

The Effects of 4-Week Serratus Anterior Strengthening Exercise Program on the Scapular Position and Pain of the Neck and Interscapular Region

Duck-hwa Kim, M.Sc., P.T.

Dept. of Sports and Fitness Management, Suncheon First College

Oh-yun Kwon, Ph.D., P.T.

Chung-hwi Yi, Ph.D., P.T.

Hye-seon Jeon, Ph.D., P.T.

Dept. of Physical Therapy, College of Health Science, Yonsei University

Institute of Health Science, Yonsei University

Abstract

The purpose of this study was to investigate the effects of serratus anterior strengthening exercises on scapular position and Visual Analog Scale (VAS) pain measurements taken at the resting position in young adults with adducted scapular. The exercise program included stretching of the scapular retractor and strengthening of the serratus anterior muscle. We measured the distance from the midline of the thorax to the vertebral border of the scapular with a tape line (Superior Kibler), and the distance from the 7th cervical spinous process to the acromial angle with 3-dimension motion analysis system, to compare the resting scapular position before and after exercise. Fifteen subjects with adducted scapular were recruited to compare the resting scapular position and VAS. The distance from 7th cervical spine process to acromial angle of the scapular and VAS decreased significantly ($p < .01$) after exercise, while the distance from the midline of the thorax to vertebral border of the scapular increased ($p < .05$). The conclusion is that the serratus anterior exercise program altered the resting scapular position and decreased VAS.

Key Words: Adducted scapular; Scapular position; Serratus anterior strengthening exercise; Superior Kibler.

Introduction

The normal scapular rest position has not been determined, in large part because of the variation between individuals (Sobush et al, 1996). However, there is general agreement that it sits on the posterior thorax between the second and seventh ribs (Culham and Peat, 1993). The spine and scapular can be palpated to assess the relative positioning of the scapular. The optimum position is such that the superior angle of the scapular corresponds with the spinous processes of T3 or T4, and the inferior angle level with T7, T8 or T9, but the inferior may be

as low as T10 (Mottram, 1997; Sobush et al, 1996).

If the scapular loses its stability mechanism, it typically influences the scapular posture. Clinically abnormal scapular positioning and poor dynamic stability is often associated with neuromusculoskeletal dysfunction of neck and shoulder region. The stabilization functions of muscles are influenced by postural changes. Changes in the contractile properties of muscles and changes in connective tissue may influence muscle function to stabilize the scapular. If with disuse there is extensive atrophy of the tonic type I fibers, there may be associated length changes (Goldspink and Williams, 1990). These changes may

influence the ability of the scapular stability muscles to maintain an ideal postural position of the scapular. Changes in the recruitment of shoulder muscles may influence muscle stability function. Pain also can inhibit stability muscle function (Hides et al, 1996), probably due to changes in the afferent input to the central nervous system. Damage to mechanoreceptors will alter proprioceptive afferent activity and decrease motor drive leading to atrophy and weakness (Hurley, 1997). Consequently, considering the physiological changes that occur with injury, disuse and disease, it is important to realign the scapular in its ideal postural position and to recruit the stabilizing muscles to maintain this position (Mottram, 1997).

Poor shoulder posture and muscle imbalance are believed to be important factors that contribute to shoulder dysfunction and insidious pain syndrome (Kelly and Clark, 1995). Some authors state that postural deviation and muscle imbalance around the shoulder area are frequently concurrent. The scapular position may not be ideal, because of the length changes in the muscles and soft tissues or muscle inhibition, but the patient is taught to position the scapular toward the ideal position and to perform an isometric contraction of the stability muscles—for instance, trapezius and serratus anterior. Altered joint position, such that some muscles appear tight or overactive and others lengthened or under active, provides early hypotheses in relation to muscle function (Kendall et al, 1993). Therefore, specific analysis of scapular and arm position will provide initial clues to the comparative load carried by the glenohumeral and scapulothoracic joints (Magarey and Jones, 2003). Also, force imbalance develops between those two muscle groups, which may produce changes in resting scapular position (Wang et al, 1999). The extensive scapular motion of the shoulder is accomplished by coordinated movement of all four joints of the shoulder girdle (Culham and Peat, 1993). If there is a deficiency in any of these structures, shoulder dysfunction may occur because of changes in scapular position, scapulohumeral rhythm, and improper

muscular balance. Such disturbances of normal motion may lead to shoulder instability, dysfunction, and shoulder pain (Paine and Voight, 1993).

