The Effects of Angle and Scale of Resistance during Scapular Protraction on Shoulder Muscle Activation

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Purpose This study was performed to determine the activity of the serratus anterior (SA), the upper trapezius (UT) and the lower trapezius (LT) muscles along the angles(20°, 0°, −20°) and scales(50%, 65%, 80% of 1RM) of resistance during scapular protraction. ***Methods*** Thirty-three health subjects with no medical history of spine, upper extremity and hand disorders were recruited for this study. Subjects performed scapular protraction at 20°, 0°, −20° angles of resistance with 50%, 65%, and 80% of 1RM scales of resistance in standing position. Muscular activation were measured by surface electro myography (EMG). A 3 (angles) × 3 (scales) two-way analysis of variance (ANOVA) was used to compare the normalize activities of the serratus anterior, the upper trapezius and the lower trapezius muscles. ***Results*** Only in the lower trapezius muscle became different significantly according to angles ($p<.05$) during the scapular protraction. The serratus anterior, the upper trapezius and the lower trapezius muscles became different significantly according to scales ($p<.05$). The shoulder muscles between angles and scales did not show significant difference during the scapular protraction ($p>.05$). ***Conclusion*** Based on the results of this study, using the shoulder muscles activity according to the angles and scales of resistance, by apply an optional exercise for each shoulder muscles may be used to for patients with the shoulder impingement syndrome by the insufficient scapular protraction and upward rotation by shoulder muscles imbalance.

Key words Shoulder Protraction, 1RM, Serratus Anterior, Upper Trapezius, Lower Trapezius

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I. Introduction

In a daily activity, upper extremities not only carry out exquisite tasks such as washing, writing, eating and putting on clothes, but also crawling, walking, balance and protective reaction is a very important role.[1] For the normal movement of upper extremity, scapular and shoulder muscles strength, recruitment pattern, muscle length is important.[2] Shoulder muscles conduct scapular movement, in order to minimize the stress to the glenohumeral joint, the optimal relationship must be maintained between the humerus and the scapular.[3] However, the imbalance of shoulder muscle activity appears by weakness, shortness, trauma, repetitive overhead work and pain.[4] The imbalance of shoulder muscles activity is restricted to scapular movement, damaged normal scapular humeral rhythm, and decreased rom of shoulder joint. As a result, shoulder impingement syndrome (SIS) occurs the upward rotation of the scapular is limited.[5] In order to decrease the incidence of SIS, scapular stabilization and restoration of normal movement are important, at this time, trapezius and serratus anterior (SA) are most important role.[4, 6-8] Among them, the Weakness of lower trapezius(LT) was affect scapular movement, it has been act to dysfunction of shoulder joint and cause of problem, it is necessary for normal posture control and normal function of shoulder joint. Also, the excessive activation of UT is decreased activity of the LT and the SA, has been cause of shoulder joint pain. For treatment of SIS, Promote the activity of muscle weakness, and is relatively strong for inhibiting muscle exercise is necessary.[8)] Recently, there are way to restore the function of shoulder muscle, Dynamic hug exercise[9)], Overhead shoulder flexion [10)], Push up plus exercise[11)], wall Push up exercise[12)], Isometric exercise[13)]. Specifically, the various push up plus exercise is being studied for control of imbalance between SA and UT.[11, 14)] Such as Standard push-up[15)], Knee push-up[9)], Knee & elbow push-up[11, 16)], Wall push-up plus[17)] modified Push up plus and push up plus according to surface is being studies.[18-20)] However, initial SIS patients were caused more shoulder pain as increased shoulder flexion.[3)] Because, Decker, Hintermeister[9)] was proposed to conduct the selective rehabilitation exercise(push-up plus, knee push-up plus, press-up, shoulder extension, serratus anterior punch, forward punch, scaption, dynamic hug) below 90°. Ludewig, Hoff[11)] was reported that the early stage of shoulder rehabilitation was difficult to perform the standard push-up plus exercise because greater load exerted on the shoulder joint. Also, Lunden, Braman[17)] was reported that wall push up plus exercise might result in increased risk for SIS. Previous studies of shoulder muscle activation, Hardwick, Beebe[12)] was compared of shoulder muscle activation at push-up plus, wall slide and scapular plane shoulder elevation. Talbott and Witt[21)] were compared of serratus anterior activation by ultrasound imaging at rest, during an active holds and while holding a three pound weight. Thus, exercise posture, method, shoulder flexion angle or constant resistances have been studied for analyzing shoulder muscle activation. However, no previous studies have investigated effect of angles and scales of resistance during scapular protraction on shoulder muscle activation. Therefore, the purpose of this study was to determine the effect of angles and scales of resistance during scapular protraction on shoulder muscle activation, to provide basic information that is helpful when providing shoulder muscle imbalance treatment. Our hypotheses were as follows. First, the angles of resistance will affect the shoulder muscles activation. Second, the scales of resistance will affect the shoulder muscles activation.

