ORIGINAL ARTICLE

Nr 2023;13 (4):578-585

Comparing Ultrasonography Changes of Semispinalis Capitis Muscle Thickness in Forward Head Posture Subjects with and Without Pain: An Observational Study

Marzieh Mortezanejad[1,2], Roghayeh Mohammadi[1], Rozita Hedayati[1]

[1] *Neuromuscular Rehabilitation Research Center, Semnan University of Medical Sciences, Semnan, Iran*
[2] *School of Rehabilitation, Shahidbeheshti University of Medical Sciences, Tehran, Iran*

CORRESPONDING AUTHOR:
Roghayeh Mohammadi
Neuromuscular Rehabilitation Research Center
Semnan University of Medical Sciences
Qods Street
Semnan, Iran
E-mail: mohamadipt@gmail.com

DOI:
10.32098/mltj.04.2023.09

LEVEL OF EVIDENCE: 2

SUMMARY

Objective. FHP people showed a reduced Semi-Spinalis Capitis muscle (SECM) size in maximal isometric voluntary contraction (MVIC). Also, other studies showed less thickness of this muscle at rest in individuals with pain. So, this muscle must be paramount in subjects with FHP-accompanied neck pain in contraction.

Materials and methods. We carried out this observational study with the participation of fifty people with a forward head posture divided into two groups: those with neck pain and those who didn't have neck pain, with a cut-off point of 3 on the VAS. Ultrasonography was used to measure the thickness of the SECM at rest and during maximum isometric contraction in a neutral position.

Rest and maximum isometric SECM thickness were normalized using the subject's body weight. For analysis, an independent t-test was used.

Results. There was a significant difference in SECM muscle size in MVIC and thickness difference (muscle contraction thickness minus muscle rest thickness) between the two groups ($p = 0.043$; $p = 0.024$, respectively). However, there is no significant difference in the resting thickness of SECM between groups ($p > 0.05$).

Conclusions. There is an alteration in SECM muscle size in maximum isometric contraction in FHP subjects with pain, while FHP people without pain didn't show this alteration. Both groups showed a similar alteration in the thickness of the SECM at rest.

KEY WORDS

Forward head posture; maximum voluntary isometric contraction; neck pain; semi spinalis capitis muscle; ultrasonography.

INTRODUCTION

Neck deviations from the plumb line are considered forward head posture (FHP) (1). People with FHP have a lower craniovertebral angle (2). The craniovertebral angle is the intersection of an even line running through the C7 spinous process and a line interfacing the midpoint of the tragus of the ear to the skin on the C7 spinous process (3). A lower craniovertebral angle from the expected value (50°) (2) has expanded pain and trigger points within the sub-occipital muscles but not in all FHP individuals (4, 5).

The essential neck extensor muscle is the Semi-Spinalis Capitis Muscle (SECM) (6). SECM, in its neutral anatomical position, has been found to donate an appropriate muscle length for extension (7). According to a past study, there's a relationship between neck extensor muscle strength and the cross-sectional zone of the SECM (8). Strategies, such as ultrasonography imaging, analyze muscle morphology by measuring muscle thickness quickly and non-costly (9). One study showed this muscle has fewer changes at maximal contraction than other sub-occipital muscles in FHP

individuals than in non-FHP people (10). Also, a few studies have shown that this muscle has less thickness at rest in people with neck pain and FHP (11, 12). So, this muscle must be fundamental for subjects with FHP-accompanied neck pain.

A few investigations examined the SECM size in people with neck pain in the neutral position at rest through ultrasonography (11-14). Subjects with neck pain reported a smaller SECM size (11, 12). But others found no critical changes in SECM size between subjects with and without pain at the neutral rest position (13, 14). These irregularities may emerge from not separating subjects based on whether or not they have FHP.

One of the essential variables related to neck pain is muscle weakness (15-18). Pain may predispose people to decrease pressure against MVIC (maximal voluntary isometric contraction) (18). There's a positive correlation between the thickness and strength of neck muscles, consistent with real-time ultrasonography examinations of sub-occipital muscles (7, 11, 19, 20). It appears, in real-time ultrasonography during MVIC, people with neck pain should be shown smaller muscle sizes (21).