Sahrmann (2001) classified the scapular movement syndrome by four criteria. Classification categories are scapular downward rotation/upward rotation, scapular depression/elevation, scapular abduction/adduction, and scapular wing and tilting. Criteria for the syndrome include impaired scapular movement, associated with faulty humeral motion, pain, insufficient range of motion, and the behavior of the symptom. The ability to assess movement function and correct movement dysfunction around the scapulothoracic joint is a key issue when addressing neuromusculoskeletal dysfunction in the shoulder girdle (Mottram, 1997).

Wang et al (1999) investigated twenty subjects with forward shoulder posture to evaluate the effects of retraction exercises on shoulder kinematics and resting posture. This exercise program improved muscle strength, produced a more erect upper trunk posture, increased scapular stability, and altered scapulohumeral rhythm, but resting scapular posture did not change. Based on the theories of muscle imbalance, clinicians postulate that strengthening of the posterior scapular stabilizers, combined with stretching of the pectoral muscles, can correct body posture and muscular imbalance, and can alter scapulohumeral rhythm (Allegrucci et al, 1994; Wang et al, 1999).

In a preliminary study, Decker et al (1999) and Ludewig et al (2004) examined the muscle activity of several serratus anterior exercises and investigated the peak force. However, there is little quantitative data documenting the effect of serratus anterior strengthening exercise on adducted scapular or on shoulder kinematics. We decided to examine the effects of serratus anterior strengthening exercises on resting posture and on the shoulder pain.

The purpose of this study was to investigate the effects of serratus anterior strengthening exercises on resting posture and Visual Analog Scale (VAS) in young adults with adducted scapular before and after exercises. The exercise program included stretching of

the scapular retractor and strengthening of the serratus anterior muscle. We based our hypotheses on the assumption that the serratus anterior strengthening exercise program will normalize the resting position of the scapular and will decrease the shoulder pain.

Methods

Subjects

The adducted scapular has the following features. At the resting position, the scapular plane is less than 30 degrees anterior to the frontal plane, and the rhomboid and trapezius muscles may be short while the serratus anterior muscle is long and relatively weak. This causes imbalanced force, and may produce changes in the resting scapular position. The criteria for adducted scapular are as follows:

- 1) Insufficient scapular upward rotation during flexion and abduction of the humerus.
- 2) Increased slope of shoulders.
- 3) Scapular less than 3 inches from spine.
- 4) Vertebral border of the scapular not parallel to the spine.
- 5) Humerus in abduction relative to the scapular.
- 6) One arm may appear longer than the other.
- 7) Neck pain or inter-scapular pain (Sahrman, 2001).

We admitted subjects that satisfied more than four of the above criteria. Fifteen healthy adults (mean age=21.9±2.3 yrs, mean height=168.6±8.2 cm) with adducted scapular participated voluntarily in this study. There were seven men and eight women. All exhibited right-hand dominance. No subjects had been treated for shoulder dysfunction or had engaged in shoulder exercises. Subjects were excluded if they had overt shoulder trauma or shoulder surgery, or if they had symptoms resulting from cervical or other neurological problems. Prior to the experiment, the purpose and methods were explained in plain terms and informed consent forms were obtained. The general characteristics of the subjects are summarized in Table 1.

1) Zebris Mdizintechnik, GmbH, Isny, Germany.

Measurements

For resting scapular position, we stabilized each subject's trunk and head posteriorly with an iron rod. Next, we measured the distance from the midline of the thorax (T3/4) to the vertebral border of the scapular with a tape line, and from the seventh cervical spinous process to the acromial angle with CMS-HS¹⁾. CMS-HS was used to capture the body posture with a marker and receptor. Two markers were attached, to the seventh cervical spinous process and to the acromial angle, and the distance was calculated.

