한국전문물리치료학회지 2014년 21권 2호 67-73
Phys Ther Korea 2014;21(2):67-73
ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2014.21.2.067

Comparison of Muscle Activity Ratio of Upper Trapezius to Serratus Anterior During Shoulder Elevation Between Subjects With and Without Pain Experienced in Upper Trapezius

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Abstract

The aim of this study was to compare the activity of the upper trapezius (UT) and serratus anterior (SA) and ratio of UT to SA during shoulder elevations. Ten subjects with UT pain (UTP) and 13 subjects without UTP participated in this study. Subjects with a UTP of over five in a pain intensity visual analogue scale (0-10 ㎝) for more than 2 months and latent myofascial trigger points (MTrPs) in the UT muscle were included in the UTP group. Electromyography (EMG) data of UT and SA at 1st and 10th elevations were analyzed. Two-way repeated analyses of variance were used to compare the EMG activity of UT and SA and the ratio of UT to SA during shoulder elevations between groups with and without UTP. There was a significant increase in UT/SA ratio in the group with UTP compared to the group without UTP ($p=.01$). The activity of UT and SA measured at the 10th elevation was significantly greater than that in the first elevation ($p<.05$). The activity of SA was significantly greater in the group without UTP than the group with UTP ($p=.03$). However, there was no significant difference between groups with and without UTP in terms of UT activity ($p=.28$). These results indicate that UTP may have relevance to the increased muscle activity ratio of UT to SA during shoulder elevations.

Key Words: Electromyography; Ratio of muscle activity; Serratus anterior; Upper trapezius pain.

Introduction

Pain in the upper trapezius (UT) muscle is a common problem among industrial workers (Holtermann et al, 2008; Strøm et al, 2009; van der Windt et al, 2000). The prevalence of UT pain (UTP) may be 6%-11% among the population under the age of 50 (van der Windt et al, 2000). UTP leads to reduced productive capacity and daily life (van der Windt et al, 2000). Previous studies made an effort to identify the factors of UTP (Bongers et al, 1993; Sommerich et al, 1993; van der Windt et al, 2000). Van der Windt et al (2000) indicated physical and psychological factors that have influence on UTP. Repetitive movement and working with arms above shoulder level were the most influential factors of UTP among physical factors (English et al, 1995; Hughes et al, 1997; Johansson, 1995). Repetitive movement can change muscle tissues, such as muscle fibers and cells. Previous studies showed that muscle fibers of overused, painful muscles yielded to hypertrophy of Type I fibers and ischemic or denervation loss of Type Ⅱ fibers (Dennet and Fry, 1998). These changes contribute to muscles' localized hypoxia and blood flow reduction (Barr and Barbe, 2002). Preceding processes lead related muscles to motor dysfunction such as muscle fatigue and weakness. Eventually, chronic musculoskeletal pain occurs (Barr and Barbe, 2002).

Based on a study by Kibler and McMullen (2003),

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scapular stabilization is the result of the coupling of the UT and serratus anterior (SA) muscles. These muscles make scapular upward rotation during arm elevation. Most commonly, the scapular stabilizing muscles become fatigued from repetitive use. The SA muscles are the most vulnerable and susceptible to fatigue from repetitive movement. Previous studies have suggested that excess UT activity may attempt to compensate for a weak SA muscle (Ludewig et al, 2004). Weakness of SA and overuse of UT have been described in patients with shoulder dysfunction (Martins et al, 2008).

The muscle activity of UT and SA and ratio of UT/SA can be altered during repetitive arm elevation among patients with shoulder dysfunction. However, studies about how UTP influence UT and SA muscle activation should be furthered. The purpose of this study is to compare the activity of UT and SA and the ratio of UT to SA during repetitive shoulder elevations among subjects with and without UTP. We hypothesized that (1) the ratio of UT/SA would increase among subjects with UTP and (2) the activity of UT would increase while that of SA would decrease among subjects with UTP.

Methods

Subjects

Prior to recruiting subjects, G*power analysis was performed to determine the number of subjects required to achieve a significant α level (.05), power (.8), and effect size (.61) based on pilot study. The result showed that eight subjects were required for this study.

