Research Report

JMST

Comparison of Electromyographic Activity of the Lower and Upper Trapezius during Different Strengthening Exercises

Min-joo Ko, PT, PhD[1]; Jae-seop Oh, PT, PhD[2]

[1]Department of Exercise Prescription Center, HSD Engine, Changwon, Gyeongsangnam-do, South Korea
[2]Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University, Gimhae, Gyeongsangnam-do, South Korea

Background Force imbalances of the upper trapezius (UT) and lower trapezius (LT) can occur abnormal scapular motion.

Purpose To investigate the most effective intervention of specifically activating the LT muscle while decreasing UT muscle activity by comparing the muscle activity generated during four different exercises.

Study design Cross-sectional study

Methods 15 healthy male were recruited for this study. Surface electromyographic data were recorded from the upper trapezius and lower trapezius muscle of the dominant side while performing four different exercises: modified prone cobra, prone V-raise, wall slide exercise, and backward rocking diagonal arm lift. The results were analyzed using one-way repeated ANOVA.

Results The LT and UT muscle activities and LT/UT ratio were significantly different among the four exercises ($p<0.05$). LT muscle activity was greatest during the backward rocking diagonal arm lift and not significantly different from that during the prone V-raise ($p>0.05$). The LT/UT ratio was also greatest during the backward rocking diagonal arm lift and was not significantly different from that during the modified prone cobra ($p>0.05$). The UT muscle activity was significantly lower during the modified prone cobra than during the other exercises ($p<0.001$), followed by the backward rocking diagonal arm lift.

Conclusions The backward rocking diagonal arm lift should be considered effective as a exercise for the LT muscle while decreasing UT muscle activity. A scapular posterior tilt should be confirmed during exercise testing.

Key words Electromyography; Lower trapezius; Selective muscle activation; Upper trapezius.

J Musculoskelet Sci Technol
2023; 7(1): 40-47
Published Online
Jun 30, 2023
pISSN 2635-8573
eISSN 2635-8581

Article History
Received 31 Mar 2023
Revised 20 Apr 2023 (1st)
Revised 18 May 2023 (2nd)
Accepted 23 May 2023

CONTACT
ysrehab@inje.ac.kr
Jae-seop Oh, Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University, Gimhae, Gyeongsangnam-do, South Korea

INTRODUCTION

The trapezius muscle acts as an important dynamic function in creating and supporting functional activities in the shoulder complex.[1] The upper trapezius (UT) acts to draw the acromion, clavicle, and scapula spine posteriorly and medially[2] and to extend the neck and elevate the scapula.[3] Other authors have suggested that the primary function of the lower trapezius (LT) is scapular depression, adduction, thoracic rotation, and extension.[3] The LT is considered as an important muscle for the maintaining proper posture alignment and glenohumeral function. However, force imbalances of the UT and LT can occur abnormal scapular motion.[4]

The force imbalances result in subacromial impingement and rotator biceps tendonitis or cuff, which can alter acromioclavicular joint forces, and tend to degenerative changes.[4] Cools et al.[4] demonstrated that excessive UT activity combined with decreased LT activity cause abnormal scapular motion, which may result in subacromial impingement syndrome. Increased UT activity is generally accepted to contribute to subacromial impingement,[4-9] but inconsistent findings with regard to LT activity have been reported in these patients. Consequently, minimizing muscle activity of UT with selective LT activity would be advantageous.

Although isolating muscle is a fundamental principle for manual muscle testing,[3] little evidence is available to determine the ideal method to assess or increase the strength of the LT muscle, which isolated from the other part of the trapezius muscle. Representative exercises include the modified prone cobra, wall slide exercise, prone V-raise, and backward rocking diagonal arm lift.[10-11] The prone V-raise is used by physical therapists while manual muscle testing of the LT muscle.[3] Garcia et al. suggested that wall slide exercise produces the highest peak EMG for the lower trapezius than the other exercises.[12] Among five different exercises, Arlotta et al.[13] reported that the modified prone cobra is the most effective exercise to targeting strengthening of the LT muscle. Ha et al.[11] showed that the backward rocking diagonal arm lift showed significant greater activity in the LT muscle compared to the other exercises.