So far, one study has investigated the magnitude of strength in SECM in real-time contraction via load cell, not via ultrasonography (11). Rezasoltani *et al*. reported that the MVIC of SECM at rest is lower in people with neck pain than in subjects without pain (11). So, people with neck pain may have a smaller SECM in real ultrasonography at MVIC. So, they did not investigate the relationship between SECM strength and SECM size in MVIC via real-time ultrasonography.

Therefore, since most past investigations have compared subjects with and without FHP in the rest state but not in the maximal contraction state via ultrasonography (10-12, 22, 23), and in addition, these studies do not compare these muscles based on the presence or no presence of pain, in FHP individuals, this study aimed to investigate if there is a difference in SECM thickness between FHP subjects with and without pain.

METHODS

Study design

In this observational study, 50 participants with FHP, with or without pain, underwent ultrasonography imaging of the SECM. This study has been conducted following the principles outlined in the Helsinki Declaration. The local University's Ethical Committee of Semnan University of Medical Sciences accepted the study's experimental techniques by number IR.SEMUMS.REC.1398.26. Before participating in the study, all subjects signed a written informed consent form.

Participants

Fifty people with FHP (age: FHP group 42.56 ± 1.33, Non-FHP group 39.44 ± 1.91, Weight: FHP group 78.36 ± 3.82, Non-FHP group 78.52 ± 3.24, Height: FHP group 159.88 ± 1.883, Non-FHP group 166.04 ± 1.77) participated in this study. The participants were selected using an available non-random sampling method. Participants were divided into two groups based on VAS < 3 or VAS > 3: 1-FHP with pain and 2-FHP without pain. In both groups, the subjects and the analyzer were blinded to the groups. Subjects were included in the study if they had neck pain and a craniovertebral angle of fewer than 50 degrees (2). They were excluded if they had a history of cervical spine trauma, inflammatory or infectious disorders, congenital spinal deformities, or disc bulging (24-26). The subjects in both groups were matched in age, body mass index, and height (**table I**).

Table I. Normality with Kolomogrov-Smirnov test.

Variable	Group	n	Statistic	P-value
Age	1	25	0.158	0.110
	2	25	0.086	0.2
Weight(kg)	1	25	0.145	0.189
	2	25	o.135	0.2
Height(cm)	1	25	0.133	0.2
	2	25	0.149	0.156
CVA (degree)	1	25	0.205	0.008
	2	25	0.209	0.006
Normalized Rest SECM thickness(mm)	1	25	0.085	0.2
	2	25	0.083	0.2
Normalized Contracted SECM thickness (mm)	1	25	0.122	0.2
	2	25	0.169	0.063

1: FHP group with pain; 2: FHP group without pain.

Setting

The subjects sat on the table with their arms resting on their thighs to measure the craniovertebral angle. C7's spinous process was palpated, and a conical adhesive marker was used to identify it. The patients were then asked to execute three rounds of head flexion and extension to determine their self-balanced head posture (27). At a distance of 1.5 meters from each subject's shoulder, a digital camera (Canon model IXUS, Canon, Tokyo, Japan) was located. Digital lateral view photographs of each participant's head, neck, and shoulder were taken for further measurement. The junction of a horizontal line running through the C7 spinous process and a line connecting the midpoint of the tragus of the ear to the skin atop the C7 spinous process were used to calculate the craniovertebral angle (3). The FHP detected a craniovertebral angle of fewer than 50 degrees (2) (**figure 1**). The AutoCAD Software Version 12 was used to make the measurements (Autodesk, San Rafael, California).

Figure 1. Craniovertebral measurement in FHP.

Ultrasonography

Ultrasonography imaging 1800 (Ultrasonix Medical Corporation, Honda, Japan) with a linear 4.5-cm and 7.5-10 MHz transducer was used to image the SECM. The subjects were instructed to sit in a chair with their sternal notch, chin, and nasal tip vertically aligned. From the side view, the head and neck were kept neutral. Participants were instructed to sit comfortably on a chair with their hands on their legs and their gaze directed ahead, keeping their heads and necks in a neutral position. Through palpation, the third cervical (C3) spinous process was detected (28). It was aligned with the angle of the mandible. As a result, the transducer was positioned transversely at the level of the C3 spinous process. It was slowly dragged upward until the echogenic image could be identified. SECM thickness was observed at the same level at rest and MVIC. The maximum distance between the muscle's fascia boundaries was used to determine the thickness (**figure 2**) (29, 30).

