Original Article

EFFECT OF SCAPULAR STABILIZATION EXERCISE USING A SUSPENSION DEVICE ON ALIGNMENT AND PAIN IN ADULTS WITH LOSS OF CERVICAL LORDOSIS

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Abstract

This study was conducted to investigate the effect of stabilization exercise the closed kinetic chain method and open kinetic chain method applied to the scapular on the alignment and pain of adults with loss of cervical lordosis. The subjects of this study were 20 adults with a cranioververtebral angle (CVA) of 55 degrees or more. This experiment was conducted during the month of May 2022. Subjects were randomly divided into 10 people in the open chain scapular stabilization exercise group and 10 people in the suspension scapular stabilization exercise group, and exercise was performed twice a week for 4 weeks. As a result of the experiment, there was a significant difference in CVA measurement between the open chain group and the suspension group before and after intervention within the group ($p<0.05$). In addition, as a result of comparison between the open chain group and the suspension exercise group before and after the intervention, a significant difference was found according to time ($p<0.05$), and an interaction between time and the group was found ($p<0.05$). There was no significant difference in the post hoc test ($p<0.025$). There was also no significant difference between groups ($p>0.05$). In the CRA measurement results of the open and suspension exercise groups, there was no significant difference before and after the intervention within the group, and there was no interaction between time and group and between time and group before and after the intervention between the open chain exercise and suspension exercise group ($p>0.05$). Both the open chain exercise group and suspension exercise group showed a statistically significant decrease in pain score ($p<0.05$), and there was no significant difference between the groups after the experiment ($p<0.05$). In this study, the effect of scapular stabilization exercise for each type of exercise was confirmed for adults with a loss of cervical lordosis.

Keywords: loss of cervical lordosis, suspension device exercise, craniovertebral angle, cranial rotation angle, pain.

1. Introduction

The prevalence of touch screen usage has increased with the development of modern society; concomitantly, the number of people with myoskeletal diseases related to the neck has risen significantly (Toh et el., 2017). According to a study by Öğrenci et al. (2018), in a cohort who used mobile devices with various screens for an average of two hours per day for 10 years, 70% reported a loss of cervical lordosis. This loss of cervical curvature is called text neck or turtleneck syndrome (Jyothsna, 2019). It is defined as repetitive stress or overuse syndrome

wherein the pain felt is attributed to maintaining a repetitive posture with the head positioned forward when using electronic devices for a long time (Samani et al., 2018).

In a normal spine alignment, the plumb line passes through the outer ear path, dentate axis, vertebral body of the lumbar vertebrae, and the protrusion of the sacrum (Kendall et al., 1993). It affects the distribution of the load applied to the intervertebral disc (Keller et al., 2005). Notably, in the cervical vertebrae, various alignments, such as a straight form due to hyperkyphosis and an "S"-shaped alignment which is a combined form of lordosis and kyphosis, may appear (Ohara et al., 2006). The overall alignment of the vertebrae suggests that the loss of cervical lordosis is accompanied by excessive kyphosis of the thoracic region and excessive lordosis of the lumbar region (Boden et al., 1960). In addition, according to a study by Wei et al. (2013), the loss of cervical lordosis caused by excessive kyphosis of the cervical region reduces the active range of motion by 24%-33% compared to the normal range of motion of the cervical vertebrae. Meanwhile, the stress applied to the cervical vertebrae is reduced by 95%. reported to increase.