Therefore, the primary aim of this study was to compare the UT and LT muscle activities while four exercises using the method described by Kendall et al.,[3] and three other positions, which are the common clinical envirmonment.[11-13] We hypothesized that the LT and UT muscle activities would be differ among the four specific exercises. If the most beneficial exercise are identified for activating the LT muscle, more effective rehabilitative program will be designed by clinicians.

METHODS

Subjects

Fifteen healthy male subjects were recruited for this study (age: 23.6±1.9 years, height: 174.5±4.3 cm, weight: 68.5±8.9kg). The inclusion criteria were able to easily perform full flexion, full abduction, and full scaption; and levator scapulae, pectoralis minor, and rhomboid muscles within the normal length determined using the muscle length test.[14-15] The exclusion criteria were (1) shoulder surgery or current shoulder pain (2) history of musculoskeletal, neurological, or cardiopulmonary disease. Prior to the experiment, the investigator explained the procedure to the subjects, and all subjects provided written informed consent. This study was approved by the institutional review board of Inje University (No. 2022-04-044-001). The estimation of sample size was calculated with G*Power 3.1.9.7 for Windows (University of Dusseldorf, Dusseldorf, Germany). Power analysis determined that at least 15 subjects were required to obtain a power of 0.8, and significance level of .05.[16]

Instrumentation

Before electromyography (EMG), we performed a test to determine the dominance of the arms; the dominant arm was defined as the throwing side during sports performance.[17] A Trigno wireless EMG system (Delsys, Inc., Boston, MA, USA) was used to assess the muscle activity of the dominant UT and LT. The EMG signals were sampled at 1,000 Hz with a 20-450 Hz bandpass filter. The raw EMG data were converted to root mean square data. The electrodes of the UT and LT muscles were placed in accordance with Criswell.[18] The each electrode site was shaved and cleaned to decrease skin impedance. For normalization, the maximum voluntary isometric contraction (MVIC) of the muscles was measured using method presented previously.[19] The MVIC trials were carried out three times for 5 s, and middle 3 s of three trials was used to obtain steady-state results. All EMG data during four specific therapeutic exercises are expressed as percentages of the MVIC (%MVIC).

Procedures

After attaching the electrodes, all participants performed the modified prone cobra, wall slide exercise, prone V-raise, and backward rocking diagonal arm lift. Subjects were asked performing three trials of four different exercises considered to effectively activate the fibers of the LT muscle. Before testing, several practice trials were performed to familiarization with the exercises. The exclusion criteria were those who could not do requested exercise, but all participants carried out all the exercises correctly. All exercises remained isometric contraction for 5 s while data were recorded, with a minimum of 30 s of rest between contractions. The order of the exercises was randomized among participants. The four exercises were as follows:

1) Modified prone cobra[12]: The participant was lying face down on the floor with his arm side and his fingers pointing toward his toes. The individual performed trunk extension, to raise his chest approximately 10 cm off the floor. Then, the participant pulled shoulder blades back and down with thumb facing the ceiling as if the fingertips were toward the feet (Figure 1).

2) Wall slide exercise[11,15,20]: The participant stood facing a wall with the wall from nose to knees with feet shoulder-width apart. Then, the ulnar border of the forearms contacted the wall with shoulder 90° abduction and elbow 90° flexion. The subject was sliding his arms against the wall. The sliding motion was ended until the shoulder 145° ab-

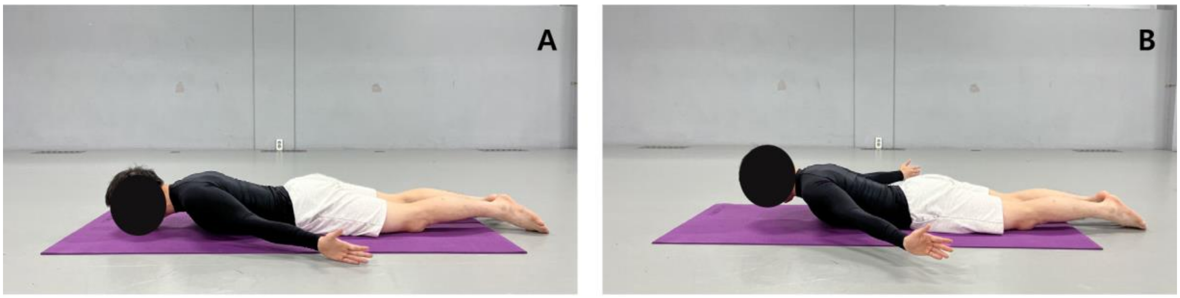

Figure 1. Modified prone cobra. (A) starting position; (B) end position.

duction. Then, the subject lifted both hands with the elbows extended and remained the arm position (Figure 2).