II. Materials and Methods

1. Participants

Thirty-three health subjects participated in this study (age 29.96±4.01years, weight 73.75±12.64kg, height, 174.25±4.63cm). Who worked myongji hospital in Goyang-si, Gyeonggi-do and Incheon hospital in Incheon, South Korea. All subjects were right handed and with no medical history of spine, upper extremity and hand disorders. Participants were required to sign an information and informed consent form, upon becoming well-acquainted with the content and method.

2. Study design

This study was performed to determine the activation of shoulder muscles along the angles(20°, 0°, −20°) and scales 50% for muscular endurance, 65% for muscular hypertrophy, 80% for muscular strengthening on 1RM of resistance during scapular protraction.[25)] In this study unlike previous studies, the resistances were applied of 1RM by based on subject. All subjects practiced a minimum load until they were familiar performing the scapular protraction and then gradually increased the load <Figure 1>. To reduce the error occurrence, it was instructed to select the appropriate

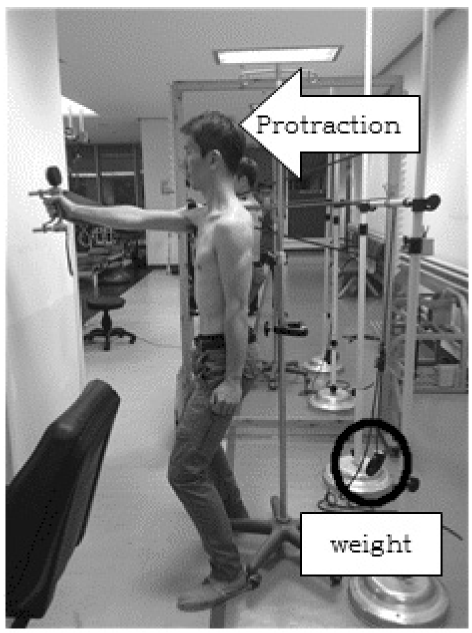

Figure 1. Measuring 1RM

Table 1. Definition of 1RM

$1RM = W + (W \times 0.025 \times R)$

Note 1RM: One Repetition Maximum; W: Weight; R: Repetition (26)

weight to a small number. The result of count and weight were applied indirect formula for 1RM <Table 1>. The angles of resistance were controlled by height control bar. Also, it used mirror of marked 20, 0, -20 angles for guideline.[27] Subjects were instructed to standing front of height-control bar. The knee joint was slightly bending, and the feet were positioned shoulder-width with the toes indicating forward. Subjects were holding the line on hand, at each angles and scales of resistance were conducted scapular protraction. Following the "start" cue, each action was maintained for 10 seconds and the action was repeated 3 times. It were randomized during a single session. The rest time between each action was 2 minute.[2]