Mechanical stability of the cervical vertebrae is provided by the muscles associated with the neck rather than the bony ligament system (Panjabi et al., 1998). However, in the cervical vertebra in which loss of cervical lordosis occurs, the biomechanics of the cervical vertebrae become distorted because the axial load moves forward compared to the normal curvature; thereafter, the abnormally altered biomechanics increase the compressive force and cause degeneration (Ferrara, 2012; Harrison et al., 2001). This degeneration occurs along with the weakening of the cervical muscles, and through the mechanical instability of the cervical vertebrae, the proprioceptive sensation of the cervical vertebra is decreased, and the agonist and antagonist muscles become imbalanced (Cheng et al., 2014; Beinert et al., 2015). In a previous study targeting adults with loss of cervical lordosis, it was reported that cervical laminoplasty could be applied to reduce intervertebral disc pressure based on radiological judgment (Sharma et al., 2019). A study has reported that the loss of cervical lordosis may occur after surgery depending on the patient (Kim et al., 2020). In addition, Alpayci et al. (2016) reported a significant decrease in muscle strength in the extensors of the neck in patients with loss of cervical lordosis compared to normal subjects. Another previous study by Wang et al. (2021) reported that the tension in the neck extensor muscles of patients with cervical vertebra misalignment is higher and the muscle function is not that good compared to those of normal persons. Among these neck extensors, the upper trapezius muscle typically has poor motor control ability due to the abnormal alignment of the cervical vertebrae and may cause dysfunction in the scapula and neck (Castelein et al., 2015).

Based on the results of various studies suggesting that neck problems are related to shoulder dysfunctions (Cagnie et al., 2014; Zakharova-Luneva et al., 2012), scapular stabilization exercise has recently become a well-known option to solve neck problems. Many other interventions have also been suggested (Im et al., 2015; Javdaneh et al., 2020; Edwards 2021). The purpose of scapular stabilization exercise in addressing problems in the neck is to improve the muscle balance of the scapula by controlling the low activity of the lower trapezius and serratus anterior and the excessive activity of the upper trapezius caused by neck misalignment. It is used to do this (Karabay et al., 2019). The improved ability to control the upper trapezius through exercise may help improve problems in the neck due to the locational characteristics of the upper trapezius attached over the neck and shoulder (Kim et al., 2013), particularly the ability to control the upper trapezius in the lost neck bone (Alpayci et al., 2016).

Horsak et al., (2017) reported that exercise using a sling suspension device is helpful in improving the muscle balance of the scapula. At the same time, it is beneficial in that it enhances stability (Tucci et al., 2017). In a previous study on the closed chain exercise method including suspension exercise, it was reported that scapular extension exercise applied with a closed chain using a sling significantly increased the muscle strength around the shoulder joint (Chi & Kim., 2019). Park and Chon (2017) reported that it helps to increase the ratio of serratus anterior and upper trapezius muscles when shoulder exercise is performed through this closed chain exercise method.

The open-chain exercise method is advantageous because it effectively strengthens the agonist muscle by using the distal part; by contrast, the proximal part of the body is fixed (Stensdotte et al., 2003). According to a

systematic review of the related literature, the open-chain method of scapular retraction exercise, performed with the arm bent between 60° and 180° in the prone position, produces the optimal muscle ratio (Schory et al., 2016).

Although scapular stabilization exercises to solve neck problems have been reported in various literature, there is a dearth of studies on the differences between the suspension exercise method and the open-chain exercise method for the alignment of the cervical vertebrae. Therefore, the purpose of this study is to investigate the effects of open- and scapular stabilization exercise using a suspension on the scapula of adults with loss of cervical lordosis with regard to changes in neck alignment and neck pain.

Table 1. General Characteristic of Participants

	EGI (n=10)	EGII (n=10)	p
Age(year)	26±.58 [a]	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/m²)	20.8±.49	22.81±2.12	.19

[a] mean±standard deviation

EGI : Open kinematic exercise group

EGII : Suspension exercise group

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. To determine the number of subjects, the effect size .60, significance level (α) .05, statistical power (1-β) in repeated measures ANOVA, the analysis method of this study, using the G*power 3.1.9.7 program. As a result of calculating .8, the minimum number of people of the appropriate sample size was calculated to be 14, and finally the experiment was conducted with 20 subjects (Faul et al., 2009). The subjects were randomly assigned to 10 people each into an open chain scapular stabilization exercise group and closed chain scapular stabilization exercise group using suspension device.