3) Prone V-raise[3,21]: The participant was lying face down on the floor with shoulder 180° flexion at a shoulder 120° abduction and with elbows extended. The participant lifted off his arms from the floor to ear level with thumbs pointing toward the ceiling (Figure 3).

4) Backward rocking diagonal arm lift[11]: The subject was instructed to performing the quadruped position and then rocking backward. The investigator abducted the subject's shoulder to 145° and instructed the subject lifting the dominant arm with the elbows extended up to his shoulders flexed to 180° (Figure 4).

Statistical analysis

The EMG activation recorded from the LT muscle relative to that recorded from both the LT and UT muscles was computed for each trial using the following equation:

$$\text{LT/UT ratio (\%)}=\text{EMG(LT)}/(\text{EMG(LT)}+\text{EMG(UT)})\times 100,$$

Perfect LT/UT ratio of the lower trapezius muscle (LT/UT ratio = 100%) would result when there was no activity of the upper fibers of the trapezius muscle during an exercise.

A one sample Kolmogorov-Smirnov test was used to investigate the normality of the distribution of the EMG. A one-way repeated-measures analysis of variance (ANOVA) was used to test for differences in the UT and LT muscle

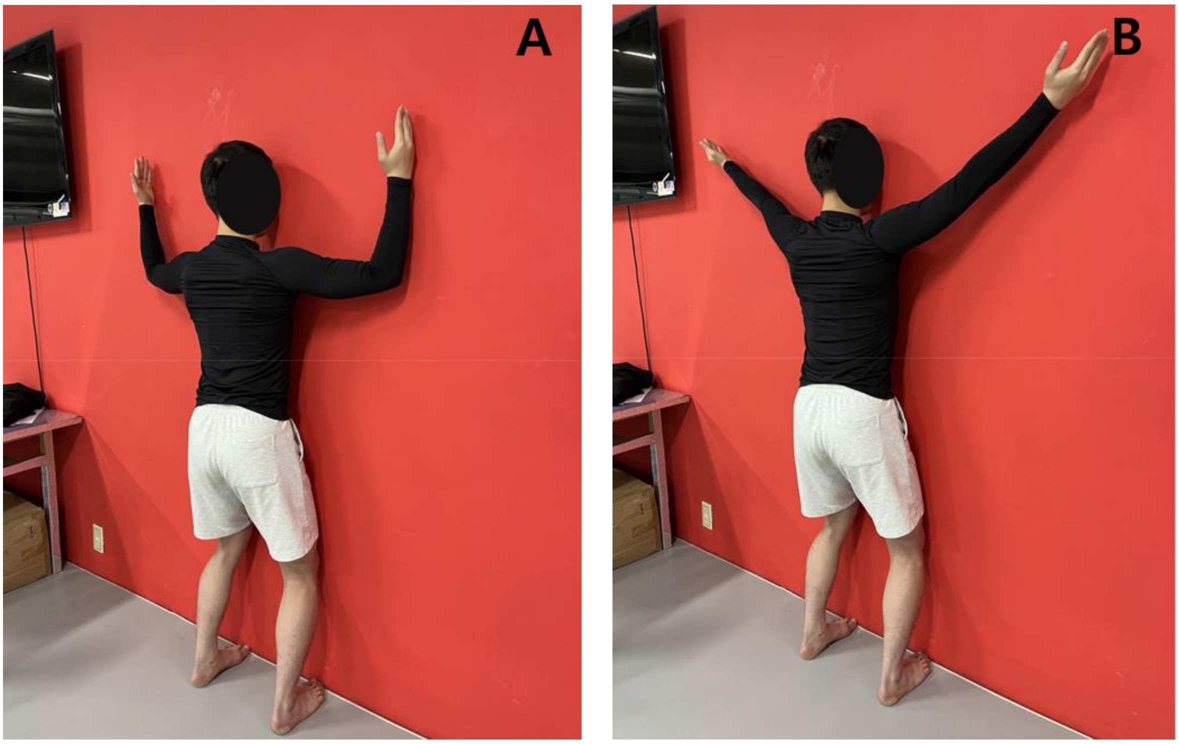

Figure 2. Wall slide exercise. (A) starting position; (B) end position.

