

# EFFECTS OF CLOSED CHAIN STABILIZATION EXERCISE APPLIED TO THE SCAPULAR ON MUSCLE ACTIVITY AND NECK DYSFUNCTION IN ADULTS WITH LOSS OF CERVICAL LORDOSIS

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## Abstract

This study was conducted to investigate the effect of scapular stabilization exercise of the closed chain method and the open chain method on adults with a loss of cervical lordosis. The subjects of this study were 20 adults with a craniocervical angle (CVA) of 55 degrees or more. This experiment was conducted during the month of May 2022. The subjects were randomly divided into 10 people in the open chain scapular stabilization exercise group and 10 people in the closed chain scapular stabilization exercise group, and exercise was performed twice a week for 4 weeks. Surface EMG was used to evaluate the muscle activity of the upper trapezius muscles before and after intervention, and the Neck disability index (NDI) was performed to determine the degree of neck disability. In the muscle activity of the upper trapezius muscle during neck extension in the sitting position, both the open chain group and the closed chain group showed a significant decrease in muscle activity with time before and after intervention ( $p < 0.05$ ), but between time and group there was no significant difference between interaction and group ( $p > 0.05$ ). In the muscle activity of the upper trapezius muscle during the 120° arm flexion and abduction motion in the standing position, both the open chain group and the closed chain group showed a significant decrease in muscle tone with time before and after intervention ( $p < 0.05$ ), and time There was an interaction between the group and the group ( $p < 0.05$ ), and in the post-mortem test, the muscle activity of the trapezius muscle during arm bending was significantly decreased in the closed chain group than in the open chain group ( $p < 0.025$ ). There was no significant difference between groups ( $p > 0.05$ ). In the results of comparison of the average values of neck disability scores in the pre-intervention and post-intervention tests of the open chain group and the closed chain group, the open chain group showed a statistically significant decrease in scores to  $9.6 \pm 3.84$  points before exercise and  $5.3 \pm 3.92$  points after exercise. ( $p < 0.05$ ), and even in the closed chain group, there was a statistically significant decrease in scores of  $11.4 \pm 4.48$  before exercise and  $6 \pm 3.56$  after exercise ( $p < 0.05$ ). However, no significant difference was found between groups. did not ( $p > 0.05$ ). This study confirms the effect of each type of exercise of the scapular stabilization exercise, which has been widely used for shoulder-related problems, so that it can be used as a new treatment method for neck-related problems.

**Keywords:** Loss of cervical lordosis, Close kinetic, Open Kinetic, Scapular retraction exercise, Muscle Activation, Neck Disability Index.

## 1. Introduction

According to Pew Research, an American market research institute, Korea ranked first in the world in terms of high Internet penetration rate and fast average network speed, along with a smartphone penetration rate of 94% (Taylor & Silver, 2019). Due to the development of information and communication technology, addiction or overdependence on smartphones is becoming widespread (Seung-Goo, & Jin-Wook.). Notably, the continuous use of smartphones increases the activity of the muscles related to the neck and shoulder compared to the usage of computers with large screens (Straker et al., 2008). The increase in the activity of muscles around the neck and shoulder is a risk factor that is deeply involved in musculoskeletal pain in the neck and scapula (Lee et al., 2016).

The upper trapezius, which substantially contributes to the normal movement of the neck and scapula, is located across the neck and shoulder (Johnson et al., 1994). Greig et al. (2005) reported that the muscle activity of the upper trapezius is maintained at more than 5% of the maximum EMG while using a video terminal, such as a smartphone. Correspondingly, it has been reported that the load in the muscles around the neck increases. Recently, the prevalence of touch-screen electronic device usage has increased, along with the time when the arm is not supported, thereby augmenting the load on the neck and shoulders (Shin & Zhu, 2011).

The ordered deformation of the neck is classified into various forms, such as the forward head posture (FHP), which appears due to an increase in lordosis of the cervical vertebrae, a straight form due to a decrease in lordosis, and a D-shaped form due to an increase in kyphosis (Ohara et al., 2006). The condition of straight neck shape due to loss of cervical lordosis is common in patients complaining of neck pain and may increase the fatigue of the muscles around the neck and shoulder, as well as the risk of nerve compression (Lee et al., 1999).