Thirteen subjects without UTP and ten subjects with UTP participated in this study. All volunteers were recruited from Yonsei University. The general characteristics of the subjects were shown in Table 1. Subjects with UTP were included based on the following symptoms: (1) experience of UTP for more than 2 months, (2) latent myofascial trigger points (MTrPs) in the UT muscle, (3) visual analogue scale (VAS) score over 5. In this study, latent MTrPs was identified by painful taut band in the UT by manual palpation and a pressure-pain threshold (PPT) less than that of normal muscle (Lucas et al, 2004). The lowest PPT of normal UT muscle was 2.9 ㎏/㎠ for males and 2.0 ㎏/㎠ for females (Lucas et al, 2004). People who had glenohumeral joint instability, neurological dysfunction, pain in glenohumeral joint, and surgery experience were excluded (Lucas et al, 2004). All subjects were instructed about this study before participation, and consent were obtained from all of them. The investigation was approved by the Yonsei University Wonju Institutional Review Board.

Instruments

Electromyography

Surface electromyography (EMG) was used for measuring the activity of UT and SA muscle during repetitive arm elevation. Bipolar Ag/AgCL disposable electrodes were used in this study. EMG data were collected at a sampling frequency of 1000 ㎐. Myoresearch-XP 1.08 Master Edition (Noraxon Inc., Scottsdale, AZ, USA) was used for data collection and processing. Raw data were filtered at a

Table 1. General characteristics of the subjects. (N=23)

Variables	Subjects with UTP[a] (n_1=10)	Subjects without UTP (n_2=13)	p
Age (year)	24.8±1.7[b]	24.0±1.9	.605
Height (㎝)	175.1±5.6	174.0±7.37	.306
Weight (㎏)	69.0±6.6	65.8±6.8	.936
VAS[c] (㎝)	6.2±1.0	.9±1.0	<.001*
PPT[d] (㎏/㎠)	2.1±.9	3.4±1.1	.005*

[a]upper trapezius pain, [b]mean±standard deviation, [c]visual analogue scale, [d]pressure pain threshold.

band-pass of 10-500 ㎐. The root mean square (RMS) values were calculated using a moving window of 150 ㎳. Electrodes were attached to the UT and SA muscles, parallel to the muscle fibers. For the UT, electrodes were attached to the middle point between the acromion and 7th cervical spine. For the SA, electrodes were attached to the anterior to the latissimus dorsi muscle, at the level of scapular inferior angle (Criswell, 2010; McLean, 2005). Each location of attachment was shaved and cleaned with alcohol before electrodes were attached to the muscles.

Hand-held dynamometer

Commander muscle tester device (Commander Muscle Tester, JTECK Medical, Salt Lake City, USA) was used for determining the dumbbell load during arm elevation. Subjects sat on the chair in upright position and elevated their arm 90° in scapular plane. Hand-held dynamometer (HHD) was placed on the wrist of the tested arm, which was pressed downward until subjects could hold their arm to 90° elevation. Maximal force was recorded by HHD.

Pressure algometer

Pressure algometer (FPK 60, Wagner Instruments Inc., CT, USA) was used to measure the PPT of UT muscle. The rubber tip of the pressure algometer was placed on the taut band of the UT vertically. Pressure was given to subjects until they felt pain or discomfort. The unit of PPT was ㎏/㎠.

Data analysis

EMG data were collected during 10 times of repeated arm elevations. Arm elevation task was performed for 5 seconds to target 90° position using metronome. The term between each elevation task was 1 second. The absolute RMS of shoulder muscles was collected during the middle 3 seconds of the 1st and 10th elevation sections. Absolute RMS value was normalized by maximal voluntary isometric contraction (MVIC). MVIC recorded data in manual muscle testing position (Hislope and Montgomery, 2007). For the assessment of UT MVIC, resistance was applied to depress the scapula and neck side bending to the opposite side during scapular elevation, neck ipsilateral side-bending, and contralateral rotation position. The maximal resistance for fully scapular protraction was applied for SA muscles. Data for MVIC were recorded 3 times for 5 seconds, with the middle 3 seconds used for analysis. Normalization was conducted to account for the intersubject variability of temporal and spectral estimators due to skin fold thickness of muscle size (Ge et al, 2012).