2.2 Participants

The subjects of this study were 20 people living in Seoul and Gyeonggi-do with a head-neck angle of 53 degrees or more. The general characteristics of the study subjects are presented in Table 1, those who have never received neck disease or surgical treatment, those who have not taken drugs that may affect the experiment, and others that may affect the experiment Subjects were those without orthopedic diseases, those with mental or cognitive problems, or those with no communication problems. Before the experiment, the purpose and method of this study were sufficiently explained, and informed consent was written, and if the subject complained of temporary fatigue or acute pain during the experiment, the study was immediately stopped and rested.

2.3 Intervention

2.3.1 Open kinetic scapular stabilization exercise

The shoulder stabilization exercise of the open chain method was applied as follows. After the subject lay down on the bed, both arms were extended and bent by 120°, rotated outward, and the thumb was asked to point in the dorsal direction (Oyama et al., 2010). Afterwards, the subjects were asked to raise their arms in the dorsal direction and contract by retraction of both scapular. During the exercise, the movement was maintained so that the overtense of the trapezius muscle and the compensatory action of exaggerating the lower back did not appear during the exercise. In the last step of gathering the scapular, it was held for 5 seconds and then slowly returned to the starting position. 5 seconds (Sahrmann, 2001).

Table 2. Before and after intervention, CVA and CRA.

(Unit. °)

	Group	Pre-test	4weeks	Time	Group	Time*group	Effect size (d)
CVA	EGI	59.82±3.74 [a]	58.8±4.05*	.00*	.74	.03*	.25
	EGII	59.86±2.77	57.7±3.44*				
CRA	EGI	152.99±6.06	152.75±6.2	.15	.36	.33	.05
	EGII	151.29±4.58	150.1±4.08				

[a] mean±standard deviation

*p<.05

CVA : Craniovertebral angle

CRA : cranial rotation angle

EGI : Open kinematic exercise group

EGII : Suspension exercise group

2.3.2 Suspension exercise

A sling was used for scapular stabilization exercise of the closed chain method. After the subject lay down on the bed, the knee was bent 90°, and the suspension point of the sling was aligned with the shoulder joint. Using two straps, they were placed on both upper arms and then exercise was performed. A strap was also placed on the back of the head to prevent possible compensatory action in the neck during exercise. During the exercise, both arms were opened and rotated 120° outward so that the thumbs were facing the floor. It was requested to press the part where the strap was fixed with the arm, and to retract both scapular at the same time. During the exercise, the movement was maintained by requesting to eliminate the overactivation of the upper trapeziusand the compensatory action to elevate the chest by lumbar extension. In the last step of retracting the shoulder blade, it was maintained for 5 seconds and then slowly returned to the starting position.

2.4 Equipment and Measurement

2.4.1 Cervical alignment

In this study, alignment was confirmed by measuring CVA and CRA. For the measurement of CVA and CRA, a mobile phone(Iphone, Apple, USA) was used and a tripod was used to fit the subject's eye level, and the images were taken from a distance of 1 m. For the photograph taken, CVA and CRA were measured through Image J (version 1.46, National Institutes of Health, USA). For CVA, the spinous process and the tragus of the 7th cervical vertebra were marked with white tape, and the angle formed by the intersection of the line connecting the 7th cervical vertebra and the ear ball and the horizontal line passing through the 7th cervical vertebra was used. White tape was used to mark the spinous process of the 7th cervical vertebra, the ear ball, and the outer canthus of the eye, and the angle formed by the line connecting the spinous process of the 7th cervical vertebra and the ear ball and the ear ball and the outer canthus of the eye was used. Before using Image J, a total of 3 pictures were taken, and after taking 1 picture, the body tension was reduced by walking in place, and the result was taken again, and the average of each value through 3 pictures was used (Diab & Moustafa, 2011; Harman et al., 2005).

2.4.2 Pain

In this study, a visual analog scale was used to evaluate the degree of pain. How to apply: After drawing a straight line of 10 cm, write the words 'No pain at all (0)' on one end and 'The most severe pain (10)' on the other end, and ask the subject to indicate the level of pain they feel on the straight line. Then, the pain level was evaluated by measuring the length from 0 to the marked area (Cole, 1994).

