Int. J. Morphol.,
43(2):373-378, 2025.

Is There Cervical Muscle Weakness in Patients with Loss of Cervical Lordosis? Morphometric Evaluation of Muscle Cross-Sectional Areas on MRI

¿Existe Debilidad Muscular Cervical en Pacientes con Pérdida de Lordosis Cervical? Evaluación Morfométrica de Áreas Transversales Musculares con Resonancia Magnética

Gülüzar Gül[1]; Ayla Tekin[2] & Özgür Çakır[2]

GÜL, G.; TEKIN, A. & ÇAKıR, Ö. Is there cervical muscle weakness in patients with loss of cervical lordosis? Morphometric evaluation of muscle cross-sectional areas on MRI. *Int. J. Morphol., 43(2)*:373-378, 2025.

SUMMARY: The objective of this study was to compare the relative cross-sectional area (R-CSA) of the cervical muscles of two groups of patients with chronic nonspecific neck pain, with and without cervical lordosis loss, and to investigate the morphologic differences and cervical intervertebral disc degeneration status between the groups. Additionally, the study aimed to examine the effect of cervical lordosis loss on R-CSA of the cervical muscles and disc degeneration. A total of 201 patients with chronic nonspecific neck pain were included in the study, comprising 91 patients with cervical lordosis loss and 100 patients without cervical lordosis loss. The R-CSAs of both the cervical flexor and extensor muscles were retrospectively measured separately in the superficial and deep groups on magnetic resonance imaging (MRI) to determine the disc degeneration status. The R-CSA of superficial flexor, deep flexors, superficial extensors, deep extensors, total extensors, total flexors, and total cervical spine muscles were found to be significantly lower in the lordosis group with cervical lordosis loss than in the straight group without cervical lordosis loss ($p < 0.01$). Additionally, a significantly higher CSATFs/CSATEs (ratio of total flexor cross-sectional area (CSA) to total extensor CSA) ratio was observed in the lordosis group compared to the straight group ($p < 0.01$). A significant positive correlation was also observed between the R-CSA of the flexor and extensor muscles in both the lordosis and straight groups ($p < 0.001$). It was demonstrated that patients exhibiting a loss of cervical lordosis exhibited a high prevalence of disc degeneration, a pronounced weakness in both cervical flexors and extensors, and an imbalance between the R-CSA of the cervical flexors and extensors, which was attributed to the weakness of the extensors.

KEYWORDS: Lordosis; MRI; Neck muscles.

INTRODUCTION

Neck pain has an annual prevalence of 30 % among musculoskeletal disorders and is the fourth leading cause of disability in adults (Kazeminasab *et al*., 2022). Neck pain with an unknown etiology and symptoms that persist for a duration exceeding three months is designated as nonspecific chronic neck pain (Cerezo-Téllez *et al*., 2018). The anterior convexity between the cervical vertebrae from the first thoracic vertebra to the foramen magnum is designated as cervical lordosis (Been *et al*., 2014). The etiology of loss of cervical lordosis remains unclear. However, clinical conditions such as muscle spasms, congenital defects, cervical trauma, cervical muscle weakness, and surgical complications have been reported to be associated with loss of cervical lordosis (Alpaycı & Ilter, 2017). Furthermore, the increasing prevalence of a sedentary lifestyle among the general population has led to an increased prevalence of forward head posture during activities such as television viewing, reading, driving, computer use, and smartphone usage. This forward head posture can result in strain on the cervical spine and imbalance in the cervical muscles, which may lead to loss of cervical lordosis and neck pain (Nishida *et al*., 2020). In the event of a loss of cervical lordosis, the axial load may shift forward, resulting in several undesirable symptoms, including neck pain, shoulder pain, degeneration of the intervertebral disc, radiculopathy, and

[1] Department of Anatomy, Faculty of Medicine, Kocaeli University, Kocaeli, Turkey.
[2] Department of Radiology, Faculty of Medicine, Kocaeli University, Kocaeli, Turkey.

Received: 2024-06-16 Accepted: 2024-12-20

myelopathy (Okada *et al*., 2009). As disc degeneration progresses, it can lead to herniation and spinal canal stenosis, which in turn can result in a high cost of surgical treatment (Duman *et al*., 2014; Yuksel *et al*., 2022). However, the stability of the cervical spine is provided by the neck muscles (80 %) rather than the bones and ligaments (20 %), and a reduction in the strength of the cervical muscles can result in instability of the vertebral column and a loss of cervical lordosis (Panjabi *et al*., 1998; Beinert *et al*., 2015).