Abnormal movements of the scapula and erratic control of the shoulder muscles may decrease postural stability and increase symptoms such as neck pain (Finely & Lee, 2003). In particular, the overactivation of the upper trapezius muscle involved in neck and shoulder movements is common in individuals with incorrect posture and neck pain (Page et al., 2011). Overactivation of the upper trapezius occurs with a decrease in the activity of the middle trapezius and lower trapezius muscles, which can be involved in an upward rotation of the scapula, together with the upper trapezius (Wadsworth & Bullock-Saxton, 1997).

Various stabilization exercises applied to the shoulder have been mainly used to solve problems such as shoulder impingement syndrome and scapular dysfunction by correcting the erroneous mechanism of the scapula (Başkurt et al., 2011; Moghadam et al., 2020). Recently, numerous literature on improving neck problems through exercise applied to the shoulder have been published (Shiravi et al., 2019; Kang et al., 2021), especially elevation and depression of the scapula along with the movement of the humerus. A study has shown that exercise is the most effective way to normalize trapezius activity and is most helpful in stabilizing the scapula (Ekstrom et al., 2003; Ha et al., 2012). Muscle imbalance and dysfunction can be said to be the effects of increasing the control ability of the muscles connecting the neck and shoulders through scapular stabilization exercise (Kim et al., 2013).

Mendez-Rebolledo et al. (2021) reported that in a literature review of 29 cases of closed-chain shoulder exercise, the optimal activity ratio of the upper trapezius and middle and lower trapezius muscles was seen in the scapula stabilization exercise, including scapular retraction and depression. Meanwhile, Šmite et al. (2017) found that at the starting position of the scapula stabilization exercise, including the raising and lowering of the scapula, the activity of the stabilizing muscles, such as the upper trapezius, was higher in the open-chain exercise method than in the closed-chain exercise method. They reported that there was no significant difference between open-chain motion and closed-chain motion.

An open-chain exercise is a single-joint exercise performed without supporting the body weight while the distal end of the body is free (Stensdotte et al., 2003). For this reason, the open-chain exercise is a treatment option that can be easily applied to people with a high body mass index (Irish et al., 2010) because the load on the joints is minimal (Irish et al., 2010), and it is easy to activate the muscles individually (Kisner & Colby, 2007). On the other hand, closed-chain exercise contributes to improving stability (Kisner & Colby, 2007) and promotes proprioceptive sensation for multiple joints and simultaneous muscle contraction. There is a report that the exercise is good biomechanically because it uses all of the muscles and the force applied to the joint is minimal, even within a limited range (Tang et al., 2001).

Therefore, this study applied open- and closed-chain stabilization exercises to the scapula of an adult with cervical lordosis loss to determine its effects on changes in the muscle activity of the trapezius upper trapezius, a muscle that works together on the shoulder and neck and is involved in the function of the neck.

## 2. Method

### 2.1 Study design

This study was approved by the Bioethics Committee of Daegu University(1040621-202203-HR-028) and was conducted according to the procedure. In this study, Program G-power 3.1.9.2 was used to determine the number of subjects with loss of lordosis of the neck. In repeated measures ANOVA, an analysis method, the effect size (effect size) .60, significance level ( $\alpha$ ) .05, and statistical power ( $1-\beta$ ) .8 were calculated. As a result, the minimum number of people with an appropriate sample size was calculated to be 20, Finally, the experiment was conducted with 20 subjects (Faul et al., 2009). Subjects were randomly assigned to an open scapular stabilization exercise group and a closed scapular stabilization exercise group by 10 participants.

### 2.2 Participants

The subjects of this study were 20 adults living in Seoul and Gyeonggi-do with a head and neck angle of 53 degrees or more. Table 1 shows the general characteristics of the subjects. Experience with neck disease or surgical treatment This study was conducted in those who did not have the disease, who did not have other orthopedic conditions that could affect the trial, were not taking drugs that could affect the trial, or had mental, cognitive or communication problems. person without. Before the experiment, the purpose and method of the study were fully explained and informed consent was written. In addition, if the subject complained of temporary fatigue or acute pain during the experiment, the study was immediately stopped and rest.

### 2.3 Intervention

#### 2.3.1 Open kinetic scapular stabilization exercise

The subject placed his forehead on the floor in a comfortable supine position on the treatment bed, and a towel was rolled up between the forehead and the floor. ) direction (Oyama et al., 2010). During the exercise, the subjects were asked to raise their arms toward the back and at the same time bring both scapular together and contract. The motion was maintained so that the compensatory action of over-tension and lower back did not appear. In the last step of gathering the scapular, it was held for 5 seconds and then slowly returned to the starting position (Saharmann, 2001).

