University of Alberta Edmonton, Alberta T6G 2R7
p 403 492 [illegible] f 403 492 [illegible]
[illegible]

health research
3-48 Corbett Hall University of Alberta
Edmonton, Alberta T6G 2G4
p 403 492 [illegible] f 403 492 [illegible]
[illegible]

UNIVERSITY OF ALBERTA HEALTH SCIENCES FACULTIES, CAPITAL HEALTH AUTHORITY, AND CARITAS HEALTH GROUP

HEALTH RESEARCH ETHICS APPROVAL

Date: April 1999

Name(s) of Principal Investigator(s): Mr. Masaki Katayose

Organization(s): University of Alberta

Department: Graduate Studies; Department of Physical Therapy

Project Title: Muscle Thickness and Cross-sectional Area of Supraspinatus as Measured by Diagnostic Ultrasound

The Health Research Ethics Board has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the patient information material and consent form.

The approval for the study as presented is valid for one year. It may be extended following completion of the yearly report form. Any proposed changes to the study must be submitted to the Health Research Ethics Board for approval.

Dr. Sharon Warren
Chair of the Health Research Ethics Board (B: Health Research)

File number: B-120499-REM

APPENDIX F:

Letter of support from

Dr. Tsuyoshi Sato,
Dean , School of Health Sciences, Sapporo Medical University, Japan

Sapporo Medical University
School of Health Sciences
S. 1, W. 17, Chuo-ku
Sapporo 060 Japan

Tel +81-11-611-2111
Fax +81-11-613-7134

January 30, 1999

To Whom it Concerns, Unversity of Alberta

Regarding Mr. Katayose's data collection on his research toward a requiremnt for the master thesis, there is no need to submit consent procedure and forms to the Ethics Committee in Japan, if the data are collected from individuals with no particular medical problems. Mr. Katayose may only need to obtain a written consent from each individual if necessary. For that matter I will certainly assist him for completing the requirement in Japan.

Tsuyoshi Sato, PhD, OTR/L
Dean, School of Health Sciences
Sapporo Medical University

APPENDIX G

APPENDIX G-1:
Project Information Letter - English version-

APPENDIX G-2:
Project Information Letter - Japanese version-

Project Title: Muscle thickness and cross-sectional area of supraspinatus as measured by diagnostic ultrasound

Investigators Mr. Masaki Katayose,
Instructor, Sch. of Health Sciences, Sapporo Medical University
Dr. David Magee,
Professor, University of Alberta
Professor, Sch. of Health Sciences, Sapporo Medical University
S1-W17, Sapporo Japan
Tel (011)-611-2111 ext. 2973

Purpose:
The purpose of this study is to find out how thick and how wide the shoulder muscle called supraspinatus is in a group of normal Japanese men who do not do a lot of physical activity.

Background:
We need to know just how thick and wide this shoulder muscle is as many shoulder problems are related to this muscle called supraspinatus. One of the ways health care providers use to see how badly a muscle is hurt is by using ultrasound. We need to know what the thickness and area of a normal muscle looks like on an ultrasound image. It enables clinicians to compare with what an abnormal muscle looks like. This study is being done to collect information on normal shoulders. Therefore, in the future, this data can be used to compare with the information of people who injure this muscle.

Procedures & Risks:
If you agree to take part in this study, please call Masaki Katayose at the 011-611-2111 ext. 2973 listed above. If you are selected for the study, we will ask you to come to the laboratory just one time. The examination will be arranged at a convenient time for you. In the examination, you will be asked basic questions about yourself (age, what hand you use for different activities such as writing, eating and throwing). The shoulder joint will be examined for the amount of movement it has in different directions. Also the length of the arm will be measured using a tape measure, and your body height and body weight will be measured. The shoulder muscles will then be imaged using diagnostic ultrasound. Diagnostic ultrasound has been shown to be a safe diagnostic method which does not damage any tissue. During the imaging using diagnostic ultrasound, a gel will be applied to your skin to allow the ultrasound probe to slide over your skin. You will feel only the movement of the probe on your skin. You will not feel any pain or any other abnormal sensation. The interview and examination will take about one hour. On the day of scheduled appointment, if you can not come to the laboratory, you are encouraged to call in and postpone the appointment. We can easily reschedule the appointment.

Benefit:
The findings of this study will improve clinical diagnostic ultrasound evaluations for the shoulder. They may be also used in the objective evaluation of physical therapy for treating shoulders.

Confidentiality:
All information in this study will be treated confidentially and no one will know you have taken part in this study except the researchers. The data will be kept for at least 7 years in a secured area accessible only to the research team. Only the investigators will have access to the data. Your name will not be described in any reports which are related to this study. All information in this study will be presented in a summary form.