Magnetic resonance imaging (MRI) has been recognized as the gold standard for muscle imaging and measurement of muscle CSA (cross-sectional area) from MRI images provides an objective and non-invasive assessment of muscle atrophy and hypertrophy (Oksanen *et al*., 2008). The objective of this study is to compare the degree of disc degeneration and relative cross-sectional area (R-CSA) of the cervical muscles as observed on MRI scans of patients presenting with chronic neck pain. The study will examine two groups: those with normal cervical lordosis and those with loss of cervical lordosis. The aim is to provide information on whether there is cervical spine muscle weakness or a mismatch between cervical flexor and extensor group muscles and cervical intervertebral disc degeneration status in the group with loss of cervical lordosis. Additionally, our objective is to offer a novel perspective on existing studies and contribute to the treatment of individuals with cervical lordosis loss.

MATERIAL AND METHOD

Study participants: A total of 1,281 patients who applied to the Kocaeli University Faculty of Medicine Research and Application Hospital between 2020 and 2022 with a complaint of chronic neck pain and underwent cervical spine MRI were retrospectively evaluated. The following criteria were used to exclude patients from the study: previous cervical spine surgery, cervical trauma, congenital defects, myelopathy, diseases that may affect cervical spine posture, such as spinal cord tumors, rheumatologic/ autoimmune diseases, such as rheumatoid arthritis or ankylosing spondylitis, and inadequate medical records. Finally, 1,080 patients who met the exclusion criteria were excluded from the study, and a total of 201 patients aged between 18 and 65 years were included. We recorded the demographic characteristics of the patients including age, gender and background from the patients' files. The study was approved by Kocaeli University Non-Interventional Ethics Committee with the decision number KÜ GOKAEK 2021/22.25 and project number 2021/361.The study was conducted in accordance with the principles of the Declaration of Helsinki.

MRI procedure: All patients who met the inclusion criteria underwent cervical spine MRI scans, which were obtained from the hospital's Picture Archiving and Communications System (PACS) radiographic system. The images were obtained using a 1.5T MR imaging device (GE Healthcare, Milwaukee, Wisconsin) in the standard neutral position. The measurement parameters consisted of 14 slices with a slice thickness of 4 mm, a field of view of 160 × 160 mm, a repetition time/echo time of 4438/116 ms, and a matrix size of 160 × 256. Patients were divided into two groups based on the C2-C7 Cobb angle value in the cervical MRI results. Those with a loss of cervical lordosis were classified as the lordosis group (C2-C7 Cobb angle >10º, n=91), while those with a normal cervical lordosis were classified as the straight group (C2-C7 Cobb angle ≤10º, n=110) (Zhang *et al*., 2022). The presence or absence of C4/5 disc degeneration was recorded by examining simultaneous sagittal T2 and axial T1 images on the PACS system. The presence of degenerative changes is indicated by the observation of low-intensity alterations in the nucleus pulposus, the degeneration of the annulus fibrosus, the bulging, herniation, or the reduction of more than a quarter of the height of the cervical intervertebral disc (Suzuki *et al*., 2018).

CSA of the cervical muscles was measured according to the technique used in previous studies, independently of each other and under the supervision of 2 radiologists experienced in cervical MR evaluation and blinded to the clinical information of the patients. CSA of the cervical muscles was measured on axial T2- and T1-weighted images at the upper vertebral endplate of the C4/5 intervertebral level. A region of interest (ROI) was delineated for each muscle bilaterally using Synapse software. The CSA of the superficial cervical extensors was quantified by manually delineating the ROI boundaries, with a vertical line extending from the lateral margin of the ipsilateral facet serving as the lateral margin for the ROI. Bilaterally, the deep cervical flexors (DFs) formed by the longus cervicis and longus capitis, the superficial cervical flexor (SF) formed by the sternocleidomastoideus, the deep cervical extensors (DEs) formed by the multifidus cervicis and semispinalis cervicis (DEs) and superficial cervical extensors (SEs) formed by splenius capitis and semispinalis capitis and trapezius descendens were measured and recorded in square millimeters (mm^2) (Fig. 1) (Li *et al*., 2020). It is possible that muscle cross-sectional areas may differ according to body fat percentage. To control for this discrepancy, the aforementioned areas were divided by the C5 vertebral body area (VBA) and the muscle CSAs/VBAs were calculated separately. These were defined as R-CSAs. The mean bilateral R-CSAs were calculated for the total