3. Outcome Measures

Electromyographic (EMG) recordings of the serratus anterior (SA), the upper trapezius (UT) and lower trapezius (LT) were performed using a Trigno wireless system (Delsys, Boston, MA, USA). The sampling rate was 2000 Hz; the band-pass filter was 20-500 Hz. Raw data for the shoulder muscles were processed into root-mean square (RMS) data.[22] Before placing electrodes, the skins were shaved and cleaned using alcohol cotton to reduce skin resistance. The electrode placements for the shoulder muscles were as follows: SA, below the axilla, anterior to the latissimus, placed vertically over the ribs 4~6; UT, at the angle of the neck and shoulder, over the belly of the muscle in line with the muscle fibers; LT, 5cm down from the scapular spine, next to the medial edge of the scapular at 55° oblique.[9, 18, 23] To normalize EMG data, subjects performed maximal voluntary isometric contractions (MVIC) of the SA, UT and LT against manual resistance using previously study[10, 24]. The SA MVIC was performed with shoulder flexed to 125° as resistance is applied above the elbow and at the inferior angle of the scapula attempting to de-rotate the scapula with the subject sitting in an erect posture with no back support. The UT MVIC was performed with shoulder abducted to 90° with the neck first side-bent to the same side, rotated to the opposite side, and then extended as resistance is applied at the head and above the elbow with the subject sitting in an erect posture with no back support. The LT MVIC was performed with arm raised above the head in line with the lower trapezius muscle as resistance is applied above the elbow with the subject in the prone position. The EMG signals were recorded while the test was being measured, and the first and last seconds of the 5-second measurement were deleted. The EMG signals of the middle 3 seconds were used in %MVIC. The electromyogram signals were converted to root mean square (RMS) values.

4. Statistical analysis

Data are expressed as means±SD. significant differences among the three angles (20, 0 and −20) and three scales (50%, 65% and 80% of 1RM) were examined using a 3 × 3(angles×scales) repeated-measures analysis of variance (ANOVA). Data were analyzed using the SPSS software (ver. 20.0; Chicago, IL, USA), and the significance level was set at $p < 0.05$.

III. Results

The serratus anterior EMG activity during scapular protraction is shown <Table 2>, <Figure 2>. A significant main effect of scales (between 50% and 65%, 65% and 80%) of resistance was observed ($F = 11.530$, $p < .05$), but no significant main effect of angles of resistance was found ($F = 201$, $p = .818$). No significant angles x scales of resistance interaction was found ($F = .535$, $p = .710$) <Table 3>. The upper trapezius EMG activity during scapular protraction is shown <Table 2>, <Figure 3>. A significant main effect of scales (between 50% and 80%, 65% and 80%) of resistance was observed ($F = 38.502$, $p < .05$), but no significant main effect of angles of resistance was found ($F = 239$, $p = .787$). No significant angles x scales of resistance interaction was found ($F = .159$, $p = .959$)

Table 2. Muscle activities of shoulder muscles

(%MVIC) (N=32)

Angles	Scales of 1RM	SA	UT	LT
		Mean±SD	*Mean±SD*	*Mean±SD*
0°	50%	758.59±1025.20	116.33±98.81	59.15±65.98
	65%	400.38±295.27	72.74±55.15	53.60±61.19
	80%	779.14±652.45	297.55±228.70	112.18±93.93
20°	50%	715.81±773.71	139.39±144.55	89.60±92.22
	65%	454.02±340.26	92.86±101.64	73.86±107.29
	80%	846.70±606.32	287.19±243.35	147.77±117.29
−20°	50%	565.12±443.23	131.40±128.13	98.94±105.95
	65%	375.55±365.82	109.14±99.76	110.12±126.28
	80%	903.61±853.08	296.12±292.24	184.12±119.63

Note. SA: serratus anterior; UT: upper trapezius; LT: lower trapezius , 1RM: one repetition maximum

Table 3. Two-way ANOVA results with angles and scales as factors in shoulder muscles

(N=32)

Muscle Source	SA		UT		LT	
	F	P	F	P	F	P
Angles	.201	.818	.239	.787	7.632	.001*
Scales of 1RM	11.530	.000**	38.502	.000**	14.603	.000**
Angles × Scales of 1RM	.535	.710	.159	.959	.306	.874

Note. SA: serratus anterior; UT: upper trapezius; LT: lower trapezius
1RM: one repetition maximum
*Statistically significant at the level of p<. 05
**Statistically significant at the level of p<. 001.