Table 3. The Comparsion of Visual analog scale in Each trial in each group

(Unit. Score)

Group	Pre	Post	Z(p)
EGI	3.8±1.03[a]	2.9±1.29	-2.31(.02[*])
EGII	4.3±2.31	3.1±1.45	-2.41(.02[*])
Z(p)		.29 (.8)	

[a]mean±standard deviation

[*]p<.05

EGI : Open kinematic exercise group

EGII : Suspension exercise group

2.5 Data Analysis

The data analysis of this study was performed using IBM SPSS Statistics 20.0 program. 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. was carried out, and Shapiro-Wilks test was performed for normality test.

Two-way repeated ANOV was performed to examine the changes in CVA and CRA before and after the intervention of the open chain exercise group and the closed chain exercise group. Comparison between groups of difference values before and after the intervention was performed with an independent sample t-test using the Bonferroni test ($p<0.025$). A paired t-test was performed to check the differences before and after intervention within each group.

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

3. Result

3.1 Cervical alignment

As a result of CVA measurement of the open chain group and the suspension exercise group, there was a significant difference before and after intervention within the group ($p<0.05$). As a result of comparison between the EGI and the EGII before and after intervention, there was a significant difference according to time ($p<0.05$). An interaction between time and group was observed ($p<0.05$) and was not significant in the post-hoc test ($p<0.025$). There was no significant difference between groups ($p>0.05$) (Table 2).

As a result of CRA measurement of the EGI and EGII groups, there were no significant differences before and after intervention within the group, and there was no interaction between the groups, time and groups before and after the intervention between the EGI and EGII groups. ($p>0.05$).

3.2 Pain

The results of comparison of the average values of the visual analog scale in the pre- and post-intervention pain tests of the both groups are as follows.

The open chain group showed a statistically significant decrease in score to 3.8±1.03 points before exercise and 2.9±1.29 points after exercise ($p<0.05$), and in the EGII, 4.3±2.31 points before exercise and 3.1±1.45 points after exercise with a statistically significant decrease in scores ($p<0.05$).

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

4. Discussion

This study confirmed the effects of open-chain scapular stabilization exercise and suspension scapular stabilization exercise classified according to duration on neck alignment and pain.

Based on the CVA comparisons within the groups before and after the intervention in this study, there was a significant difference between the two groups. In addition, based on the comparison of the durations of the open-chain group and the suspension exercise group, there was a significant difference in the time before and after the intervention. However, there was no significant difference between the groups themselves. Notably, an interaction between time and the groups was observed. Consequently, a post-hoc test was conducted. The result indicated no significant difference. As the value of CVA increases, the head is directed in the dorsal direction, and the lordosis of the neck decreases (Singla et al., 2017). Alpayci et al. (2016) reported that the decrease in lordosis is attributed to a weakness of the neck extensor muscles. Meanwhile, Schomacher and Falla (2013) reported higher fat concentrations in the neck extensors of patients with neck pain than in normal subjects. In a previous study targeting patients with such a decrease in lordosis, Alpayci and Ilter (2017) reported a significant recovery from loss of lordosis of the cervical vertebrae through isometric neck extension exercise. Evidently, this method can accelerate disc degeneration of the neck. Moreover, as an exercise to compensate for this condition, Lee et al. (2020) reported a significant recovery from cervical lordosis by controlling the muscle activity of the neck extensors through a neck extensor-strengthening exercise combined with a shoulder lift-in motion. Given that the intervention was conducted through retraction of the scapula without movement in the neck, it can be applied