Freedom of withdraw:
You may withdraw from the study at any time without consequences to yourself.

If you have any question about this study, you may contact Mr. Masaki Katayose, 011-611-2111 ext. 2973. at your convenience. You may also contact Dr. Shigenori Miyamoto(011-611-2111 ext. 2971), Chair of Department of Physical Therapy, Sapporo Medical University, who is not involved with this study, if you have any other questions or concerns.

研究計画概要

研究課題：　超音波診断による健常成人男性の肩棘上筋の筋厚，筋横断面積

研究者：　片寄正樹（カタヨセ　マサキ）
札幌医科大学保健医療学部　助手，理学療法士
（電話：011-611-2111，内線2972）
David Magee（デーヴィト　マギー）
札幌医科大学保健医療学部　教授，博士，理学療法士
アルバータ大学リハビリテーション医学部　教授

研究目的：
本研究の目的は健常成人男性を対象として，超音波画像診断により肩関節に位置する棘上筋の筋厚，筋横断面積を明らかにすることであります。

研究背景：
様々な肩の障害が棘上筋と関連がみられ，この筋の萎縮の程度を評価する必要性が検討されています。臨床的に筋萎縮を評価する手法のひとつとして超音波が用いられますが，その正常データが確立されていません。正常データの確立は病態評価の基礎となります。今回の研究では健常人が対象となり，将来的に病態を有した人のデータとの比較に利用できます。

研究手順と危険性：
研究への参加に同意していただけば，本研究の研究者である片寄（011-611-2111内線2973）まで御連絡をいただければ幸いです。研究への参加が可能な状況であれば，研究室に訪問いただくことをお願いすることになります。検査，問診は被検者の方が都合のよい日時に調整することができます。検査では問診，視診，および肩関節関節可動域検査，上肢長測定，身長，体重測定，両肩関節の超音波画像検査を行います。超音波画像検査は非侵襲的検査であり安全性が確立されており，生体組織に危害が加わることはありません。超音波画像診断検査中はゼリーを添付した皮膚上の検査探子の移動を感じるのみで痛みなどはまったく伴いません。問診，検査等の時間は約１時間です。検査当日，研究室への訪問が不可能になった場合，御連絡をいただければ幸いです。その場でスケジュールの変更をすることができます。

研究による成果：
本研究結果より超音波診断による肩関節の評価の向上が期待されます。また，肩周囲筋の筋力増強などの理学療法の治療効果の客観的評価が期待されます。

守秘事項：
本研究に関わる一切の情報は守秘に取り扱われます。情報も安全な場所で少なくとも７年間保存されます。
またこれらの情報は上記の研究者のみが取り扱うものとします。また研究成果の公表においては，研究者の名前は公表されますが，被検者の氏名等は一切公表されることはありません。

研究からの逸脱の自由：
被検者はいかなる時でも，なんらかの制約をうけることなく研究から逸脱することができます。

上記研究に関する御質問，御意見は研究代表者片寄正樹（011-611-2111内線2973）まで御連絡下さい。また本研究には直接関与しておりませんが必要がございましたら札幌医科大学保健医療学部理学療法学科学科長宮本重範（011-611-2111内線2871）でもお受けします。

APPENDIX H:

QUALIFICATION CRITERIA OF SUBJECT

Subject ID: **Name:**

Inclusion Criteria

Sex: Male	Yes	No
Age between 20 y.o and 79 y.o. **specify: ______ y.o.**	Yes	No

Dominant hand (Right side)

Side of writing	Right	Left
Side of throwing	Right	Left
Side of using chopsticks	Right	Left

Normal shoulder

Normal active range needed to participate in this study

Flexion	165.0 ± 15.0	(160 - 180)	Yes	No
Extension	57.3 ± 24.3	(33 - 81.6)	Yes	No
Internal Rotation	67.1 ± 12.3	(54.8 - 79.4)	Yes	No
External Rotation	99.6 ± 22.8	(76.8- 122.4)	Yes	No
Abduction	165.0 ± 15.0	(160 - 180)	Yes	No

(Cited from Boone et al 1979, (8) Range is mean ± 3SD)

Pain in the shoulder	Yes	No
Clinical symptoms in the shoulder	Yes	No
History of surgery in the shoulder	Yes	No
Difficulty in using upper extremity in ADL	Yes	No

Exclusion Criteria

Regular sports activity : More than 4 times per week	Yes	No
Disease which has possibility of affecting muscle eg. Diabetes mellitus, Neurological disorders Collagen diseases.	Yes	No
Medication which has possibility of affecting the muscle (eg. Steroid)	Yes	No

---

Qualification for this study **Yes No**

APPENDIX I:

SAMPLE SIZE CALCULATIONS

Sample size was calculated with a power index which compromises significance level and power.