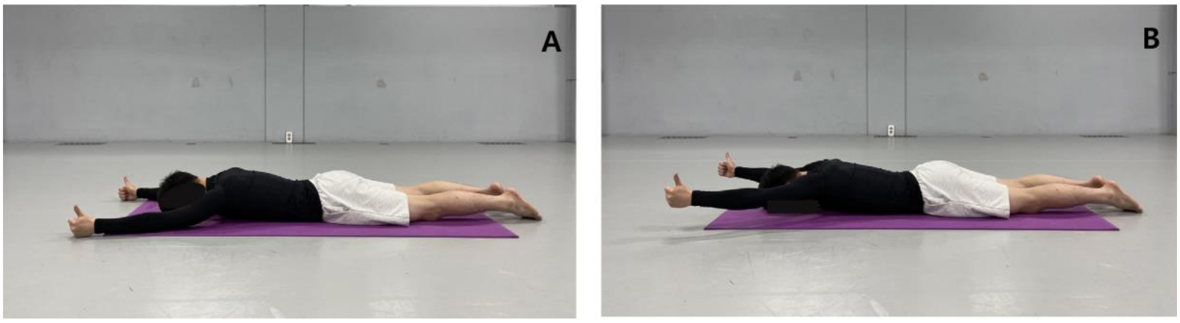

Figure 3. Prone V-raise. (A) starting position; (B) end position.

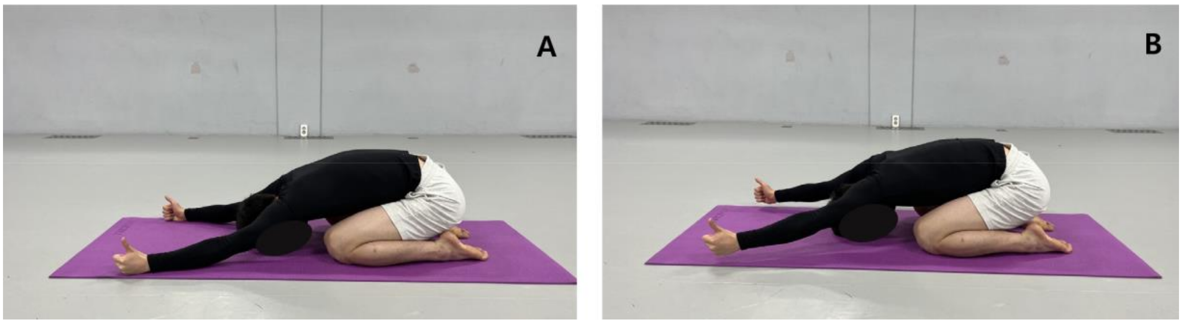

Figure 4. Backward rocking diagonal arm lift. (A) starting position; (B) end position.

activities and LT/UT ratios among the four exercises. Significant main effects were followed up using the Bonferroni post hoc test. All statistical analyses were conducted with SPSS Statistics version 18 (SPSS Inc., Chicago, IL, USA), and $\alpha < .05$ was taken to indicate statistical significance. If a significant interaction was found, the Bonferroni correction was set at .017 (.05/3) at a statistically significant level.

RESULTS

In this study, 15 healthy male subjects were recruited without missing data. The dominant arm of all subjects was the right. The results of statistical analyses are shown in Table 1. UT muscle activity was significantly lower during the modified prone cobra than during the other exercises ($p<.001$), followed by the backward rocking diagonal arm lift (Figure 5). LT muscle activity was significantly greater during the backward rocking diagonal arm lift than the wall slide exercise ($p<.001$) or modified prone cobra ($p<.001$), and was not significantly different from that during the prone V-raise ($p=1.000$) (Figure 6). The LT/UT ratio was significantly greater during the backward rocking diagonal arm lift than during the wall slide exercise ($p<.001$) or prone V-raise ($p<.001$), and was not significantly different from that during the modified prone cobra ($p=1.000$) (Figure 7).

