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EFFECTS OF VARIOUS GROUND ANGLE ON SHOULDER MUSCLE ACTIVITY DURING SHOULDER PROTRACTION EXERCISE

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Abstract -The purpose of this study was to examine differences in surface electromyography (EMG) activities in *upper trapezius, pectoralis major, and serratus anterior muscles during shoulder protraction exercise with various ground angle. The research subjects included 16 healthy participants (M=10, F=6) who volunteered. All subjects were measured EMG activities in the serratus anterior, upper trapezius, and pectoralis major during performance of shoulder protraction exercise on a surface at 0° tilt, 30° tilt, 60° tilt, and 90° tilt, respectively. Statistical analysis was performed one-way analysis of variance (ANOVA). There was significant difference in the serratus anterior ($p < 0.05$). The results of post-hoc analysis showed significantly greater value of serratus anterior on a surface at a 0° tilt angle than at 60° and 90° tilt angles ($p < 0.05$). This study suggest that performance of shoulder protraction exercise on the 0°angled ground can be regarded as the best choice to strengthen the serratus anterior with healthy adults.*

KEY WORDS:*, Protraction exercise, Push-up plus, Serratus anterior, Winging scapular*

I INTRODUCTION

Normal movement of the scapular for shoulder joint consists of six motion, including, respectively, elevation, depression, retraction, protraction, downward and upward rotation[1,2]. Both the serratus anterior muscle and the upper trapezius muscle play role to stabilize the scapular to the thoracic ribcage and are performed the major

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upward rotators of the scapular[3]. During active protraction of scapular, the serratus anterior and pectoralis major muscle can be activated at the same time[4]. It is also possible that the pectoralis major may compensate for a weak serratus anterior because the pectoralis major may act as a synergist when the serratus anterior lacks power[5]. In some aspect, the excessive pectoralis major activation may elicit shoulder complex joint pathology such as decreased compression forces on the glenoid joint or forward translations of glenohumeral joint [6,7].

The serratus anterior is an important scapular stabilizer, which holds the medial border and inferior angle of the scapula against the thorax during arm elevation in order to prevent anterior tilting or winging of the scapular within them[8]. Therefore lack of strength or endurance of the serratus anterior will cause improper positioning of scapular during arm adduction, meaning that the scapular will be unable to complete upward rotation, the medial border and inferior angle of the scapular will be gradually raised into a winging scapular. Thus, the strengthening exercise of the serratus anterior is a key intervention of therapeutic programs for management and rehabilitation of winging scapulae[9]. In a state of fatigue, the serratus anterior will reduce the degree of rotation or protraction of the scapular, and will move forward or move up the humerus head and may then cause secondary subacromial impingement or tearing of the rotator cuff[10]. Therefore, weakness and abnormal muscle activation orders of the serratus anterior can cause the shoulder joint to diverge from the normal scapulohumeral rhythm, causing the dysfunction of shoulder joint[11].

Previously, shoulder and scapular movement abnormalities were attributed to the overall weakening of strength of the scapulothoracic musculature[12]. But now there is an increasing tendency to think that shoulder pathology and abnormal scapular motion may be linked to imbalances of shoulder muscle activity rather than global weakness of the scapulothoracic musculature[12,13]. In order to improve the imbalance, this study attempted to recruit subjects to perform the shoulder protraction exercise on a surface at four different tilt angles.

II MATERIAL AND METHODS

Subjects

The research subjects included 16 healthy participants (M= 10, F=6) attending Daegu University in South Korea. The characteristics of subjects were mean age of 23.38 ± 1.78 years, mean height of 170.63 ± 7.78 cm, and

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a mean weight of 56.88 ± 10.45 kg. The exclusion criteria were past or present musculoskeletal conditions affecting the shoulder joint, rotator cuff muscles, or winging scapulae. All the subjects volunteered to take part in the study and provided written informed consent. The study was approved by the Daegu University Institutional Review Board.

Instruments

Muscle activity during the shoulder protraction exercise was collected via the wireless surface electromyography (EMG) system (TeleMyo DTS, Noraxon Inc., Scottsdale, AZ, U.S.A.). The inclined plate was made with wood. As a tool for the experiment, the wooden plate was constructed by the right triangle shape with 30°, 60°, and 90° tilt angle (Figure 1).

Figure 1: Shoulder protraction exercise on four surfaces

Outcome Measures

Surface EMG was used to measure each muscle activity, and electrodes were attached to the serratus anterior, the upper trapezius and the pectoralis major which was located on the chest wall horizontal from the arising muscle mass. The root-mean-square (RMS) values of EMG data were calculated to quantify the amplitude of EMG signals, which used 3 s of the 5 s of EMG data for the three muscles, excluding the initial and final 1 s. To normalize EMG activity, the maximal voluntary isometric contraction (MVIC) activity was measured for the tested muscles. The average EMG activity was expressed as a percentage of the MVIC value (%MVIC).