#### 2.3.2 Closed kinetic scapular stabilization exercise

For the closed chain scapular stabilization exercise, a sling was used, and the subject was asked to bend the knee 90° while lying on the treatment bed. The suspension point of the sling was aligned with the shoulder joint and two straps were used to placed on the upper arm. A strap was also placed on the back of the head to prevent compensation from the neck during exercise. During the exercise, spread both arms 120° and rotate them outward so that the thumbs face the floor, and the arms are fixed with the straps. Press the part to face the floor to give strength, and at the same time, they were asked to bring both scapular together. During the exercise, move the upper trapezius muscle to avoid over-tension of the trapezius muscle and the compensatory action of raising the chest by using the lower back. In the last step of gathering the scapular, it was held for 5 seconds and then slowly returned to the starting position. After one exercise, the rest time was 5 seconds.



## 2.4 Equipment and Measurement

### 2.4.1 Muscle activity

In this study, 4D-MT 2EM (Relive Co., Ltd, Gimhae, South Korea) was used to measure the activity of the subject's upper trapezius (UTZ) muscle. (Relive Co., Ltd) was used for collection.

The EMG data obtained through the study were analyzed by recording the average RMS value of each muscle by repeating the motion of extending the neck backward in the sitting position and flexion, abduction the arm 120° in the standing position 3 times.

The maximum voluntary isometric contraction(MVIC) was measured a total of 3 times based on the voluntary muscle posture, and was maintained for 5 seconds.

### 2.4.2 Neck disability index

To evaluate the degree of neck disability, the Korean version of the Neck Disability Index questionnaire, which has a very high reliability of .93 by the ICC, was used. It was verified that there were no errors by the original author. For the interpretation of the questionnaire, for a total of 10 questions, the total score of 0-4 was no disability, 5-14 was mild disability, 15-24 was moderate disability, and 25-34 was severe. Disability, a score of 35 or higher is interpreted as complete disability(Song et al., 2009).

## 2.5 Data Analysis

The data analysis of this study was performed using IBM SPSS Statistics 20.0 program. The mean and standard deviation were used for all measured variables, and an independent t-test was used to test the homogeneity of the general characteristics of subjects. , and Shapiro-Wilks test was performed for normality test.

Two-way repeated analysis of variance (ANOVA) was performed to investigate the change in activity of the upper trapezius muscle before and after the intervention of the open chain exercise group and the closed chain exercise group. Comparison of the difference values before and after intervention was performed using an independent sample t-test using the Bonferroni test ( $p < 0.025$ ). A paired t-test was performed.

Mann-Whitney U test was performed to verify NDI between groups according to the intervention method, and Wilcoxon rank test was used to verify NDI before and after treatment within the group. did Statistical significance level was set as  $\alpha < .05$ .

Table 1. General Characteristic of Participants

OKC(n=10)	CKC(n=10)	<i>p</i>
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Age(year)	26±.58a	26.2±.65	.89
Height(cm)	166.9±2.08	166.90±2.47	.52
Weight(Kg)	58.10±7.17	64±10.91	.08
BMI(Kg/m <sup>2</sup> )	20.8±.49	22.81±2.12	.19

<sup>a</sup>mean±standard deviation

OKC :Open kinematic exercise group

CKC :Close kinematic exercise group

Table 2. Muscle activities during neck extension and shoulder 120° flexion and abduction. (Unit. %MVIC)

	Group	Pre-test	4weeks	Differ	Time	Group	Time*group	Effect size (d)
Sitting neck extension	OKC	28.3±9.5a	27.21±9.41	-1.09±-0.09	.00*	.57	.13	.3
	CKC	27.09±8.15	23.98±7.1	-3.11±-1.05				
Arm raise	OKC	52.8±15.95	51.09±15.64	-1.71±-0.31	.00*	.79	.00*	.69
	CKC	57.43±11.53	49.7±9.56	-7.73±-1.97				

<sup>a</sup>mean±standard deviation

\*p<.05

OKC : Open kinematic exercise group

CKC : Close kinematic exercise group

### 3. Result

#### 3.1 Muscle activity of the upper trapezius muscle

In the muscle activity of the upper trapezius muscle during neck extension in the sitting position, both the open chain group and the closed chain group showed a significant decrease in muscle activity with time before and after exercise ( $p<0.05$ ). There was no interaction between time and group ( $p>0.05$ ) (Table 2). There was no significant difference between groups ( $p>0.05$ ). In the muscle activity of the upper trapezius muscle during the 120° arm flexion and abduction motion in the standing position, both the open chain group and the closed chain group showed a significant decrease in muscle tone with time before and after exercise ( $p<0.05$ ), and time There was an interaction between the group and the group ( $p<0.05$ ), and in the post-hoc test, the muscle activity of the trapezius muscle during arm bending was significantly decreased in the closed chain group than in the open chain group ( $p<0.025$ ). There was no significant difference between groups ( $p>0.05$ ).