DISCUSSION

We investigated UT and LT muscle activity during four specific therapeutic exercises. LT muscle activity was sig-

Table 1. Muscle activity and ratio on various exercises

Variables	Mean±SD				*p* value
	Modified prone cobra	Wall slide exercise	Prone V-raise	Backward rocking diagonal arm lift	
Upper trapezius (%MVIC)	7.40±6.54	40.43±13.01	48.39±21.03	26.13±12.83	<.001*
Lower trapezius (%MVIC)	18.28±9.30	18.86±9.10	57.16±18.90	53.49±18.53	<.001*
LT/UT ratio (%)	71.47±12.00	31.28±9.27	54.65±12.10	68.12±9.70	<.001*

MVIC, maximal voluntary isometric contraction; LT, lower trapezius; UT: upper trapezius. * $p<.05$.

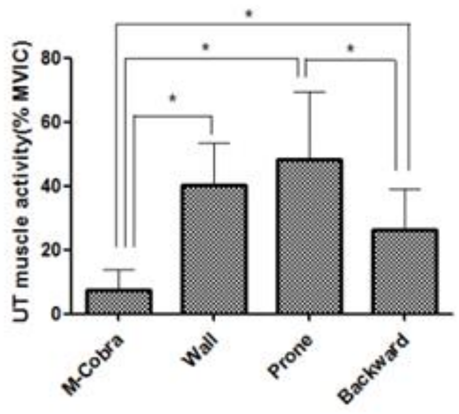

Figure 5. Upper trapezius (UT) muscle activity on different exercise (M-cobra: modified prone cobra, Wall: wall slide exercise, Prone: prone V-raise, Backward: backward rocking diagonal arm lift).

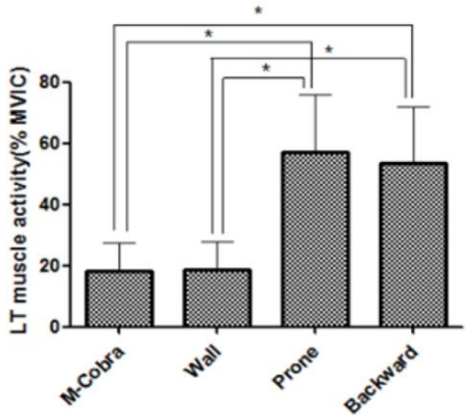

Figure 6. Lower trapezius (LT) muscle activity on different exercise (M-cobra: modified prone cobra, Wall: wall slide exercise, Prone: prone v-raise, Backward: backward rocking diagonal arm lift).

nificantly greater during the backward rocking diagonal arm lift than during the wall slide exercise or modified prone cobra, and was not significantly different from that during the prone V-raise. The LT/UT ratio was significantly greater during the backward rocking diagonal arm lift than during the wall slide exercise or prone V-raise, and was not significantly different from that during the modified prone cobra. Finally, UT muscle activity was significantly lower during the modified prone cobra than during the other exercises, followed by the backward rocking diagonal arm lift.

LT muscle activity was significantly greater during the backward rocking diagonal arm lift than during the wall

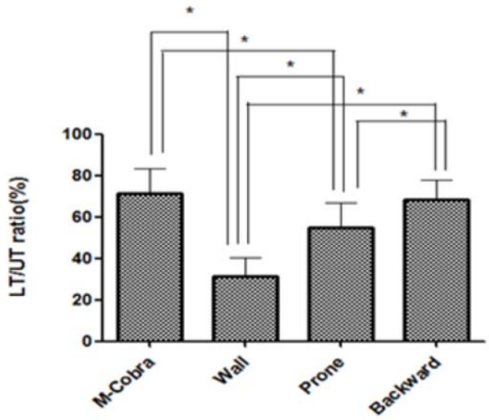

Figure 7. Lower trapezius (LT)/upper trapezius (UT) muscle ratio on different exercise (M-cobra: modified prone cobra, Wall: wall slide exercise, Prone: prone V-raise, Backward: backward rocking diagonal arm lift).