Procedures

Subjects sat on the chair with hip and knee 90° flexion and feet on the ground (Lucas et al, 2010). 90° arm elevation in scapular plane was performed with extended elbow and neutral forearm rotation. Scapular plane was controlled by a vertical wooden bar that was set 30° anterior to the coronal plane (Lucas et al, 2010). 90° arm elevation was also controlled by a target bar that could adjust to the shoulder level of each subject. Strap was applied on the rib to prevent compensatory trunk side bending. In addition, external load was applied by dumbbell. The weight of dumbbell was decided by 25% of the maximum force measured by HHD (Wickham et al, 2010). Subjects elevated their arm to 90° in 5 seconds and 5 seconds for maintaining their wrist attached to the target bar using metronome. There was a remaining second for return to start position. These serial movements were repeated 10 times (Figure 1).

Statistical analysis

Two-way repeated analyses of variance were used to determine the statistical significance differences of the muscle activity of UT and SA and ratio of UT/SA during arm elevations between groups with and without UTP. Significant level was set at α=.05.

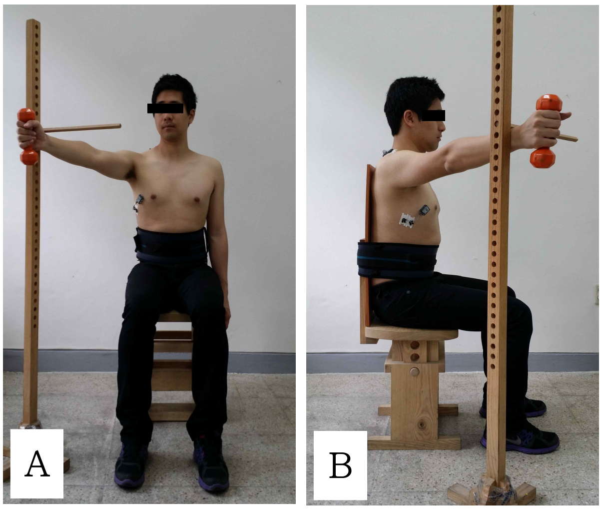

Figure 1. Shoulder elevation with dumbbell (A: coronal plane, B: sagittal plane).

If a significant interaction between elevation time (1st and 10th elevations) and groups (with and without UTP) was observed, the simple effect was compared using Bonferroni correction (α=.05/4=.013). SPSS ver. 21.0 (SPSS Inc., Chicago, IL, USA) was used for analyzing.

Results

Upper trapezius

There was no significant interaction effect between number of elevation and groups (F=1.05, p=.32). A significant main effect was observed between the 1st and 10th elevations [(F=39.13, p<.05), 27.6±13.7% MVIC (1st elevation) vs. 47.0±12.9%MVIC (10th elevation) for the group with UTP, 17.7±7.8%MVIC (1st elevation) vs. 44.7±28.5%MVIC (10th elevation) for the group without UTP]. There was no significant main effect between groups (F=1.21, p=.28).

Serratus anterior

There was no significant interaction effect between number of elevation and groups (F=3.84, p=.06). A significant main effect was observed between 1st and 10th elevations (F=48.43, p<.05), while the significant main effect was found between groups (F=5.12, p=.03). The SA activity was significantly less in the group with UTP than the group without UTP (1st elevation: 17.6±5.4% MVIC for the group with UTP vs. 23.9±11.3% MVIC for the group without UTP; 10th elevation: 32.8±14.6% MVIC for the group with UTP vs. 51.0±21.1% MVIC for the group without UTP) (Figure 2).