#### 3.2 Neck disability index

The results of comparison of the average values of neck disability scores in the pre- and post-exercise tests of the open chain group and the closed chain group are as follows. There was a decrease in the score ( $p < 0.05$ ), and in the closed chain group, a statistically significant decrease was also observed in the score,  $11.4 \pm 4.48$  before exercise and  $6 \pm 3.56$  after exercise ( $p < 0.05$ ).

There was no significant difference in the comparison of each group with respect to the results after the experiment ( $p > 0.05$ ).

Table 3. The Comparison of Neck Disability Index in Each trial in each group.  
(Unit. Score)

Group	Pre	Post	Z(p)
OKC	$9.6 \pm 3.84a$	$5.3 \pm 3.92$	$-2.68(.01^*)$
CKC	$11.4 \pm 4.48$	$6 \pm 3.56$	$-2.81(.01^*)$
Z(p)		$-1.03(.3)$	

<sup>a</sup>mean  $\pm$  standard deviation

\*  $p < .05$

OKC : Open kinematic exercise group

CKC : Close kinematic exercise group

#### 4. Discussion

This study attempted to compare the muscle activities of the upper trapezius muscles, while the open-chain scapular stabilization exercise and the closed-chain scapular stabilization exercise evaluated the extension of the neck in a sitting position, the muscle activity of the upper trapezius muscle in  $120^\circ$  flexion and abduction, and the effect on the neck disability index.

Based on the comparison of the muscle activity of the upper trapezius muscle within the group during neck extension before and after the intervention in this study, both groups showed a significant decrease in the activity of the muscles before and after with time ( $p < .05$ ). There was no significant difference between groups ( $p > .05$ ), and there was no interaction between time and groups ( $p < .05$ ). The loss of cervical lordosis creates mechanical instability of the cervical vertebrae and weakens the neck muscles (Beinert et al., 2015). Prolonged weakening of the neck muscles causes muscle fatigue and excessive muscle tension (Yildirim et al., 2018). In particular, among the extensors of the neck, the upper trapezius is used for extension and lateral flexion of the head and neck, together with the clavicle, which is relatively fixed to the neck (Mansfield & Neumann, 2018). It limits the range of motion in the neck and is accompanied by decreased activation of the lower trapezius (Camargo & Neumann, 2019). If there is hypertension in the upper trapezius muscle, weakness of the lower trapezius and serratus anterior muscles may arise due to an imbalance in the muscles around the scapula. Pasinato et al. (2016) reported that patients with neck pain had weaker muscles around the neck compared to those with healthy necks. Alghadir et al. (2020) reported that excessive activity of the upper trapezius muscle causes myofascial pain syndrome, which is believed to cause imbalance and pain in the area. According to a previous study on scapular retraction, the activation of the lower trapezius muscle is at the highest when performing scapular retraction in the  $120^\circ$  flexion and abduction motion of the arm compared to other angles (Bressel et al., 2001). Similarly, in this study, because the exercise was performed through scapula retraction in  $120^\circ$  flexion and abduction motion, the lower trapezius and serratus anterior muscles were strengthened after exercise, and the balance of the surrounding muscles of the scapula reverted to normal relatively. It is thought that the muscle activity of the upper trapezius muscle decreased.