cervical spine muscles (R-CSA_{TCMs}), total extensors (R-CSA_{TEs}), total flexors (R-CSA_{TFs}), superficial extensors (R-CSA_{SEs}), superficial flexor (R-CSA_{SF}), deep extensors (R-CSA_{DEs}) and deep flexors (R-CSA_{DFs}) at the C4/C5 intervertebral level. In order to demonstrate the relationship between the cervical muscle groups at the same level, the CSATFs/CSATEs (ratio of total flexor CSA to total extensor CSA) was also calculated.

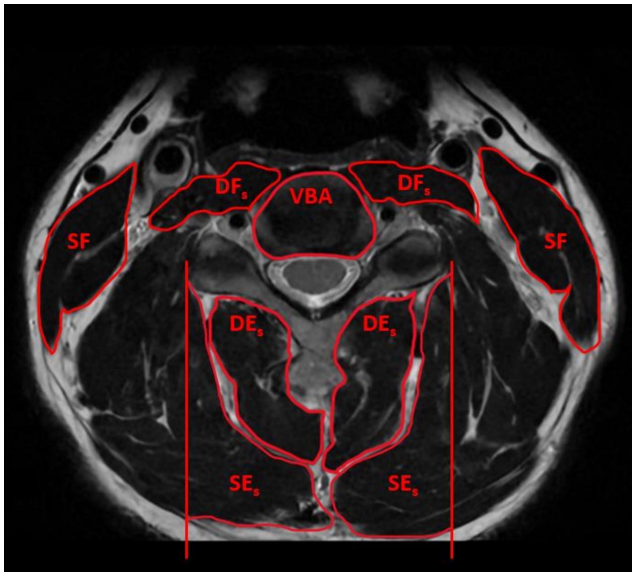

Fig. 1. Measurements of the cervical muscles areas on axial T2 and T1 weighted passing through the C4/5 intervertebral disc level. DEs: deep extensors, DFs: deep flexors, SEs: superficial extensors, SF: superficial flexor, VBA: vertebral body area.

Data analysis: The statistical evaluation was conducted using IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA). The compliance with normal distribution was analyzed by means of the Shapiro-Wilk and Kolmogorov-Smirnov tests. Variables that exhibited a normal distribution were expressed as the mean ± standard deviation. Variables that did not exhibit a normal distribution were expressed as the median (25th-75th percentile). The categorical variables were expressed as frequencies (percentages). The differences between the groups were determined by either an independent sample t-test or a Mann-Whitney U test, depending on the assumption of normal distribution. The relationships between categorical variables were determined by means of a Chi-square analysis. The relationships between numerical variables were determined by Pearson correlation analysis. In hypothesis testing, a p-value of less than 0.05 was deemed sufficient for statistical significance.

RESULTS

The mean ages of the straight group and the lordosis group were 43.14 ± 8.97 and 42.75 ± 9.31 years, respectively. There was no significant difference between the groups in terms of age ($p > 0.05$). The straight group comprised 57 female (51.8 %) and 53 male (48.2 %) patients, while the lordosis group included 64 female (70.3 %) and 27 male (29.7 %) patients. There was a significant difference between the groups in terms of gender ($p < 0.05$). A total of 54 patients (49.1 %) exhibited C4/5 disc degeneration in the straight group, while 82 patients (90.1 %) exhibited this condition in the lordosis group. This difference between the groups was statistically significant ($p < 0.001$) (Table I).

Table I. Demographic data and disc degeneration status.

	Straight group (n = 110) Mean ±SD	Lordosis group (n = 91) Mean ±SD	p
Age (years)	43.14 ±8.97	42.75 ±9.31	0.764
	n (%)	n (%)	p
Sex (M/F)	57 (51.8) /53 (48.2)	64 (70.3)/27 (29.7)	0.009
C4/5 disc degeneration	54 (49,1)	82 (90.1)	0.000

M: male; F: female; SD: Standard deviation; p: p value.

The lordosis group exhibited significantly smaller values for R-CSADFs, R-CSASF, R-CSADEs, R-CSASEs, R-CSATEs, R-CSATCMs, and R-CSATFs than the straight group ($p < 0.01$). Furthermore, the lordosis group exhibited a higher CSATFs/CSATEs ratio than the straight group, with a statistically significant difference ($p < 0.01$) (Table II).