without disc degeneration in the neck. Furthermore, the increase in the control ability of the trapezius muscle through the retraction of the shoulders was significant in the CVA before and after the intervention. It is thought to have brought about a decrease. Moreover, in a previous study targeting patients with neck pain, Schory et al. (2016) reported that the open-chain exercise produced more hyperactivity of the trapezius muscle than the suspension exercise, while Karabay et al. (2019) reported that the muscles around the shoulder Based on a review of the literature using activity as an evaluation tool, it was reported that suspension exercise reduced the activity of the upper trapezius muscle and increased the activity of the serratus anterior muscle, thereby facilitating selective muscle strengthening in the early stages of rehabilitation. Similarly, in this study, a significant decrease in CVA based on the period of shoulder retraction through the suspension exercise method compared to the open-chain method was found, that is, the suspension exercise method performed by fixing a distant part of the body that provided stability. This is thought to be due to the relatively small compensatory effect.

Based on the comparisons of CRA within the groups pre- and post-intervention in this study, there was no significant difference between the two groups. In addition, based on the comparison according to the duration of the open-chain group and the suspension group, there were no significant differences between the groups before and after the intervention, and there was no interaction according to time and group. CRA is a method used to check the degree of bending of the upper cervical vertebra in the sagittal plane, and the higher the CRA value, the more overextended the upper cervical vertebra (Raine & Twomey, 1997). In a previous study that reported changes in muscle activity around the neck and the alignment of the cervical vertebrae through an intervention that combined shoulder exercise and neck exercise for four weeks, the intervention using shoulder motion resulted in a significant decrease in CRA and improved lower trapezius and lower trapezius muscles compared to the control group. A significant increase in the activity of the serratus anterior muscle was also reported (Kim et al., 2011). These aforementioned results are in agreement with the results of this study in terms of a decrease in CRA, but unlike previous studies, a significant difference could not be confirmed in this study, which did not include a direct intervention on the neck. In another previous study, scapular stabilization exercise significantly lowered the excessive muscle activity of the upper trapezius and increased the muscle activity of the lower trapezius and serratus anterior muscles compared to the relaxation exercise of the scapula to correct neck alignment, This strategy has been reported to be helpful (Im et al., 2015). Nitayarak and Charntaraviroj (2021) attempted to improve the alignment of the shoulder and cervical vertebrae by relatively increasing the flexibility of the pectoralis minor muscle through the retracting motion used in scapular stabilization exercise and proved that it could be done. Similar to previous studies, the current research did not unveil any significant results. The reason for the improvement in CRA was that the shoulder scapular retraction, which is commonly used in the open and closed kinetic chain methods, improved the flexibility of the pectoralis minor muscle relatively. It is thought that the stability of the neck was secured according to the theory of Panjabi et al. (1998), namely, that at the same time the activity of the trapezius lower muscle was increased, the overactivity of the trapezius upper muscle was decreased, and the stability of the neck was constituted through the muscles related to the neck.

Based on the comparison of the pain scores before and after the intervention in this study, there was a significant decrease in the before and after scores in both groups. There was no significant difference in the pain scores between the groups. Chansirinukor et al. (2001) reported that the change in the kinematics of the scapula also increased the pain in the neck by changing the deformation of the scapula and the alignment of the spine. In addition, Andersen et al. (2014) reported a significant decrease in neck pain as a result of applying lower trapezius-strengthening exercise in a study on adults with chronic neck pain. reported to relieve pain. This is similar to the results of this study, and it is believed that the lower trapezius muscle, which was strengthened due to the retraction of the shoulder blade used as an intervention in this study, normalized the movement pattern of the shoulder blade and reduced neck pain.

The limitations of this study are as follows. First, it is difficult to generalize the study results because only 20 subjects were involved in the investigation. Second, the effects of long-term intervention could not be confirmed because the intervention period was not long (four weeks). Third, there is a possibility that it acted as a variable in the research results because the physical characteristics and living environments of the subjects could not be controlled. Finally, this study was not able to objectively apply the intensity of the intervention as a comparison between the open-chain method and the closed kinetic chain method. In the future, studies on various occupational

groups that can play an important role in neck pain should be undertaken. It is expected that additional long-term studies will be needed to verify the efficacy of the intervention effects after the end of the study.