Based on a comparison of the activity of the trapezius muscle within the group during the 120° flexion of the arm before and after the intervention in this study, both groups showed a significant decrease in muscle activity before and after with time ( $p < .05$ ). There was no significant difference between groups ( $p > .05$ ), but there was an interaction between time and group ( $p < .05$ ). In the post-hoc test, the activity of the upper trapezius muscle during arm flexion and abduction significantly decreased in the closed-chain group compared to the open-chain group ( $p < .25$ ). As a result of the induction and depression movements applied while keeping the arms at 90° and 120° in the previous study, the activity of the upper trapezius muscle was significantly reduced during the induction and depression movements in the 120° flexion and abduction motions, similar to those applied in this study (Oyama et al., 2010). Falla et al. (2007) measured the location of the trapezius muscle according to the arm bending angle and the surface electromyography for each part after repeated arm flexion for 5 minutes in healthy adults. It was reported that the largest average rectified value and instantaneous mean power spectral frequency were observed in the attached electrode located at the upper trapezius. This means that excessive activity of the trapezius muscle is more likely to appear compared to other trapezius regions. Repetitive posture maintenance, which can cause neck muscle fatigue, such as prolonged computer work and repeatedly raising the arm, causes neck pain (Mekhora et al., 2000) and overactivity of the upper trapezius muscle. This results in the weakening of the trapezius muscles working together (Wadsworth & Bullock-Saxton, 1997). In addition, in this study, both groups showed a significant decrease in the upper trapezius, but based on the post-test, the activity of the upper trapezius decreased more significantly in the closed-chain group ( $p < .05$ ). This is thought to be due to the closed-chain exercise method, which promoted a unique sense of water solubility in multiple joints and simultaneous contraction of muscles compared to the open-chain exercise method (Tang et al., 2001). In this experiment, the open-chain exercise increased the activity of the lower trapezius through retraction and depression of the scapula, reducing the relative activity of the upper trapezius (Ekstrometal et al., 2004). However, unlike the closed-chain exercise, the upper trapezius is thought to have been activated.

Based on a comparison of the neck disability index before and after intervention in this study, there was a significant decrease in scores before and after intervention ( $p < .05$ ). In comparing the neck disorder index between groups, there was no significant difference ( $p > .05$ ). Zakharova-Luneva et al. (2012) reported that the motor control ability of the upper trapezius is more important in patients with neck pain than in healthy adults during shoulder movements of patients with chronic neck pain and scapular dysfunction. This is believed to be due to changes in the activity pattern of the lower trapezius due to neck pain, and the common point between the open and closed chain movements applied in this study is that the retraction and depression of the scapula increased the activity of the lower trapezius muscle.

The limitations of this study are as follows. First, the total number of subjects involved in this research is only 20, so there is a limit to the generalization of the results. Second, the intervention period was only four weeks, which is not long enough. Therefore, the effects of long-term intervention application remain unknown. Third, this study could not uniformly apply the degree of weight applied by comparing the open-chain and the closed-chain exercise methods. Fourth, it is difficult to explain the effect on the shoulders because only the muscle activity of the gastric was measured. In future studies, it is necessary to enroll a sufficient number of subjects and implement a longer study time to evaluate the effectiveness of the intervention on both shoulder muscles and necks.

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## References

- [1] Taylor, K. & Silver, L. (2019). Smartphone Ownership is growing rapidly around the world, but not always equally. Pew Research Center, 3-4.
- [2] Seung-Goo K, & Jin-Wook K. (2019). A study on smartphone addiction among adolescents: focusing on the comparison of factors influencing smartphone addiction, game addiction, and SNS addiction. *Life Research*, 52, 179-200.