Ratio of upper trapezius to serratus anterior

There was no significant interaction effect between number of elevation and groups (F=.13, p=.72). No significant main effect was observed between 1st and 10th elevations (F=1.85, p=.19), but significant main effect was found between groups (F=7.88, p=.01). The ratio of UT/SA was significantly greater in subjects with UTP compared to subjects without UTP (1st elevation: 1.6±.7 for the group with UTP

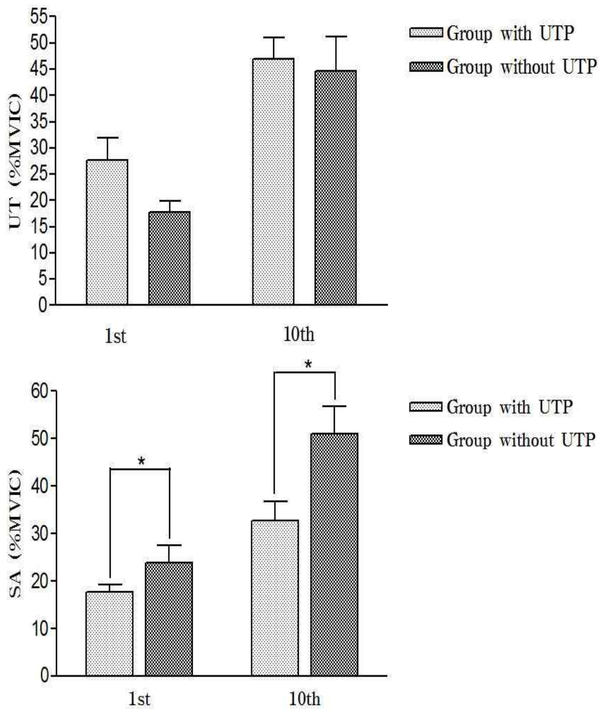

Figure 2. Comparison of the UT and SA activity between subjects with and without UTP (UT: upper trapezius, SA: serratus anterior, MVIC: maximal voluntary isometric contraction, UTP: upper trapezius pain, *p<.05).

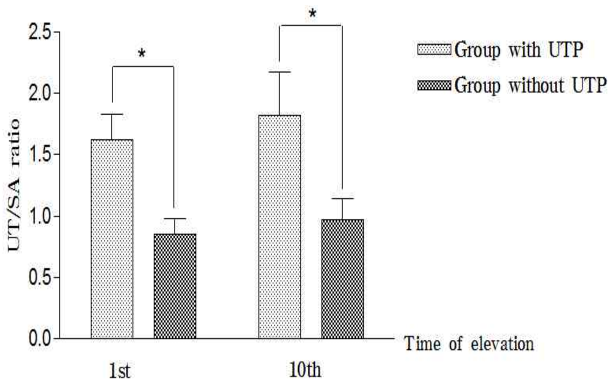

Figure 3. Comparison of the UT/SA activity during 1st and 10th elevation in subjects with and without UTP (UT: upper trapezius, SA: serratus anterior, UTP: upper trapezius pain, $^*p<.05$).

vs. .9±.5 for the group without UTP; 10th elevation: 1.8±1.1 for the group with UTP vs. 1.0±.6 for the group without UTP) (Figure 3).

Discussion

In this study, the UT and SA muscle activity and ratio of UT/SA during repetitive arm elevations were compared between groups with and without UTP. UT and SA muscle activity significantly increased at 10th elevation compared to 1st elevation in both groups. The result of SA muscle activity showed a significantly small increase in the UTP group. However, UT muscle activity had no significant difference between the two groups. The ratio of UT/SA had significant difference between the two groups. The group with UTP had increased UT/SA ratio compared to the group without UTP.

In both groups, the muscle activity of UT and SA significantly increased at the 10th elevation compared to the 1st elevation. This can be explained by muscle fatigue due to repetitive shoulder elevations. When muscle is fatigued, motor unit recruitment is increased to compensate for the reduced force output (Ge et al, 2012; Piscione and Garnet, 2006). Increase of motor unit recruitment means increase of EMG amplitude (Piscione and Garnet, 2006). Although we did not measure directly muscle fatigue in this study, fatigue evoked by repetitive arm elevation seemed to contribute to increased muscle activity in the UT and SA.