References

[1] Toh, S. H., Coenen, P., Howie, E. K., & Straker, L. M. (2017). The associations of mobile touch screen device use with musculoskeletal symptoms and exposures: A systematic review. PloS one, 12(8), e0181220. https://doi.org/10.1371/journal.pone.0181220

[2] Öğrenci, A., Koban, O., Yaman, O., Dalbayrak, S., & Yılmaz, M. (2018). The Effect of Technological Devices on Cervical Lordosis. Open access Macedonian journal of medical sciences, 6(3), 467–471. https://doi.org/10.3889/oamjms.2018.107

[3] Jyothsna, G. Text Neck Syndrome in Adolescents: How to Stem the Tide?. International Journal of Pediatric Nursing IJPEN, 35.

[4] Samani PP, Athavale NA, Shyam A, Sancheti PK. Awareness of text neck syndrome in youngadult population. Int J Community Med Public Health. 2018 Aug;5(8):1-5

[5] Kendall, F. P. M. E., McCreary, E., & Provance, P. (1993). Muscles Testing and Function Baltimore. MD: Williams & Wilkins, 126.

[6] Keller, T. S., Colloca, C. J., Harrison, D. E., Harrison, D. D., & Janik, T. J. (2005). Influence of spine morphology on intervertebral disc loads and stresses in asymptomatic adults: implications for the ideal spine. The spine journal : official journal of the North American Spine Society, 5(3), 297–309. https://doi.org/10.1016/j.spinee.2004.10.050

[7] 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.

[8] Borden, A. B., Rechtman, A. M., & Gershon-Cohen, J. (1960). The normal cervical lordosis. Radiology, 74(5), 806-809. https://doi.org/10.1148/74.5.806

[9] Wei, W., Liao, S., Shi, S., Fei, J., Wang, Y., & Chen, C. (2013). Straightened cervical lordosis causes stress concentration: a finite element model study. Australasian physical & engineering sciences in medicine, 36(1), 27–33. https://doi.org/10.1007/s13246-013-0182-4

[10] Panjabi, M. M., Cholewicki, J., Nibu, K., Grauer, J., Babat, L. B., & Dvorak, J. (1998). Critical load of the human cervical spine: an in vitro experimental study. Clinical biomechanics (Bristol, Avon), 13(1), 11–17. https://doi.org/10.1016/s0268-0033(97)00057-0

[11] Ferrara L. A. (2012). The biomechanics of cervical spondylosis. Advances in orthopedics, 2012, 493605. https://doi.org/10.1155/2012/493605

[12] Harrison, D. E., Harrison, D. D., Janik, T. J., William Jones, E., Cailliet, R., & Normand, M. (2001). Comparison of axial and flexural stresses in lordosis and three buckled configurations of the cervical spine. Clinical biomechanics (Bristol, Avon), 16(4), 276–284. https://doi.org/10.1016/s0268-0033(01)00006-7

[13] Cheng, C. H., Cheng, H. Y., Chen, C. P., Lin, K. H., Liu, W. Y., Wang, S. F., Hsu, W. L., & Chuang, Y. F. (2014). Altered Co-contraction of Cervical Muscles in Young Adults with Chronic Neck Pain during Voluntary Neck Motions. Journal of physical therapy science, 26(4), 587–590. https://doi.org/10.1589/jpts.26.587

[14] Beinert, K., Keller, M., & Taube, W. (2015). Neck muscle vibration can improve sensorimotor function in patients with neck pain. The spine journal : official journal of the North American Spine Society, 15(3), 514–521. https://doi.org/10.1016/j.spinee.2014.10.013

[15] Sharma, R., Borkar, S. A., Goda, R., & Kale, S. S. (2019). Which factors predict the loss of cervical lordosis following cervical laminoplasty? A review of various indices and their clinical implications. Surgical neurology international, 10, 147. https://doi.org/10.25259/SNI_339_2019