- [3] Straker, L. M., Coleman, J., Skoss, R., Maslen, B. A., Burgess-Limerick, R., & Pollock, C. M. (2008). A comparison of posture and muscle activity during tablet computer, desktop computer and paper use by young children. *Ergonomics*, 51(4), 540-555.
- [4] Lee, S. T., Moon, J., Lee, S. H., Cho, K. H., Im, S. H., Kim, M., & Min, K. (2016). Changes in activation of serratus anterior, trapezius and latissimus dorsi with slouched posture. *Annals of rehabilitation medicine*, 40(2), 318.
- [5] Johnson, G., Bogduk, N., Nowitzke, A., & House, D. (1994). Anatomy and actions of the trapezius muscle. *Clinical biomechanics*, 9(1), 44-50.
- [6] Greig, A. M., Straker, L. M., & Briggs, A. M. (2005). Cervical erector spinae and upper trapezius muscle activity in children using different information technologies. *Physiotherapy*, 91(2), 119-126.
- [7] Shin, G., & Zhu, X. (2011). User discomfort, work posture and muscle activity while using a touchscreen in a desktop PC setting. *Ergonomics*, 54(8), 733-744.
- [8] Ohara A, Miyamoto K, Naganawa T, Matsumoto K, Shimizu K. Reliabilities of and correlations among five standard methods of assessing the sagittal alignment of the cervical spine. *Spine (Phila Pa 1976)*. 2006 Oct 15;31(22):2585-91; discussion 2592.
- [9] Byung-ryeol, Lee., Hyun, Lee., & Tae-gyun. Park., (1999). Literature Papers: A Clinical Study of 50 Cases of Chronic Pain Pain. *Journal of the Korean Acupuncture Society*, 16(2), 69-82.
- [10] Finley, M. A., & Lee, R. Y. (2003). Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. *Archives of physical medicine and rehabilitation*, 84(4), 563-568.
- [11] Page, P., Frank, C., & Lardner, R. (2011). Assessment and treatment of muscle imbalance: The Janda approach. *Journal of orthopedic & sports physical therapy*, 41(10), 799-800.
- [12] Wadsworth, D. J. S., & Bullock-Saxton, J. E. (1997). Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. *International journal of sports medicine*, 18(08), 618-624
- [13] Başkurt, Z., Başkurt, F., Gelecek, N., & Özkan, M. H. (2011). The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. *Journal of back and musculoskeletal rehabilitation*, 24(3), 173-179.
- [14] Moghadam, A. N., Rahnama, L., Dehkordi, S. N., & Abdollahi, S. (2020). Exercise therapy may affect scapular position and motion in individuals with scapular dyskinesis: a systematic review of clinical trials. *Journal of shoulder and elbow surgery*, 29(1), e29-e36.
- [15] Shiravi, S., Letafatkar, A., Bertozzi, L., Pillastrini, P., & Khaleghi Tazji, M. (2019). Efficacy of abdominal control feedback and scapula stabilization exercises in participants with forward head, round shoulder postures and neck movement impairment. *Sports Health*, 11(3), 272-279.
- [16] Kang, N. Y., Im, S. C., & Kim, K. (2021). Effects of a combination of scapular stabilization and thoracic extension exercises for office workers with forward head posture on the cervicovertebral angle, respiration, pain, and disability: A randomized-controlled trial.
- [17] Ekstrom, R. A., Donatelli, R. A., & Soderberg, G. L. (2003). Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *Journal of Orthopaedic & Sports Physical Therapy*, 33(5), 247-258.
- [18] Ha, S. M., Kwon, O. Y., Cynn, H. S., Lee, W. H., Park, K. N., Kim, S. H., & Jung, D. Y. (2012). Comparison of electromyographic activity of the lower trapezius and serratus anterior muscle in different arm-lifting scapular posterior tilt exercises. *Physical Therapy in Sport*, 13(4), 227-232.
- [19] Kim, M., Lee, Y., Kim, J., & Bae, W. (2013). A Comparison of Various Exercises for Scapular Stabilization. *Journal of The Korean Society of Integrative Medicine*, 1(3), 51-62.
- [20] Mendez-Rebolledo, G., Morales-Verdugo, J., Orozco-Chavez, I., Habechian, F. A. P., Padilla, E. L., & de la Rosa, F. J. B. (2021). Optimal activation ratio of the scapular muscles in closed kinetic chain shoulder exercises: A systematic review. *Journal of Back and Musculoskeletal Rehabilitation*, 34(1), 3-16.
- [21] Šmite, D., Upeniece, I., Runce, A., & Gapeyeva, H. (2017, May). Activity of scapular muscles: Comparison of open and closed kinetic chain exercises. In *SOCIETY. INTEGRATION. EDUCATION. Proceedings of the International Scientific Conference (Vol. 3, pp. 429-436)*.
- [22] Stensdotter, A. K., Hodges, P., Mellor, R., Sundelin, G., & Häger-Ross, C. (2003). Quadriceps activation in closed and in open kinetic chain exercise. *Medicine & Science in Sports & Exercise*, 35(12), 2043-2047.
- [23] Irish, S. E., Millward, A. J., Wride, J., Haas, B. M., & Shum, G. L. (2010). The effect of closed-kinetic chain exercises and open-kinetic chain exercise on the muscle activity of vastus medialis oblique and vastus lateralis. *The Journal of Strength & Conditioning Research*, 24(5), 1256-1262.
- [24] Kisner, C., & Colby, L. A. (2007). *Therapeutic exercise: Foundations and Techniques*. Philadelphia: Davis Company.
- [25] Tang, S. F., Chen, C. K., Hsu, R., Chou, S. W., Hong, W. H., & Lew, H. L. (2001). Vastus medialis obliquus and vastus lateralis activity in open and closed kinetic chain exercises in patients with patellofemoral pain syndrome: an electromyographic study. *Archives of physical medicine and rehabilitation*, 82(10), 1441-1445.
- [26] Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G\* Power 3.1: Tests for correlation and regression analyses. *Behavior research methods*, 41(4), 1149-1160.
- [27] Oyama, S., Myers, J. B., Wassinger, C. A., & Lephart, S. M. (2010). Three-dimensional scapular and clavicular kinematics and scapular muscle activity during retraction exercises. *Journal of orthopaedic & sports physical therapy*, 40(3), 169-179.
- [28] Sahrmann, S. (2001). *Diagnosis and treatment of movement impairment syndromes*. Elsevier Health Sciences.
- [29] Kyeong-jin, Song., Byeong-wan, Choi., Seol-jeon, Kim., & Seon-joong Yun., (2009). Cultural adaptation and validity of the Korean version of the Neck Disability Index. *Journal of the Korean Orthopedic Society*, 44(3), 350-359.
- [30] Beinert, K., Keller, M., & Taube, W. (2015). Neck muscle vibration can improve sensorimotor function in patients with neck pain. *The Spine Journal*, 15(3), 514-521.
- [31] Yildirim, M. A., Kadriye, Ö. N. E. Ş., & Gökşenoğlu, G. (2018). Effectiveness of ultrasound therapy on myofascial pain syndrome of the upper trapezius: randomized, single-blind, placebo-controlled study. *Archives of rheumatology*, 33(4), 418.
- [32] Mansfield, P. J., & Neumann, D. A. (2018). *Essentials of kinesiology for the physical therapist assistant e-book*. Elsevier Health Sciences.
- [33] Camargo, P. R., & Neumann, D. A. (2019). Kinesiology considerations for targeting activation of scapulothoracic muscles - part 2: trapezius. *Brazilian journal of physical therapy*, 23(6), 467-475. <https://doi.org/10.1016/j.bjpt.2019.01.011>
- [34] Pasinato, F., Bordin, J., Santos-Couto-Paz, C. C., Souza, J. A., & Corrêa, E. C. (2016). Cervical-scapular muscles strength and severity of temporomandibular disorder in women with mechanical neck pain. *Fisioterapiaem Movimento*, 29, 269-278.
- [35] Alghadir, A. H., Iqbal, A., Anwer, S., Iqbal, Z. A., & Ahmed, H. (2020). Efficacy of Combination Therapies on Neck Pain and Muscle Tenderness in Male Patients with Upper Trapezius Active Myofascial Trigger Points. *BioMed research international*, 2020, 9361405. <https://doi.org/10.1155/2020/9361405>
- [36] Bressel, M. E., Bressel, E., & Heise, G. D. (2001). Lower trapezius activity during supported and unsupported scapular retraction exercise. *Physical Therapy in Sport*, 2(4), 178-185.