Table II. Comparison of R-CSAs of cercical muscles in two groups.

	Straight group (n=110) Mean± SD	Lordosis group (n=91) Mean± SD	p
R-CSA_{DFs}	1.01±0.24	0.89± 0.20	0.000[a]
R-CSA_{SF}	2.83± 0.68	2.58± 0.57	0.006[a]
R-CSA_{DEs}	2.03± 0.46	1.82± 0.41	0.001[a]
R-CSA_{SEs}	3.69± 1.02	2.94± 0.78	0.000[a]
R-CSA_{TEs}	5.72± 1.31	4.77± 1.02	0.000[a]
R-CSA_{TCMs}	9.59± 1.98	8.24± 1.56	0.000[a]
CSA_{TFs}/CSA_{TEs}	0.68± 0.12	0.74± 0.12	0.002[a]
	Median (25th- 75th percentile)	Median (25th- 75th percentile)	p
R-CSA_{TFs}	3.81 (3.20- 4.52)	3.38 (3.04- 3.89)	0.001[b]

M: male; F: female; a: Independent Sample t Test; b:Mann Whitney U Test.

A moderate positive correlation was observed between R-CSA_{DFs} and R-CSA_{DEs}, as well as between R-CSA_{SF} and R-CSA_{SEs}, in both the straigth and lordosis groups ($p<0.001$; Table III).

Table III. Correlation between R-CSA_{DFs} and R-CSA_{DEs}, an R-CSA_{SF} and R-CSA_{SEs} in two groups.

	R-CSA_{DEs}					R-CSA_{SEs}			
	Straight group		Lordosis group			Straight group		Lordosis group	
	r	p	r	p		r	p	r	p
R-CSA_{DFs}	0.423	0.000	0.431	0.000	R-CSA_{SF}	0.556	0.000	0.532	0.000

Pearson correlation analysis was performed; p: p value; r: correlation coefficient.

DISCUSSION

A review of the literature revealed no studies that had investigated the morphologic differences by measuring the R-CSAs of both cervical flexor and cervical extensor muscles in patients with chronic non-specific neck pain with and without cervical lordosis loss, nor had any studies compared the cervical intervertebral disc degeneration status. A comparison of the demographic characteristics between the groups in our study revealed that there was no significant difference in age between the group without cervical lordosis loss and the group with cervical lordosis loss. This finding is consistent with the literature and indicates that age does not influence the observed differences in our results (Alpayci *et al*., 2016; Yoon *et al*., 2018). Given that chronic neck pain and loss of cervical lordosis are more prevalent in women, we observed a markedly higher prevalence of female patients in the group with cervical lordosis loss (Helliwell *et al*., 1994; Rajalaxmi *et al*., 2019). In addition to the sagittal alignment of the cervical spine, other risk factors for discdegeneration include smoking, heavy physical labor, and genetics (Zielinska *et al*., 2021). The results of our study indicated a significant difference between the two groups in terms of C4/5 disc degeneration. The group with cervical lordosis loss exhibited a considerably higher rate of patients with C4/5 disc degeneration. In conclusion, it can be stated that misalignment of the cervical spine results in degeneration of the intervertebral disc (Gao *et al*., 2019). In the group without cervical lordosis loss, C4/5 disc degeneration was observed in approximately 45 % of patients. This may be attributed to the fact that cervical intervertebral disc degeneration is the primary cause of chronic neck pain (Peng & DePalma, 2018).