[16] Kim, K. R., Lee, C. K., Park, J. Y., & Kim, I. S. (2020). Preoperative Parameters for Predicting the Loss of Lordosis After Cervical Laminoplasty. Spine, 45(21), 1476–1484. https://doi.org/10.1097/BRS.0000000000003604

[17] Alpayci, M., Şenköy, E., Delen, V., Şah, V., Yazmalar, L., Erden, M., Toprak, M., & Kaplan, Ş. (2016). Decreased neck muscle strength in patients with the loss of cervical lordosis. Clinical biomechanics (Bristol, Avon), 33, 98–102. https://doi.org/10.1016/j.clinbiomech.2016.02.014

[18] Wang, D., Ding, Y., Wu, B., Si, F., Yu, F., Xiao, B., & Liu, B. (2021). Cervical Extensor Muscles Play the Role on Malalignment of Cervical Spine: A Case Control Study With Surface Electromyography Assessment. Spine, 46(2), E73-E79.

[19] Castelein, B., Cools, A., Bostyn, E., Delemarre, J., Lemahieu, T., & Cagnie, B. (2015). Analysis of scapular muscle EMG activity in patients with idiopathic neck pain: a systematic review. Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology, 25(2), 371–386. https://doi.org/10.1016/j.jelekin.2015.01.006

[20] Cagnie, B., Struyf, F., Cools, A., Castelein, B., Danneels, L., & O'leary, S. (2014). The relevance of scapular dysfunction in neck pain: a brief commentary. The Journal of orthopaedic and sports physical therapy, 44(6), 435–439. https://doi.org/10.2519/jospt.2014.5038

[21] 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.

[22] Im, B., Kim, Y., Chung, Y., & Hwang, S. (2015). Effects of scapular stabilization exercise on neck posture and muscle activation in individuals with neck pain and forward head posture. Journal of physical therapy science, 28(3), 951-955.

[23] Nitayarak, H., & Charntaraviroj, P. (2021). Effects of scapular stabilization exercises on posture and muscle imbalances in women with upper crossed syndrome: A randomized controlled trial. Journal of back and musculoskeletal rehabilitation, 34(6), 1031–1040. https://doi.org/10.3233/BMR-200088

[24] Javdaneh, N., Letafatkar, A., Shojaedin, S., & Hadadnezhad, M. (2020). Scapular exercise combined with cognitive functional therapy is more effective at reducing chronic neck pain and kinesiophobia than scapular exercise alone: a randomized controlled trial. Clinical rehabilitation, 34(12), 1485–1496. https://doi.org/10.1177/0269215520941910

[25] Edwards C. M. (2021). Exercise Programs Targeting Scapular Kinematics and Stability Are Effective in Decreasing Neck Pain: A Critically Appraised Topic. Journal of sport rehabilitation, 30(6), 952–955. https://doi.org/10.1123/jsr.2020-0448

[26] Karabay, D., Emük, Y., & Özer Kaya, D. (2019). Muscle Activity Ratios of Scapular Stabilizers During Closed Kinetic Chain Exercises in Healthy Shoulders: A Systematic Review. Journal of sport rehabilitation, 29(7), 1001–1018. https://doi.org/10.1123/jsr.2018-0449

[27] 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.

[28] 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.

[29] Schory, A., Bidinger, E., Wolf, J., & Murray, L. (2016). A SYSTEMATIC REVIEW OF THE EXERCISES THAT PRODUCE OPTIMAL MUSCLE RATIOS OF THE SCAPULAR STABILIZERS IN NORMAL SHOULDERS. International journal of sports physical therapy, 11(3), 321–336.

[30] Horsak B, Kiener M, Pötzelsberger A, Siragy T. Serratus anterior and trapezius muscle activity during knee push-up plus and knee-plus exercises performed on a stable, an unstable surface and during sling-suspension. Phys Ther Sport. 2017 Jan;23:86-92. doi: 10.1016/j.ptsp.2016.08.003. Epub 2016 Aug 5. PMID: 27693098.