- [37] Falla, D., Farina, D., & Graven-Nielsen, T. (2007). Spatial dependency of trapezius muscle activity during repetitive shoulder flexion. *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology*, 17(3), 299–306. <https://doi.org/10.1016/j.jelekin.2006.03.005>
- [38] Mekhora, K., Liston, C. B., Nanthavanij, S., & Cole, J. H. (2000). The effect of ergonomic intervention on discomfort in computer users with tension neck syndrome. *International Journal of Industrial Ergonomics*, 26(3), 367-379.
- [39] Tang, S. F., Chen, C. K., Hsu, R., Chou, S. W., Hong, W. H., & Lew, H. L. (2001). Vastus medialis obliquus and vastus lateralis activity in open and closed kinetic chain exercises in patients with patellofemoral pain syndrome: an electromyographic study. *Archives of physical medicine and rehabilitation*, 82(10), 1441-1445.
- [40] Ekstrom, R. A., Bifulco, K. M., Lopau, C. J., Andersen, C. F., & Gough, J. R. (2004). Comparing the function of the upper and lower parts of the serratus anterior muscle using surface electromyography. *Journal of Orthopaedic & Sports Physical Therapy*, 34(5), 235-243
- [41] Zakharova-Luneva, E., Jull, G., Johnston, V., & O'Leary, S. (2012). Altered trapezius muscle behavior in individuals with neck pain and clinical signs of scapular dysfunction. *Journal of manipulative and physiological therapeutics*, 35(5), 346-353.