Yoon *et al*. (2018), compared the CSA of some cervical muscles between 40 patients with cervical lordosis loss and two groups without cervical lordosis loss, and found that the CSA of semispinalis capitis, which is one of the superficial extensors, was significantly lower in the group with loss of cervical lordosis. The results of our study indicate that the R-CSA of all flexor and extensor group muscles in patients with cervical lordosis loss was significantly lower than in the group without cervical lordosis loss. It can be concluded that the observed difference is a consequence of the larger number of patients included in the present study compared to the other study. They also found that the ratio of the CSA of flexor muscles to the CSA of extensor muscles was significantly higher in patients with cervical lordosis loss. The results of our study indicate that the R-CSA of both flexor and extensor muscles of the cervical spine is significantly lower in patients with cervical lordosis loss. This finding suggests that there is a significant weakness in both neck extensors and flexors in patients with cervical lordosis loss, which is consistent with the existing literature (Alpayci *et al*., 2016). The results of our study indicate that the question of whether the general atrophy of the cervical spine muscles is a cause or consequence of the loss of cervical lordosis remains unresolved. Furthermore, this may also be attributed to dysfunction of the anterior horn cells as a result of dynamic compression. A second finding was that the CSATFs/CSATEs was higher in the group of patients with loss of cervical lordosis. This indicates that the strength of the total flexors and extensors is incompatible. This suggests that the degree of atrophy in the extensors is more pronounced than that in the flexors in patients with cervical lordosis loss. The present study has demonstrated the existence of an imbalance between the R-CSA of the cervical flexors and extensors in patients with cervical lordosis loss caused by weakness in the extensors. For the stability of the cervical spine, there should be a harmonious force between the flexors and extensors (Cheng *et al*., 2008). Zhang *et al*. (2024) demonstrated that cervical extensor strengthening exercises enhanced the CSA of cervical extensor muscles, alleviated pain, and facilitated the restoration of cervical lordosis in 70 young adults with chronic nonspecific neck pain. Consequently, the strengthening of the cervical spine muscles and the maintenance of harmony between the flexor and extensor muscles can result in the improvement of lordosis loss and the prevention of further loss of lordosis.

The results of our study indicate a positive correlation between the CSAs of flexor and extensor

muscles in both groups. This suggests that an increase in the CSA of flexor muscles is accompanied by an increase in the CSA of extensor muscles, or vice versa. It can be posited that exercises designed to strengthen the flexor cervical muscles will simultaneously strengthen the extensor cervical muscles and vice versa. Similarly, it can be argued that exercises designed to strengthen the extensor cervical muscles will also strengthen the flexor cervical muscles. Although it has been proposed that isometric exercise of the cervical extensors can correct the lordotic angle of the cervical spine and reduce neck pain in patients with loss of cervical lordosis, its application in flexion may accelerate disc degeneration. Furthermore, it has been documented that the direct transmission of force to the disc during cervical muscle strengthening exercises may precipitate disc degeneration (Alpayci & Ilter, 2017). In light of the aforementioned issues, an alternative approach was taken, whereby the exercise designed to strengthen the neck retraction muscles was modified to include the head being elevated in order to prevent upper cervical flexion, rather than maintaining a straight head position while pushing the head and neck backward. Modified neck and shoulder retraction exercises that strengthen the neck and shoulder retraction muscles have been demonstrated to enhance cervical lordosis and alleviate neck pain (Lee *et al*., 2020).

CONCLUSIONS

In patients presenting with loss of cervical lordosis and chronic neck pain, it is of paramount importance to diagnose disc degeneration and changes in the muscle area at an early stage, in order to prevent further deterioration and to treat the condition without the necessity for surgical intervention. It is recommended that a rehabilitation program be implemented, in which modified neck and shoulder retraction exercises are utilized instead of cervical extensor muscle strengthening exercises. This approach is intended to correct the imbalance between flexor and extensor muscles, which is caused by weakness in the extensor muscles. The objective is to prevent further worsening of the disc degeneration in the majority of patients with cervical lordosis loss.

Our study has some limitations. Firstly, in some patients, the lateral margins of the superficial extensors were not clearly visible on MRI scans. Consequently, a vertical line was drawn from the lateral margin of the ipsilateral facet instead of the true lateral margins. Secondly, it is important to note that the posture of the cervical spine is also related to the posture of other parts of the spine. Therefore, future studies should pay attention to the effect of overall sagittal balance on cervical lordosis and cervical muscle imbalance.

GÜL, G.; TEKIN, A. & ÇAKıR, Ö. ¿Existe debilidad muscular cervical en pacientes con pérdida de lordosis cervical? Evaluación morfométrica de las áreas transversales musculares con resonancia magnética. *Int. J. Morphol., 43(2)*:373-378, 2025.