The position of the scapular was measured, based on the model shown in Figure 1 (Superior Kibler distance was described by McKenna et al, 2004). Figure 1 (a) represents the distance measured by CMS-HS and Figure 1 (b) that measured by a tape line at a resting position. The measurement in Figure 1 (b) has been used by previous authors for identification of the spinous process of T3/4, and is called the 'Superior Kibler' (Gibson et al, 1995; McKenna et

Table 1. Characteristics of the subjects (N=15)

Characteristics	Mean±SD	Range
Age (yrs)	21.9±2.3	19~33
Height (cm)	168.6±8.2	155~190

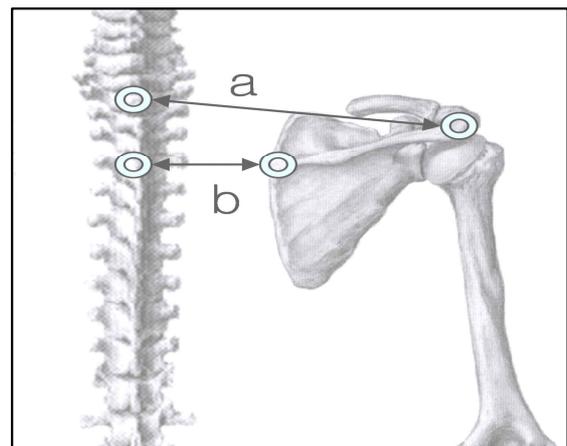


Figure 1. (a) The distance between the C7 and the acromial angle of the scapular. (b) The distance between the midline of the thorax and the vertebral border of the scapular.

al, 2004). Accuracy of locating scapular and thoracic spinous process landmarks appears to be acceptable (Lewis et al, 2002). All measurements were taken on the right side with the arm at rest. Visual Analog Scale (VAS) was used to investigate the muscular pain in the neck or in the inter-scapular region.

Procedures

All measurements were taken by the primary investigator to assure the reliability and repeatability. To prevent trunk movement during the measurement of resting position, each subject (standing) was stabilized posteriorly with an iron rod on the thorax and occipital bone of the head. We first measured the distance between the midline of the thorax and the vertebral border of the scapular with a tape line. For measurement of resting scapular position with CMS-HS, two single markers were used. One marker was placed on the seventh spinous process, and the other was placed on the acromial angle of the scapular. For data collection, the subject was required to produce three times for 3 seconds each with hold their breath.

Reliability

A pilot study was conducted to ascertain the intra-rater reliability of measurements with CMS-HS and with tape-line for evaluating the resting scapular

position. All of the procedures of measurement with the tape line and CMS-HS were conducted twice, by the primary investigator, on each of the 15 subjects with adducted scapular, with at least a 3-day interval between measurements. The results of the two measurements were compared to calculate the intra-class correlation coefficients. The value of resting position of the scapular with a tape line is .87 (.87~.9) and with CMS-HS is .96 (.95~.98), which indicated high reliability. Mckenna et al (2004) reported that Superior Kibler measurement was more reliable with ICCs .79~.87 at the neutral position.

Exercise Program

All subjects with adducted scapular performed the same levels of the serratus anterior strengthening exercises. We devised two exercises: in the sitting position (Figure 2) and in the quadruped position (Figure 3). The exercises were designed so that all subjects could perform them, based on feedback from the subject and on observation by the investigator. When necessary, the performance of an exercise was corrected by the principal investigator based on observation and palpation of the target muscle. Subjects were asked to continue to rise up by protracting the scapular, and to do five repetitions of each of the exercises. All subjects were required to perform the



Figure 2. Strengthening exercise in the sitting position (Subjects was asked to realign the trunk and neck with protracting the scapular).



Figure 3. Strengthening exercise in the quadruped position (Subject was asked to continue to rise up by protracting the scapular).

Table 2. Variables before and after exercise

Variable	Before exercise	After exercise	p
MV ^b (cm)	5.60±.40 ^a	6.55±.48	.00
SA ^c (cm)	20.46±.29	19.67±.30	.01
VAS ^d (score)	3.12±1.82	1.40±1.30	.00

^aMean±SD.

^bMV: the distance from the midline of the thorax to the vertebral border (Superior Kibler).