Muscle activity of SA was significantly decreased in the group with UTP compared to the group without UTP. Less increase in SA muscle activity in the group with UTP can be explained by the alteration of a muscle's synergistic function. UT and SA work together as scapular stabilizer. Stabilizer muscles are inhibited or weakened by direct injury, microtrauma (induced strain in the muscle), fatigue from repetitive movement, or painful conditions around the shoulder, with the SA muscles being the most susceptible to the effect of the inhibition (Kibler and McMullen, 2003). Pain in the UT and fatigue from repetitive arm elevation in this study caused SA inhibition.

The result of this study showed that the ratio of UT/SA EMG activity was significantly increased in the group with UTP. UT and SA muscle produce scapular upward rotation. Scapular upward rotation is essential to the normal shoulder biomechanics during arm elevation (Martins et al, 2008). Decreased upward rotation can cause many shoulder impairments such as subacromial impingement, subacromial bursitis, and rotator cuff tear (Ludewig et al, 2004). Previous study reported that excess activation of UT and weakened SA can result in scapular elevation motion instead of scapular upward rotation (Ludewig et al, 2004). In our study, the ratio of UT/SA was 1.6 in the 1st elevation and 1.8 in the 10th elevation in the group with UTP and about .9 and 1.0 in the group without UTP, respectively.

The ratio of UT/SA 1 means the UT and SA are balanced (Ludewig et al, 2004). However, the ratio of UT to SA was greater in the group with UTP than in the group without UTP. Our result suggests that the ratio of UT/SA might have relevance to the UTP during arm elevation.

However, the ratio of UT/SA had no significant difference between 1st elevation and 10th elevation in both groups. This result shows that the ratio of

UT/SA is not affected by the number of elevations. In other words, repetitive movement might not have association with UTP. However, our study employed only 10 times of repetitive elevations. An increased number of elevations are required in further studies.

There was no significant difference in the muscle activity of the UT between the two groups. Muscle activity in the UT in the group with UTP was greater compared to the group without UTP [27.6±13.7%MVIC (1st elevation) vs. 47.0±12.9%MVIC (10th elevation) for the group with UTP; 17.7±7.8%MVIC (1st elevation) vs. 44.7±28.5%MVIC (10th elevation) for the group without UTP]. Larsson et al (1990) reported that muscle with pain had slightly increased amplitude of EMG in the UT during muscle contraction and rest. Painful muscle had altered muscle fibers as well. Type I fibers yielded to hypertrophy and Type II fibers to ischemic loss (Bar and Barbe, 2002). Increased muscle activity during muscle contraction and rest might be caused by impaired muscle microcirculation. The damaged cell membranes due to decreased microcirculation might increase nociceptive activity. It activates the gamma muscle spindle system, which may result in increased basic muscle tonus or stiffness (Larsson et al, 1990). In this study, the UTP group had experienced UTP for more than 2 months. Chronic UTP may cause impairment of microcirculation. Slightly increased muscle activity of UT in the group with UTP can be explained by decreased microcirculation.

The limitation of our investigation should be noted. First, other related muscles that participated in the movement of arm elevation were not studied. Lower trapezius and middle deltoid were activated at arm elevation movement as well as UT and SA. However, in this study, only UT and SA were observed because SA muscle is closely linked to UT pain and activation. Second, kinematic data of scapular upward rotation was not studied. Abnormal scapular upward rotation during arm elevation caused scapular dysfunction. Therefore, it is important to study how altered UT and SA activation affect scapular kinematics. Third, the data was only collected at 1st and 10th elevation time. Further investigation require more various shoulder elevation time such as 5th or more than 10 times.

Conclusion

This study investigated the activation of UT and SA and the ratio of UT to SA during 10 times of repeated arm elevations. Our results demonstrate that the ratio of UT/SA was increased in the group with UTP during arm elevation. In clinical cases of UTP treatment, considering a decrease in the ratio of UT/SA would improve UTP.

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This article was received February 28, 2014, was reviewed February 28, 2014, and was accepted April 29, 2014.