slide exercise (183.62% improvement) or modified prone cobra (192.61% improvement), and was not significantly different from that during the prone V-raise, which caused the greatest activation. These results are consistent with previous findings. Ha et al.[11] and Yong & Weon[22] reported that LT muscle activity was significantly greater during the backward rocking diagonal arm lift than that during the wall slide exercise and modified prone cobra, respectively. These findings can be explained as the backward rocking diagonal arm lift is performed in an antigravity position and "diagonal overhead" arm position in line with the LT. However, LT muscle activity during the backward rocking diagonal arm lift was not significantly different from that during the prone V-raise in the present study, which is inconsistent with the results of Ha et al.[11] who reported that the backward rocking diagonal arm lift showed significantly more activity in the LT muscle than the prone V-raise. This difference was likely because several subjects in this study did not overcome the scapular anterior tilt. For the backward rocking diagonal arm lift, the flexed thoracic position results in a scapular anterior tilt, which make a difficult the scapular posterior tilt. The LT muscle is highly activated when overcoming a challenging posture, otherwise it becomes less active.[23] Therefore, if the subject did not overcome the scapular anterior tilt, LT muscle activity may not have been significantly different from that in the prone V-raise or may have been rather low. Based on previous studies, the backward rocking diagonal arm lift is an beneficial method for activation of the LT muscle because it challenges the scapular anterior tilt, and it will be a more effective method with monitoring of scapular posterior tilt.

The LT/UT ratio was significantly greater during the backward rocking diagonal arm lift than during the wall slide exercise (117.77% improvement) or prone V-raise (24.65% improvement), and was not significantly different during the modified prone cobra, which had the greatest activation. One possible explanation is that the backward rocking diagonal arm lift position involves slight cervical flexion compared to the other exercise positions. De Lorenzo et al.[24] suggested immobilization in a position of slight neck flexion, implying that the sarcomeres of the cervical multifidus are of optimal length in a slightly flexed posture.[25] Previous studies suggested that a neutral cervical posture reduced altered activation of the UT muscles.[26-28] Therefore, UT muscle activity was lower during the backward rocking diagonal arm lift than the other exercises due to the neck posture, which may have increased the LT/UT ratio. However, there was no significant difference in the LT/UT ratio between the backward diagonal arm lift and modified prone cobra, which had the greatest activation. The modified prone cobra posture causes slight depression and adduction of the scapula without upward rotation. In this posture, the muscle length is long for the UT and short for the LT, which increases the LT/UT muscle activity ratio. However, the LT muscle activity during the modified prone cobra was 18.28±9.30%MVIC, which is insufficient to strengthen the muscle. In most rehabilitation protocols, exercises that produce more than 40%–60% of the MVIC are desired during advanced phases of shoulder rehabilitation.[29] Furthermore, the modified prone cobra position did not include functional movement of the LT (scapular upward rotation). Activation of a specific muscle is increased during intended functional action of the muscle, which is due to stimulation of the muscle fibers.[30-31] Taken together, these observations suggest that the backward rocking diagonal arm lift may be a more effective exercise than the modified prone cobra for decreasing UT muscle activity and increasing LT muscle activity.

Finally, UT muscle activity was significantly lower during the modified prone cobra than during the other exercises, followed by the backward rocking diagonal arm lift. This is consistent with a previous report showing that the modified prone cobra produced significantly less isolation of the UT than the prone row exercise.[13] However, the modified prone cobra is performed below 90° of humeral elevation. Moseley et al.[32] reported that upper arm moving in an arc between 90° and 150° elevation most effective for recruiting LT during glenohumeral abduction and rowing exercises. The muscle fibers of the LT have been estimated to run at an angle of approximately 125°.[21] They also reported that the LT showed superior activation with the arm in line with the muscle fibers of the LT. Based on previous studies, the backward rocking diagonal arm lift may be an beneficial method to activating the LT while decreasing UT activation as the exercise was performed at 145° of humeral elevation in line with the LT and showed the second smallest level of UT activation after the modified prone cobra. In addition, UT muscle activity during the backward rocking diagonal arm lift was 26.13±12.83 (%MVIC) at relatively weak contractions (10–30%MIVIC).