^cSA: the distance from the seventh cervical spinous process to the acromial angle.

^dVAS: Visual Analog Scale.

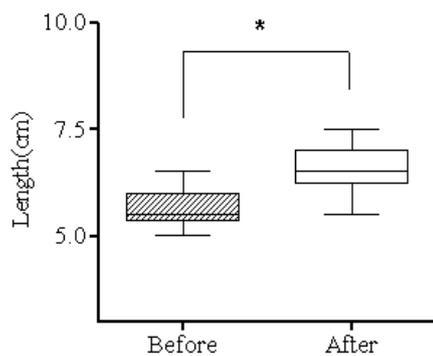


Figure 4. Mean the distance from the midline of the thorax to the vertebral border ($p<.05$).

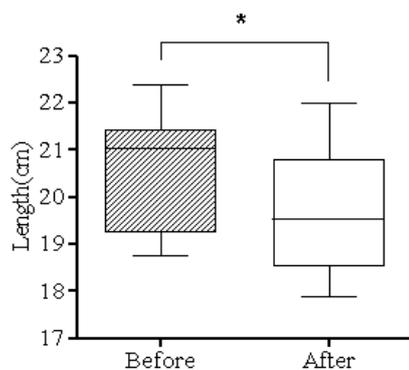


Figure 5. Mean distances from the seventh cervical spinous process to the acromial angle ($p<.05$).

exercise program four times per week at treatment room under supervision by the principal investigator. One set of 5 repetitions for one session was required every 4 weeks. At first 21 subjects were recruited, but later 6 of these were excluded because they did not complete all sessions as specified.

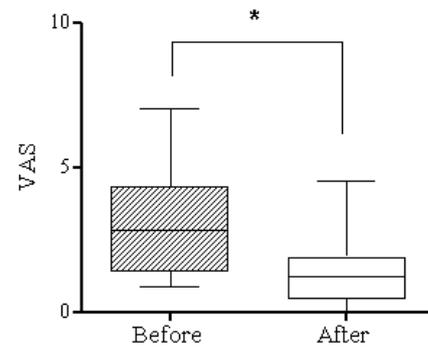


Figure 6. Mean Visual Analog Scale scores (Error bars represent standard deviation) ($p<.05$).

Statistical Analysis

All dependent variables were compared before and after exercise with a baseline developed during the preliminary study. Paired t-tests were performed to identify the resting scapular position and VAS. The statistical analysis of data was performed using SPSS version 11.0. Statistical significance was set at $p<.05$.

Results

Results of the paired t-test data relating to the resting scapular position and VAS are summarized in Table 1. Results indicate that the distance from the midline of the thorax to the vertebral border (MV) was significantly increased after the exercise program ($p<.01$) (Figure 4). The distance from the seventh cervical spinous process to the acromial angle (SA) decreased significantly ($p<.05$) (Figure 5). The VAS

score was significantly decreased after the exercise program ($p < .01$) (Figure 6). Table 2 shows the mean values of MV, SA, and VAS before and after exercise.

Discussion

Exercise Program

The exercise program was designed to strengthen the serratus anterior muscle as well as stretching the scapular retractor muscles in sitting and quadruped positions. We used isometric exercises to enhance the tonic type I fibers, because there may be length associated changes connected with body posture (Goldspink and Williams, 1990). These changes, with adducted scapular, may influence the ability of the scapular stability muscles to maintain an ideal postural position of the scapular. We designed the exercise program not to produce maximal EMG activity as in previous studies (Decker et al, 1999; Ludewig et al, 2004). The exercise program was based on feedback from the subject and on observation by the investigator, but there were some problems determining the optimal intensity of the exercises.

Scapular Position

The scapular must be examined closely as part of the evaluation of shoulder problems. Therefore, the scapular needs to be evaluated not only locally, but also distantly, in relation to its role in the kinetic chain. Evaluation of the back and trunk is especially important (Mckenna et al, 2004) because the resting scapular position is affected by the trunk muscle during activity (Kebaetse et al, 1999). For accurate measurement of resting scapular position, investigators must stabilize subject's trunk and head parallel to the vertical plane. To minimize the variation of scapular position according to trunk and head position, we stabilized each subject's trunk and head posteriorly with an iron rod in this study.