Procedures

The subjects performed shoulder protraction exercises on a surface at four different tilt angles (0°, 30°, 60°, and 90° tilt angle). As a starting position, the subjects placed their hands and feet apart at shoulder width, and then, placed their head, trunk, and hip in a straight line, and maintained this position for five seconds (Fig 1). Each subject repeated the motion three times.

Statistical Analyses

The data were indicated as mean ± standard deviation. One-way analysis of variance (ANOVA) was used for analysis of the data for comparison of differences in the activities of the upper trapezius, pectoralis major, and serratus anterior as well as the ratio of serratus anterior/upper trapezius during performance of the shoulder protraction exercise on a surface at four different tilt angles. Post-hoc analysis was performed by Bonferroni. Statistical analyses were performed using SPSS for Windows (ver. 22.0), and the statistical significance level was set at $p < 0.05$.

III RESULTS

There was significant difference in the serratus anterior ($p < 0.05$)(Table 1). The results of post-hoc analysis showed significantly greater value of serratus anterior on a surface at a 0°tilt angle than at 60° and 90° tilt angles ($p < 0.05$)(Figure 2). There were not significant difference in the upper trapezius and pectoralis major ($p > 0.05$)(Table 1).

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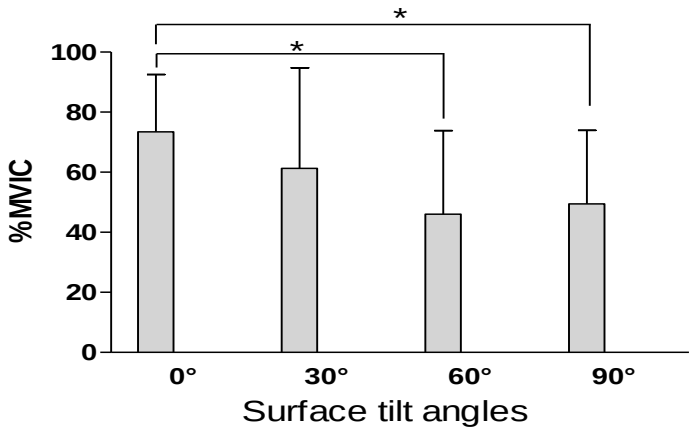

Figure 2: Comparison of serratus anterior muscle activities on four surfaces

Table 1: Muscle activities according to surface tilt angle (N=16)(Unit: %MVIC)

Muscles	0°	30°	60°	90°	F	*p*
UT	7.87±5.50[a]	6.13±4.78	5.28±4.98	5.70±4.05	0.878	0.458
PM	21.68±8.53	19.26±7.40	16.78±7.74	15.14±8.37	2.032	0.119
SA	73.48±13.45	61.32±23.66	46.05±19.68	49.47±17.29	6.962	0.000*

[a]Mean±standard deviation, *p<0.05

UT: upper trapezius, PM: pectoralis major, SA: serratus anterior,

IV DISCUSSION

In this study, motor processes were implemented on a stable surface at all tilt angles. This is according to Piraua's study (2014), which concluded that performance of the push up exercise on an unstable surface may be more favorable to producing higher levels of upper trapezius activity and lower levels of serratus anterior activity. However, if the goal of the exercise program is the strengthening of the serratus anterior, performance of the push up exercise on a stable surface was suggested[15]. In addition, in this study muscle activities were measured only in plus phase. This is because performance of push-up plus exercise during the plus phase emphasized scapular rotation and protraction and elicited the greatest serratus anterior activity[4]. The results of this study demonstrated high

activation of the serratus anterior during shoulder protraction exercise, and were in agreement with those of previous studies for winging scapulae[16].

The upper trapezius and pectoralis major activity was not significantly changed according to surface tilt angle. The most plausible explanation for this result was that horizontal abduction position was maintained during performance of shoulder protraction exercise, so that the pectoralis major was considered to have some activity throughout the entire process regardless of the angle.

However, the limitations of this study should be noted. First, both the trapezius muscle and the serratus anterior have upper, middle, and lower portions, but, in this study, we only placed electrodes on their upper portions. And the restricted age range (19 to 26) of our subjects was not representative of other ranges outside this age group. Future studies may wish to consider additional muscle groups, larger subject samples with a broader age range, and a broader sample of clinical patients.

According to the results, this study found that performance of the shoulder protraction exercise on a surface at a 0° ground angle would achieve maximum activation of the serratus anterior. Therefore, performance of shoulder protraction exercise on a surface at a 0° ground angle can be regarded as the best choice for the winging scapular.

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Conflicts of interest: The authors declare no conflicts of interest.

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