This study had several limitations. First, we did not confirm the scapular posterior tilt during each exercise. Additional studies are necessary to determine the correlation between the amount of scapular posterior tilt and other exercises. Second, all subjects were asymptomatic young men. Future studies including symptomatic and/or older subjects are required to generalize our findings. Finally, the cross-talk over the trapezius muscles has not been reported. In the trapezius muscle, cross-talk can potentially occur from deeper muscles such as the supraspinatus, or the rhomboid muscle.

CONCLUSIONS

The present study measured UT and LT muscle activity during four specific therapeutic exercises. In terms LT muscle activity and the LT/UT ratio, the backward rocking diagonal arm lift was not significantly different from the other exercises, which produced greater levels of activation. In terms of UT muscle activity, the backward rocking diagonal arm lift produced the second smallest degree of activation after the modified prone cobra, which produced the lowest level of activation. The backward rocking diagonal arm exercise should be considered an effective strengthening exercise for the LT muscle, while decreasing UT muscle activity. The scapular posterior tilt should be confirmed during exercise testing.

Key Points

Question Which of the 4 exercises (modified prone cobra, prone V-raise, wall slide exercise, and backward rocking diagonal arm lift) is effective in decreasing upper trapezius and increasing lower trapezius?

Findings In terms lower trapezius muscle activity and the lower trapezius/upper trapezius ratio, the backward rocking diagonal arm lift was not significantly different from the other exercises, which produced greater levels of activation. However, the backward rocking diagonal arm lift was greater than some of these exercises.

Meaning The backward rocking diagonal arm lift should be considered effective as a strengthening exercise for the lower trapezius muscle while decreasing upper trapezius muscle activity.

Article information

Conflict of Interest Disclosures: None.

Funding/Support: None.

Acknowledgment: None.

Ethic Approval: This study was approved by the institutional review board of Inje University, Republic of Korea (INJE 2022-04-044-001).

Author contributions

Conceptualization: JS Oh.
Data acquisition: MJ Ko.
Design of the work: JS Oh.
Data analysis: MJ Ko.
Project administration: JS Oh.
Interpretation of data: MJ Ko.
Writing – original draft: MJ Ko.
Writing–review&editing: JS Oh.

REFERENCES

1. Kinney E, Wusthoff J, Zyck A, et al. Activation of the trapezius muscle during varied forms of Kendall exercises. *Phys Ther Sport*. 2008;9(1):3-8.
2. Johnson G, Bogduk N, Nowitzke A, House D. Anatomy and actions of the trapezius muscle. *Clin Biomech*. 1994;9(1):44-50.
3. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. *Muscles: testing and function with posture and pain (Vol. 5, pp. 1-100)*. Baltimore: Lippincott Williams & Wilkins; 2005.
4. Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scand J Med Sci Sports*. 2007;17(1):25-33.
5. Chester R, Smith TO, Hooper L, Dixon J. The impact of subacromial impingement syndrome on muscle activity patterns of the shoulder complex: a systematic review of electromyographic studies. *BMC Musculoskelet Disord*. 2010;11(1):1-12.
6. Lopes AD, Timmons MK, Grover M, Ciconelli RM, Michener LA. Visual scapular dyskinesis: kinematics and muscle activity alterations in patients with subacromial impingement syndrome. *Arch Phys Med Rehabil.* 2015;6(2):298-306.
7. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther*. 2000;80(3):276-291.
8. Phadke V, Camargo PR, Ludewig PM. Scapular and rotator cuff muscle activity during arm elevation: a review of normal function and alterations with shoulder impingement. *Braz J Phys Ther.* 2009;13(1):1-9.
9. Smith M, Sparkes V, Busse M, Enright S. Upper and lower trapezius muscle activity in subjects with subacromial impingement symptoms: is there imbalance and can taping change it? *Phys Ther Sport*. 2009;10(2):45-50.
10. Bressel ME, Bressel E, Heise GD. Lower trapezius activity during supported and unsupported scapular retraction exercise. *Phys Ther Sport*. 2001;2(4):178-185.
11. Ha SM, Kwon OY, Cynn HS, et al. Comparison of electromyographic activity of the lower trapezius and serratus anterior muscle in different arm-lifting scapular posterior tilt exercises. *Phys Ther Sport*. 2012;13(4):227-232.
12. Garcia JF, Herrera C, Maciukiewicz JM, Anderson RE, Ribeiro DC, Dickerson CR. Variation of muscle recruitment during exercises performed below horizontal arm elevation that target the lower trapezius: a repeated measures cross-sectional study on asymptomatic individuals. *J Electromyogr Kinesiol*. 2023;70:102777.
13. Arlotta M, LoVasco G, McLean L. Selective recruitment of the lower fibers of the trapezius muscle. *J Electromyogr Kinesiol*. 2011;21(3):403-410.
14. Phil P, Clare C, Robert L. *Assessment and treatment of muscle imbalance. The Janda approach. 1st ed.* Champaign: Human Kinetics; 2010.
15. Sahrmann S. *Diagnosis and treatment of movement impairment syndrome*. Missouri: Mosby; 2002.
16. Yoon TL, Kim KS, Cynn HS. Slow expiration reduces sternocleidomastoid activity and increases transversus abdominis and internal oblique muscle activity during abdominal curl-up. *J Electromyogr Kinesiol*. 2014;24(2):228-232.
17. Borms D, Cools A. Upper-extremity functional performance tests: reference values for overhead athletes. *Int J Sports Med.* 2018;39(6):433-441.
18. Criswell E. *Cram's introduction to surface electromyography. 2th ed*. Sudbury: Jones and Bartlett Publishers; 2011.
19. Basmajian JV, De Luca CJ. *Their function revealed by electromyography. In: Butler J (ed) Muscles alive*. Baltimore: Williams and Wilkins Waverly; 1985.