RESUMEN: El objetivo de este estudio fue comparar el área transversal relativa (R-CSA) de los músculos cervicales de dos grupos de pacientes con dolor cervical crónico inespecífico, con y sin pérdida de lordosis cervical, e investigar las diferencias morfológicas y el estado de degeneración del disco intervertebral cervical entre los grupos. Además, el estudio tuvo como objetivo examinar el efecto de la pérdida de lordosis cervical en la R-CSA de los músculos cervicales y la degeneración del disco. Se incluyó en el estudio a un total de 201 pacientes con dolor cervical crónico inespecífico, que comprendían 91 pacientes con pérdida de lordosis cervical y 100 pacientes sin pérdida de lordosis cervical. Las R-CSA de los músculos flexores y extensores cervicales se midieron retrospectivamente por separado en los grupos superficial y profundo en imágenes por resonancia magnética (IRM) para determinar el estado de degeneración del disco. Se encontró que el R-CSA de los músculos flexores superficiales, flexores profundos, extensores superficiales, extensores profundos, extensores totales, flexores totales y músculos totales de la columna cervical era significativamente menor en el grupo de lordosis con pérdida de lordosis cervical que en el grupo recto sin pérdida de lordosis cervical ($p < 0,01$). Además, se observó una relación CSATFs/CSATEs (relación del área transversal total del flexor (CSA) al CSA total del extensor) significativamente mayor en el grupo de lordosis en comparación con el grupo sin lordosis ($p < 0,01$). También se observó una correlación positiva significativa entre el R-CSA de los músculos flexores y extensores tanto en el grupo de lordosis como en el grupo sin lordosis ($p < 0,001$). Se demostró que los pacientes que presentaban una pérdida de lordosis cervical presentaban una alta prevalencia de degeneración discal, una debilidad pronunciada tanto en los flexores como en los extensores cervicales y un desequilibrio entre la R-CSA de los flexores y extensores cervicales, que se atribuyó a la debilidad de los extensores.

PALABRAS CLAVE: Lordosis; RNM; Músculos del cuello.

REFERENCES

Alpayci, M. & Ilter, S. Isometric exercise for the cervical extensors can help restore physiological lordosis and reduce neck pain: a randomized controlled trial. *Am. J. Phys. Med. Rehabil., 96(9)*:621-6, 2017.

Alpayci, M.; S¸enköy, E.; Delen, V.; S¸ah, V.; Yazmalar, L.; Erden, M.; Toprak, M. & Kaplan, S¸. Decreased neck muscle strength in patients with the loss of cervical lordosis. *Clin. Biomech. (Bristol, Avon), 33*:98-102, 2016.

Been, E.; Shefi, S.; Zilka, L. & Soudack, M. Foramen magnum orientation and its association with cervical lordosis: a model for reconstructing cervical curvature in archeological and extinct hominin specimens. *Adv. Anthropol., 4(4)*:133-40, 2014.

Beinert, K.; Keller, M. & Taube, W. Neck muscle vibration can improve sensorimotor function in patients with neck pain. *Spine J., 15(3)*:514-21, 2015.

Cerezo-Téllez, E.; Torres-Lacomba, M.; Mayoral-Del-Moral, O.; Pacheco-da-Costa, S.; Prieto-Merino, D. & Sánchez-Sánchez, B. Health related quality of life improvement in chronic non-specific neck pain: secondary analysis from a single blinded, randomized clinical trial. *Health Qual. Life Outcomes, 16(1)*:207, 2018.

Cheng, C. H.; Lin, K. H. & Wang, J. L. Co-contraction of cervical muscles during sagittal and coronal neck motions at different movement speeds. *Eur. J. Appl. Physiol., 103(6)*:647-54, 2008.

Duman, F.; Ziylan, T.; Kiresi, D.; Çiçekcibas¸ı, A. E.; Büyükmumcu, M. & Duman, T. A comparative analysis of surface areas and ratio of the cervical spinal cord and the vertebral canal at the same levels via MRI on healthy individuals. *Int. J. Morphol., 32(4)*:1171-8, 2014.

Gao, K.; Zhang, J.; Lai, J.; Liu, W.; Lyu, H.; Wu, Y.; Lin, Z. & Cao, Y. Correlation between cervical lordosis and cervical disc herniation in young patients with neck pain. *Medicine (Baltimore), 98(31)*:e16545, 2019.

Helliwell, P. S.; Evans, P. F. & Wright, V. The straight cervical spine: does it indicate muscle spasm? *J. Bone Joint Surg. Br., 76(1)*:103-6, 1994.

Kazeminasab, S.; Nejadghaderi, S.A.; Amiri, P.; Pourfathi, H.; Araj-Khodaei, M.; Sullman, M. J. M.; Kolahi, A. A. & Safiri, S. Neck pain: global epidemiology, trends and risk factors. *BMC Musculoskelet. Disord., 23(1)*:26, 2022.