Significance level = 0.05 (1.96): alpha index (26)

Power = 80 (0.84): beta index (26)

Power Index = 2.80

According to the sample size calculation equation(26), the above mentioned values produce a sample size of 12 for each group.

Equation (26)

Sample size = $2 \{ PI \times \partial / (\mu_1 - \mu_2) \}$

PI: Power Index

Power index = a(0.05) + b(0.20) = 1.96+ 0.84 = 2.80

∂: standard deviation :

value based on pilot study (See Appendix C)

$\mu_1 - \mu_2$: difference of mean between groups

value based on pilot study (See Appendix C)

APPENDIX J:

DATA COLLECTION SHEET

Measurement data / /

Subject ID: **Name:** **Age:**

Weight (in kg to one decimal point) :

Height (in cm to one decimal point) :

Length of upper extremities (in cm to one decimal point) Rt Lt

Length between acromion and the apex of middle finger

Length between acromion and the lateral condyle of humerus

Shoulder active range of motion (in degrees)

(See Appendix H for methods)

	Rt	Lt
Flexion		
Extension		
Internal Rotation		
External Rotation		
Abduction		

Muscle CSA and thickness of supraspinatus (in millimetres to one decimal point)

Rt Lt

CSA (in cm^2 to one decimal point)

Measurement 1:

Measurement 2:

Measurement 3:

Thickness (in millimetre to one decimal point)

Measurement 1:

Measurement 2:

Measurement 3:

APPENDIX K:

QUESTIONNAIRE ITEMS

Subject ID: **Name:** **Age:**

Job/Office

Job history

ADL habits

Typical daily activity: chronological description

Time of a day:

5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Sports Activity

Sports type?

How often?