20. Hardwick DH, Beebe JA, McDonnell MK, Lang CE. A comparison of serratus anterior muscle activation during a wall slide exercise and other traditional exercises. *J Orthop Sports Phys Ther*. 2006;36(12):903-910.
21. Ekstrom RA, Donatelli RA, Soderberg GL. Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *J Orthop Sports Phys Ther*. 2003;33(5):247-258.
22. Yong JH, Weon JH. Comparison of the EMG activities of scapular upward rotators and other scapular muscles among three lower trapezius strengthening exercises. *Phys Ther Korea*. 2013;20(3):27-35.
23. Kang M. Arm lifting exercises for lower trapezius muscle activation. *J Int Acad Phys Ther Res*. 2019; 10(4):1868-1872.
24. De Lorenzo RA, Olson JE, Boska M, et al. Optimal positioning for cervical immobilization. *Ann Emerg Med*. 1996;28(3):301-308.
25. Anderson JS, Hsu AW, Vasavada AN. Morphology, architecture, and biomechanics of human cervical multifidus. *Spine*. 2005;30(4):86-91.
26. Vedsted P, Søgaard K, Blangsted AK, Madeleine P, Sjøgaard G. Biofeedback effectiveness to reduce upper limb muscle activity during computer work is muscle specific and time pressure dependent. *J Electromyogr Kinesiol*. 2011;21(1):49-58.
27. Ma C, Szeto GP, Yan T, Wu S, Lin C, Li L. Comparing biofeedback with active exercise and passive treatment for the management of work-related neck and shoulder pain: a randomized controlled trial. *Arch Phys Med Rehabil*. 2011;92(6):849-858.
28. Neblett, R, Mayer TG, Brede E, Gatchel RJ. Correcting abnormal flexion-relaxation in chronic lumbar pain: responsiveness to a new biofeedback training protocol. *Clin J Pain*. 2010;26(5):403.
29. Escamilla RF, Yamashiro K, Paulos L, Andrews JR. Shoulder muscle activity and function in common shoulder rehabilitation exercises. *Sports Med.* 2009; 39(8):663-685.
30. Mew R. Comparison of changes in abdominal muscle thickness between standing and crook lying during active abdominal hollowing using ultrasound imaging. *Man Ther.* 2009;14(6):690-695.
31. Henry SM, Westervelt KC. The use of real-time ultrasound feedback in teaching abdominal hollowing exercises to healthy subjects. *J Orthop Sports Phys Ther*. 2005;35(6):338-345.
32. Moseley JRJB, Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med*. 1992;20(2): 128-134.