[31] Tucci, H. T., Felicio, L. R., McQuade, K. J., Bevilaqua-Grossi, D., Camarini, P. M., & Oliveira, A. S. (2017). Biomechanical Analysis of the Closed Kinetic Chain Upper-Extremity Stability Test. Journal of sport rehabilitation, 26(1), 42–50. https://doi.org/10.1123/jsr.2015-0071

[32] Chi, C. Y., & Kim, S. Y. (2019). Effects of sling exercise with vibration on range of motion, muscle strength, pain, disability in patients with shoulder injuries. Physical Therapy Korea, 26(3), 11-22.

[33] Park, J. J., & Chon, S. C. (2017). Comparison of the Effects of Closed Kinetic Chain Exercise and Open Kinetic Chain Exercise According to the Shoulder Flexion Angle on Muscle Activation of Serratus Anterior and Upper Trapezius Muscles During Scapular Protraction. Physical Therapy Korea, 24(4), 11-19.

[34] 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.

[35] 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.

[36] Sahrmann, S. (2001). Diagnosis and treatment of movement impairment syndromes. Elsevier Health Sciences.

[37] Diab,Aliaa A,and Ibrahim M Moustafa.(2011).Theefficacy offorward head correction on nerve root function and pain in cervical spondyloticradiculopathy:arandomizedtrial.ClinicalRehabilitation.

[38] Harman, Katherine, Cheryl Hubley-Kozey, and Heather Butler. (2005). Effectiveness of an exercise program to improve forward head posture in normal adults: A randomized,controlled 10-week trial. JournalofManual& ManipulativeTherapy13(3):163-76.

[39] Cole, B. (1994). Physical rehabilitation outcome measures. Canadian Physiotherapy Assn.

[40] Singla, D., Veqar, Z., & Hussain, M. E. (2017). Photogrammetric Assessment of Upper Body Posture Using Postural Angles: A Literature Review. Journal of chiropractic medicine, 16(2), 131–138. https://doi.org/10.1016/j.jcm.2017.01.005

[41] Alpayci, M., & İlter, S. (2017). Isometric Exercise for the Cervical Extensors Can Help Restore Physiological Lordosis and Reduce Neck Pain: A Randomized Controlled Trial. American journal of physical medicine & rehabilitation, 96(9), 621–626. https://doi.org/10.1097/PHM.0000000000000698

[42] Schomacher, J., & Falla, D. (2013). Function and structure of the deep cervical extensor muscles in patients with neck pain. Manual therapy, 18(5), 360–366. https://doi.org/10.1016/j.math.2013.05.009

[43] Lee, M. Y., Jeon, H., Choi, J. S., Park, Y., & Ryu, J. S. (2020). Efficacy of Modified Cervical and Shoulder Retraction Exercise in Patients With Loss of Cervical Lordosis and Neck Pain. Annals of rehabilitation medicine, 44(3), 210–217. https://doi.org/10.5535/arm.19117

[44] Raine, S., & Twomey, L. T. (1997). Head and shoulder posture variations in 160 asymptomatic women and men. Archives of physical medicine and rehabilitation, 78(11), 1215–1223. https://doi.org/10.1016/s0003-9993(97)90335-x

[45] Kim, E. J., Kim, J. W., & Park, B. R. (2011). Effects of sling exercise program on muscle activity and cervical spine curvature of forward head posture. The Journal of the Korea Contents Association, 11(11), 213-220.

[46] Chansirinukor, W., Wilson, D., Grimmer, K., & Dansie, B. (2001). Effects of backpacks on students: measurement of cervical and shoulder posture. The Australian journal of physiotherapy, 47(2), 110–116. https://doi.org/10.1016/s0004-9514(14)60302-0

[47] Andersen, C. H., Andersen, L. L., Zebis, M. K., & Sjøgaard, G. (2014). Effect of scapular function training on chronic pain in the neck/shoulder region: a randomized controlled trial. Journal of occupational rehabilitation, 24(2), 316-324.