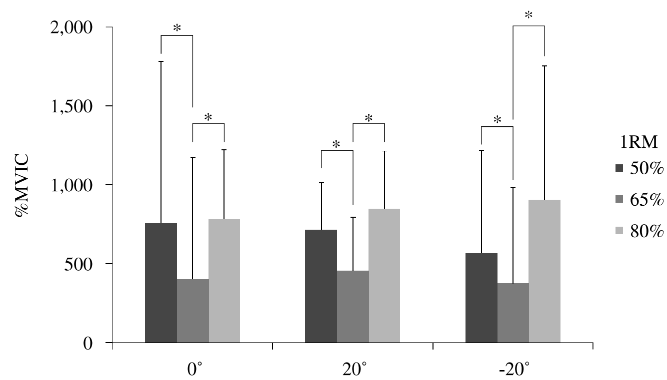

Figure 2. Comparison of the serratus anterior (a), upper trapezius (b), lower trapezius(c) activity according to the resistance angles and scales

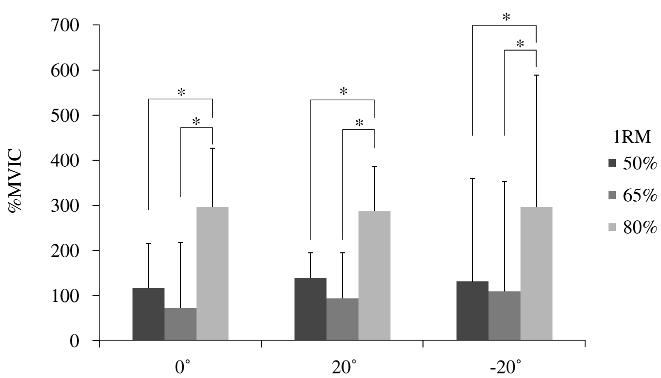

Figure 3. Comparison of the upper trapezius activity according to the resistance angles and scales

<Table 3>. The lower trapezius EMG activity during scapular protraction is shown (Table 2), <Figure 4>. In both conditions, it was confirmed that significant differences. In scales (between 50% and 80%, 65% and 80%) was significantly observed (F =14.603, p < .001), in angles was significantly observed (F = 7.632, p < .05). No significant angles x scales of resistance interaction was found (F = .306, p = .874) <Table 3>.

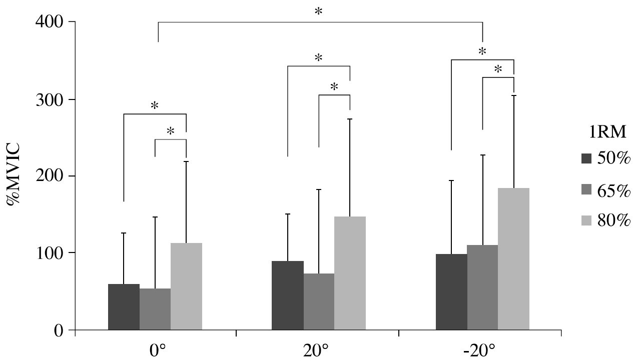

Figure 4. Comparison of the upper trapezius activity according to the resistance angles and scales

IV. Discussion

This study was performed to determine the activity of the serratus anterior (SA), the upper trapezius (UT), the lower trapezius (LT) muscles along the angles(20°, 0°, −20°) and scales 50% for muscular endurance, 65% for muscular hypertrophy, 80% for muscular strengthening on 1RM of resistance during scapular protraction. Usually, imbalance of the shoulder muscles changes the position of the scapula resulting in dysfunction of the shoulder joint.[3] Sahrmann[3] and Kibler, Sciascia[28] indicated that the couple force of the UT, LT and SA muscles plays important role when rotation of the scapula upwards. So if the muscle balance undergoes any changes, the scapula movement changes. Hence, balancing of the shoulder muscles through selective strengthening for weakened muscles is an essential management for normal movement. Previous studies were suggested that applied shoulder flexion angle and constant weight during scapular protraction for the selective strengthening of shoulder muscle. But there are no research suggested an effective exercise method through analysis of muscle activation based on the resistance angle and 1RM.