The purpose of this study was to investigate the effects of serratus anterior strengthening exercises

on scapular position and pain of neck and inter-scapular region.

First, we investigated the distance from the midline of the thorax to the vertebral border. After exercise program, the distance from the midline of the thorax to the vertebral border (MV) was significantly increased after the exercise program ($p < .01$). This result suggests that serratus anterior muscle strengthening program is useful to recover the scapular position in subjects with scapular adducted. A clinical measurement of scapular position such as the Kibler method may be required to detect differences of about 10 mm between healthy and impaired subjects found using a three-dimensional (3D) electromagnetic laboratory tracking system in a neutral arm position (Kibler, 1995; Kibler, 1998). Kebaetse et al (1999) determined that intervention, in subjects without shoulder pathology, changed lateral scapular position by .6~12.5 mm, depending on arm position. The measurement of choice would need to have an error less than these values in order to be of clinical use in detecting aberrant scapular position associated with pathology or in evaluating interventions. The Superior Kibler method used in our intervention has a .1~.7 mm error range. Therefore, it can be asserted reliably that the resting scapular position altered after exercise.

Second, the distance from the seventh cervical spinous process to the acromial angle was investigated with CMS-HS. The distance from the seventh cervical spinous process to the acromial angle decreased significantly ($p < .05$). This result means that serratus anterior strengthening exercise program can reduce scapular anterior tilt.

Pain Reduction

The stabilization function of stability muscles is influenced by postural changes of muscles, and changes in connective tissue may influence muscle function (Mottram, 1997). With disuse there are length associated changes (Goldspink and Williams, 1990). These changes may influence the ability of

the scapular stability muscles to maintain the scapular in an ideal postural position. Changes in the recruitment properties may influence muscle stability function (Mottram, 1997). Pain can inhibit stability muscle function (Hides et al, 1996).

Damage to mechanoreceptors will alter proprioceptive afferent activity and consequently decrease motor drive, leading to atrophy and weakness (Hurley, 1997). Another common theory is applied to muscles that are directly injured from direct blow trauma, have microtrauma-induced strain in the muscles leading to muscle weakness and force couple imbalance, or are inhibited by painful conditions around the shoulder (Kibler, 1998). It appears that the serratus anterior and the lower trapezius muscles are the most susceptible to inhibition (Kuhn et al, 1995; Moseley et al, 1992; Speer and Garrett, 1994). Muscle inhibition, and the resulting scapular instability, appears to be a nonspecific response to a painful condition in the shoulder (Kibler, 1998). Inhibition is seen both as a decreased ability of the muscles to exert torque and stabilize the scapular, and also as a disorganization of the normal muscle firing patterns of the muscles around the shoulder (Kuhn et al, 1995; Warner et al, 1992). We can infer that reduction of the muscular pain will decrease the risk factors contributing to shoulder dysfunction.

In this study, the VAS score was significantly decreased after exercise program ($p < .01$). Abnormal positions of scapula and head have been considered as contributing factor on neck and shoulder pain (Ludewig et al, 1996). Re-alignment of trunk, neck and scapular exercise during this exercise protocol could be improved the trunk, neck and scapular alignment. Although we did not measure the changes of trunk and neck position directly in this study, these results could be some possible reasons why VAS scores were decreased after exercise program.

Limitations

We investigated the distance from the seventh cervical spinous process to the acromial angle and from

the midline of the thorax to the vertebral border before and after exercise. However, we did not measure the changes of serratus anterior muscle strength after exercise program. We evaluated the effects of the commonly used serratus anterior strengthening exercises on resting scapular posture and pain of the neck and interscapular region. However, there are many other exercises to strengthen the serratus anterior muscle. Further studies are needed to examine the effects of various strengthening exercises on resting posture and on muscular pain, under varying treatment intensities and duration.

Conclusion

The distance from the midline of the thorax to the vertebral border significantly increased after the exercise program ($p < .01$). The distance from the seventh cervical spinous process to the acromial angle decreased significantly ($p < .05$). Also the VAS score was significantly decreased after exercise program ($p < .01$). These results suggest that serratus anterior strengthening exercise can normalize the scapular resting position and decrease pain of neck and interscapular region in subjects with scapular adducted.