History of sports activity

Subjects self rated physical health

Excellent Good Fair Poor Bad

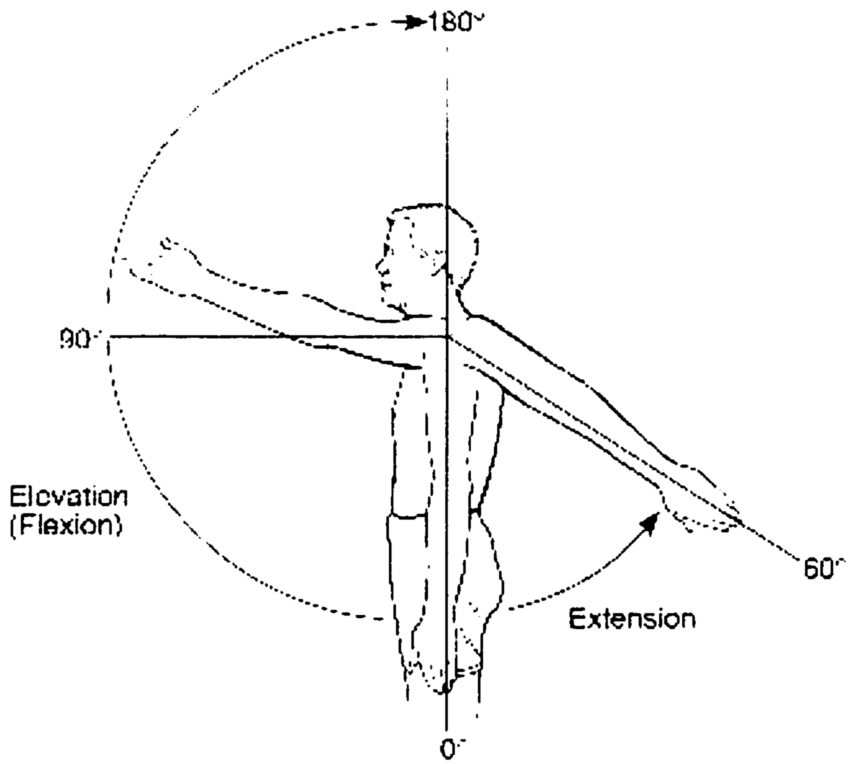
APPENDIX L

APPENDIX L-1: MEASUREMENT OF RANGE OF MOTION SHOULDER FLEXION AND EXTENSION

APPENDIX L-2: MEASUREMENT OF RANGE OF MOTION SHOULDER EXTERNAL AND INTERNAL ROTATION

APPENDIX L-3: MEASUREMENT OF RANGE OF MOTION SHOULDER ABDUCTION

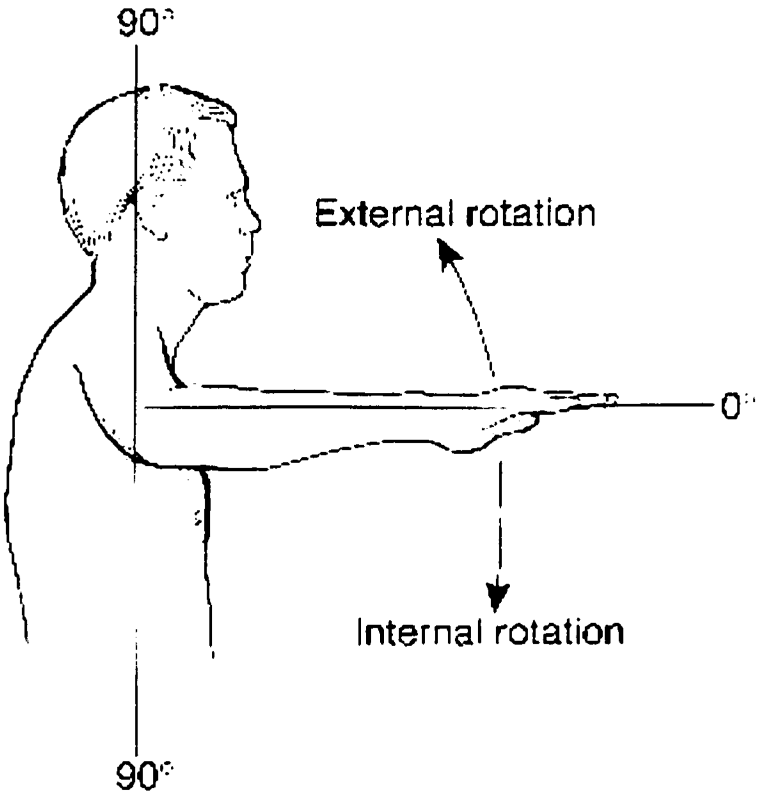
SHOULDER FLEXION AND EXTENSION



< Cited from Greene et al. 1994 p19 (22) >

The measurement is accomplished in the standing position. The axis of goniometer lies on the acromion in the sagittal plane. A based lever arm is accommodated on the major axis of trunk. A moving lever is accommodated on the major axis of humerus.

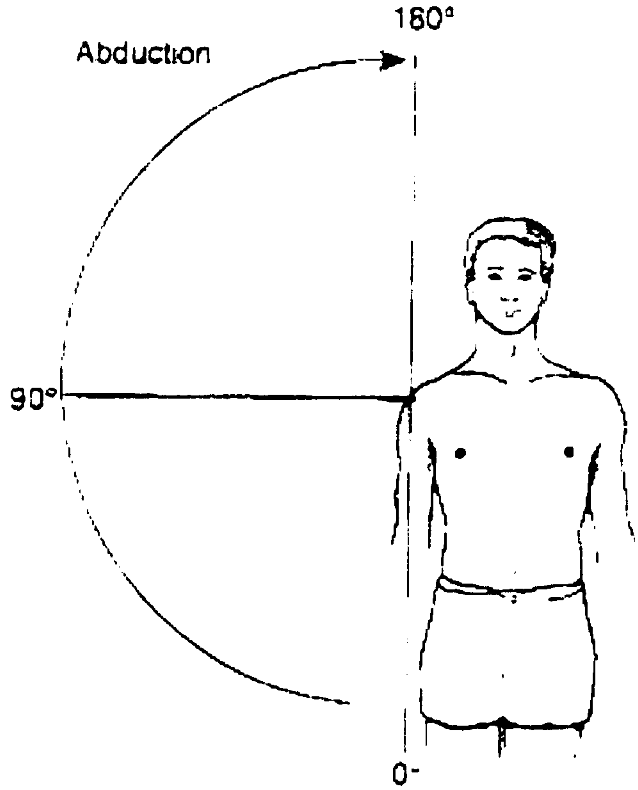
SHOULDER EXTERNAL AND INTERNAL ROTATION



< Cited from Greene et al. 1994 p23 (22) >

The measurement is accomplished in the sitting position with the shoulder in 90 degrees of abduction and elbow in 90 degrees flexion. The axis of goniometer is placed on the olecranon process in the sagittal plane. The base lever arm is placed on the vertical line because of the supine position. A moving lever is placed on the lateral side of the major axis of the ulna.

SHOULDER ABDUCTION



< Cited from Greene et al. 1994 p26 (22) >

The measurement is accomplished in the standing position. The axis of goniometer lies on the acromion in the coronal plane. A based lever arm is accommodated on the major axis of trunk. A moving lever is accommodated on the major axis of humerus.