The results of this study show that only in the lower trapezius muscle became different significantly according to angles ($p<.05$) during the scapular protraction. The serratus anterior, the upper trapezius, the lower trapezius muscles became different significantly according to scales ($p<.05$) during the scapular protraction. The shoulder muscles between angles and scales did not show significant difference during the scapular protraction ($p>.05$). As a result, scales and angles is independent variable. Hardwick, Beebe[12] mentioned that the SA activation was not significantly different between push up plus, wall slide and scapular plane shoulder elevation exercises at 90°of shoulder flexion. During the wall slide and scapular plane shoulder flexion exercises, SA activity was increased according to increasing of shoulder flexion angle. But there was no significant difference between the two exercises. Koh, Weon[29] investigated the comparison of electromyographic ratio of SA and UT according to exercise position (supine, standing) and Shoulder Flexion Angle (90°, 130°) during Scapular Protraction. In this study also SA activation increased with increasing shoulder flexion angle. our study of applied for different angles during shoulder protraction on shoulder flexion 90° was not match previous study, but it was significant difference the SA activation according to scales of resistance. It was identical with our study. This is because muscle contraction of SA increase to keep the shoulder protraction about external resistance. It could be confirmed similar results in studies of Talbott and Witt[21] and Kim, Lee[30] which identified of increases to the thickness of SA by providing resistance on the shoulder flexion posture. Hardwick, Beebe[12] and Koh, Weon[29] study was conducted certain weight, it is not based on the 1RM. Therefore, it cannot find different of muscle activation about resistance. But our study confirmed differential of SA activation about resistance between 50% and 65%, 65% and 80% of 1RM. In previous studies of the trapezius of Ekstrom, Donatelli.[10] The shoulder horizontal extension with external rotation in the prone position was found to produce the greatest EMG activity in the upper trapezius, the middle trapezius and the lower trapezius muscle. It could be explained that shoulder muscle play a role of agonist and antagonist during shoulder abduction. Moon, Kim[27] study of comparison of the serratus anterior activation according to the shoulder flexion angles for healthy subject. The UT activation was no statistical difference according to shoulder flexion angles and exercise method. On the other hand, there were significant differences in muscle activity in 80% of 1RM to the resistance in this study. Sahrmann[3] was announced that excessive activity of UT is inhibited to stabilize the scapular. However, at this study, when applied 80% of 1RM resistance the ratio in UT/SA at 0°297%MVIC/779%MVIC, at 20°of 287%MVIC/846% MVIC, at −20°296%MVIC/903%MVIC, because activation of SA higher than UT. It is difficult to see that hinder the stability of the scapula. It also should be caution when applies to the person who have problems with shoulder impingement syndrome and shoulder muscles. The greatest EMG activity in the lower trapezius muscle on −20° of resistance with 80% of 1RM was founded. Cools, Witvrouw[31] studied for healthy subject and SIS patients during scapular protraction with shoulder abduction 90°. In the study, the LT activation was higher the healthy subject than the SIS. In this study, the activity of the trapezius was experiencing significant difference. It was considered that the shoulder stabilizer muscles activation increasing for normal shoulder movement about trunk when provide resistance on scapular protraction, The scapular protraction with shoulder abduction 90°, it is similar to the open chain exercises were deliver instability to the shoulder joint, such as the MT, LT and SA of a compensatory mechanism for the weight of gravity and arm, was acted as a stabilizing muscles for scapular.[32] As a result, the scapular protraction is operated in anti-gravity posture, the agonist muscles has been able to confirm a significant change in resistance than the angle. Especially, the LT of antagonist has been able to confirm a significant change in both resistance and angle. The limit of this study is a follows. First, the subject of this study were health adult, hence there are some difficulties in generalizing the results to patients. Second, when measured of the maximum voluntary isometric contraction, manual resistance could not be objectively applied. Third, the study was conducted in a standing position, it could not limit the use of other muscles. Thus, future study will be conducted more subject, provide to objective resistance and limit the use of other muscles.

V. Conclusion

This study shows statistically significant along the angles and scales of resistance during scapular protraction. Only in the lower trapezius muscle became different significantly according to angles (p<.05) during the scapular protraction. The serratus anterior, the upper trapezius and the lower trapezius muscles became different significantly according to scales (p<.05). Based on the results of this study, when conducted to the shoulder muscles activation according to the angles and scales of resistance, the optional exercise for each shoulder muscles may be used to for patients with the shoulder impingement syndrome by the insufficient scapular protraction and upward rotation by shoulder muscles imbalance.

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