Lee, M. Y.; Jeon, H.; Choi, J. S.; Park, Y. & Ryu, J. S. Efficacy of modified cervical and shoulder retraction exercise in patients with loss of cervical lordosis and neck pain. *Ann. Rehabil. Med., 44(3)*:210-7, 2020.

Li, Z.; Zhang, W.; Wu, W.; Wei, C.; Chen, X. & Lin, J. Is there cervical spine muscle weakness in patients with Hirayama disease? A morphological study about cross-sectional areas of muscles on MRI. *Eur. Spine J., 29(5)*:1022-8, 2020.

Nishida, N.; Izumiyama, T.; Asahi, R.; Iwanaga, H.; Yamagata, H.; Mihara, A.; Nakashima, D.; Imajo, Y.; Suzuki, H.; Funaba, M.; *et al*. Changes in the global spine alignment in the sitting position in an automobile. *Spine J., 20(4)*:614-620, 2020.

Okada, E.; Matsumoto, M.; Ichihara, D.; Chiba, K.; Toyama, Y.; Fujiwara, H.; Momoshima, S.; Nishiwaki, Y.; Hashimoto, T.; Ogawa, J.; *et al*. Does the sagittal alignment of the cervical spine have an impact on disk degeneration? Minimum 10-year follow-up of asymptomatic volunteers. *Eur. Spine J., 18(11)*:1644-51, 2009.

Oksanen, A.; Erkintalo, M.; Metsähonkala, L.; Anttila, P.; Laimi, K.; Hiekkanen, H.; Salminen, J. J.; Aromaa, M. & Sillanpää, M. Neck muscles' cross-sectional area in adolescents with and without headache- MRI study. *Eur. J. Pain, 12(7)*:952-9, 2008.

Panjabi, M. M.; Cholewicki, J.; Nibu, K.; Grauer, J.; Babat, L. B. & Dvorak, J. Critical load of the human cervical spine: an in vitro experimental study. *Clin. Biomech. (Bristol, Avon), 13(1)*:11-7, 1998.

Peng, B. & DePalma, M. J. Cervical disc degeneration and neck pain. *J. Pain Res., 11*:2853-7, 2018.

Rajalaxmi, V.; Paul, J.; Abraham, M. M. & Sasirekha, M. Efficacy of endurance vs isometric neck exercise in chronic non-specific neck pain: A RCT. *Indian J. Forensic Med. Pathol., 12(2)*:147-51, 2019.

Suzuki, A.; Daubs, M. D.; Hayashi, T.; Ruangchainikom, M.; Xiong, C.; Phan, K.; Scott, T. P. & Wang, J. C. Patterns of cervical disc degeneration: analysis of magnetic resonance imaging of over 1000 symptomatic subjects. *Global Spine J., 8(3)*:254-9, 2018.

Yoon, S. Y.; Moon, H.I.; Lee, S. C.; Eun, N. L. & Kim, Y. W. Association between cervical lordotic curvature and cervical muscle cross-sectional area in patients with loss of cervical lordosis. *Clin. Anat., 31(5)*:710-5, 2018.

Yuksel, Y.; Ergun, T. & Torun, E. Relationship between cervical posterior subcutaneous fat tissue thickness and the presence and degree of cervical intervertebral disc degeneration. *Medicine (Baltimore), 101(28)*:e29890, 2022.

Zhang, L.; Cui, Z.; Yuan, C.; Zhang, X.; Ren, Z.; Wang, W.; Xia, P. & Zhu, R. Correlation between C7-T1 intervertebral foramen area and sagittal parameters in patients with cervical spondylotic myelopathy. *Orthop.Surg., 14(11)*:3003-8, 2022.

Zhang, Y.; Lin, W.; Yi, M.; Song, J. & Ding, L. Effect of long-term cervical extensor exercise program on functional disability, pain intensity, range of motion, cervical muscle mass, and cervical curvature in young adult population with chronic non-specific neck pain: a randomized controlled trial. *J. Orthop. Surg. Res., 19(1)*:9, 2024.

Zielinska, N.; Podgórski, M.; Haladaj, R.; Polguj, M. & Olewnik, L. Risk factors of intervertebral disc pathology-A point of view formerly and today-a review. *J. Clin. Med., 10(3)*:409, 2021.

Corresponding author:
Gülüzar Gül
Department of Anatomy
Faculty of Medicine
Kocaeli University
Umuttepe Campus
41380, Izmit/Kocaeli
TURKEY

E-mail: guluzarbny@gmail.com