References

- Allegrucci M, Whitney SL, Irrgang JJ. Clinical implications of secondary impingement of the shoulder in freestyle swimmers. *J Orthop Sports Phys Ther.* 1994;20(6):307-318.
- Culham E, Peat M. Functional anatomy of the shoulder complex. *J Orthop Sports Phys Ther.* 1993;18(1):342-350.
- Decker MJ, Hintermeister RA, Faber KJ, et al. Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sports Med.* 1999;27(6):784-791.
- Gibson MH, Goebel GV, Jordan TM, et al. A reli-

- ability study of measurement techniques to determine static scapular position. *J Orthop Sports Phys Ther.* 1995;21(2):100-106.
- Goldspink G, Williams PE. Muscle fibre and connective tissue changes associated with use and disuse. In: Ada L, Canning C, eds. *Key Issues in Neurological Physiotherapy.* Butterworth Heinemann, Oxford, 1990:197-218.
- Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine.* 1996;21(23):2763-2769.
- Hurley MV. The effects of joint damage on muscle function, proprioception and rehabilitation. *Man Ther.* 1997;2(1):11-17.
- Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil.* 1999;80(8):945-950.
- Kelly MJ, Clark WA. *Orthopedic Therapy of the Shoulder.* Philadelphia, Lippincott Williams & Wilkins, 1995.
- Kendall FP, McCreary Ek, Provance PG. *Muscles: Testing and function.* 3rd ed. Baltimore, Lippincott Williams & Wilkins, 1993:343.
- Kibler WB. Clinical examination of the shoulder. In: Pettrone FA, ed. *Athletic Injuries of the Shoulder.* New York, McGraw-Hill Inc., 1995:31-41.
- Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26(2):325-337.
- Kuhn JE, Plancher KD, Hawkins RJ. Scapular winging. *J Am Acad Orthop Surg.* 1995;3(6):319-325.
- Lewis J, Green A, Reichard Z, et al. Scapular position: The validity of skin surface palpation. *Man Ther.* 2002;7(1):26-30.
- Ludewig PM, Cook TM, Nawoczenski DA. Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. *J Orthop Sports Phys Ther.* 1996;24(2):57-65.
- Ludewig PM, Hoff MS, Osowski EE, et al. Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises. *Am J Sports Med.* 2004;32(2):484-493.
- Magarey ME, and Jones MA. Dynamic evaluation and early management of altered motor control around the shoulder complex. *Man Ther.* 2003;8(4):195-206.
- McKenna L, Cunningham J, Straker L. Inter-tester reliability of scapular position in junior elite swimmers. *Physical Therapy in Sport.* 2004;5(3):146-155.
- Moseley JB Jr, Jobe FW, Pink M, et al. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med.* 1992;20(2):128-134.
- Mottram SL. Dynamic stability of the scapula. *Man Ther.* 1997;2(3):123-131.
- Paine RM, Voight M. The role of the scapula. *J Orthop Sports Phys Ther.* 1993;18(1):386-391.
- Sahrmann SA. *Diagnosis and Treatment of Movement Impairment Syndromes.* St. Louis, Mosby, 2001.
- Sobush DC, Simoneau GG, Dietz KE, et al. The lennie test for measuring scapular position in healthy young adult females: A reliability and validity study. *J Orthop Sports Phys Ther.* 1996;23(1):39-50.
- Speer KP, Garrett WE. Muscular control of motion and stability about the pectoral girdle. In: Matsen FA, Fu F, Hawkins RJ, eds. *The Shoulder: A balance of mobility and stability.* Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994:159-173.
- Wang CH, McClure P, Pratt NE, et al. Stretching and strengthening exercises: Their effect on three-dimensional scapular kinematics. *Arch Phys Med Rehabil.* 1999;80(8):923-929.
- Warner JJ, Micheli LJ, Arslanian LE, et al. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using moire topographic analysis. *Clin Orthop Relat Res.* 1992;(285):191-199.
-
- This article was received September 27, 2007, and was accepted October 30, 2007.