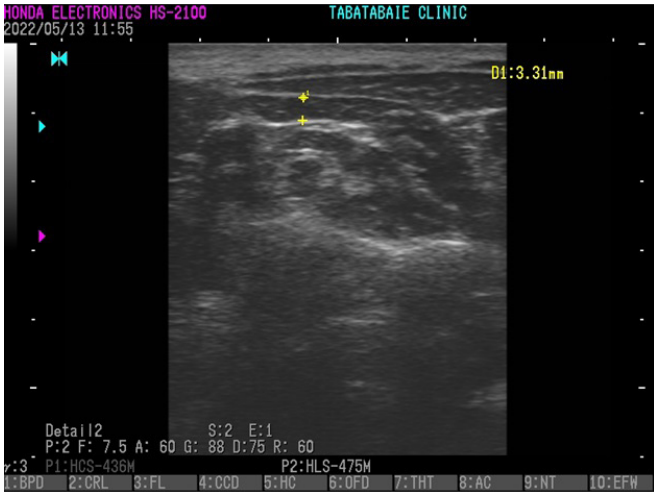

Figure 2. Semispinalis capitis muscle size via ultrasonography.

Ultrasonography of SECM in MVIC

Subjects were instructed to sit comfortably on a chair, with their hands on their legs and their gaze directed forwardly, to maintain a neutral position of their heads and necks. A permanent plate was mounted to the back of one chair where the patient sat so that a probe insertion region could be designated to get the SECM size in MVIC by biofeedback pressure (**figure 3**) (7). Subjects were told to perform three submaximal contractions of the neck extensor muscles against biofeedback pressure as a warm-up activity.

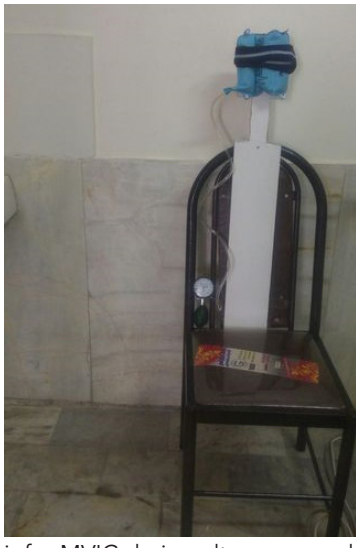

Figure 3. Chair for MVIC during ultrasonography.

Then, the subjects completed three trials of MVIC of the neck extensor muscles (26, 31). They were told not to move their chins upward or downward to prevent cranial cervical extension. Each trial lasted five seconds. A sixty-second rest interval separated the tests (29). The test determined the subject's maximum neck extensor muscle strength with the highest force (11, 19, 32). After identifying the participants' MVIC, they were given five minutes of rest (33). The subjects were then requested to execute the MVIC of neck extensor muscles and reach the target MVIC with force. Ultrasound imaging of SECM was taken at the same time. The examiner froze the ultrasound image for further measures when they kept their neck extensor MVIC for 5 seconds. To normalize the measurement, we divided muscle thickness by the subject's weight (34). The value of the muscle's normalized thickness at MVIC, rest, and the thickness difference between the muscle contraction at rest and the muscle contraction at MVIC was determined and employed in the data analysis (31). The value of MVIC in the Semi-Spinalis Capitis was not recorded as data for research in this step.

Statistical analysis

The data were analyzed using IBM's SPSS program for Windows, version 22.0 (Armonk, New York). Cronbach's Alpha was calculated to determine the accuracy of the muscle thickness measurement. Normality was determined using the Kolmogorov-Smirnov test. In addition, the independent student t-test was also used to compare the two groups' demographic data; craniovertebral angle, muscle thickness at rest and maximum contraction, and thickness difference (muscle contraction minus muscle rest thickness) were used as outcome measures. The first type of error was 0.05, and the power of the test was 80%.

RESULTS

Fifty subjects completed the test from a pool of potentially eligible sixty-two participants with FHP. **Figure 4** shows how to enter the study participants. For SECM thickness measurements, Cronbach's Alpha was 0.970.

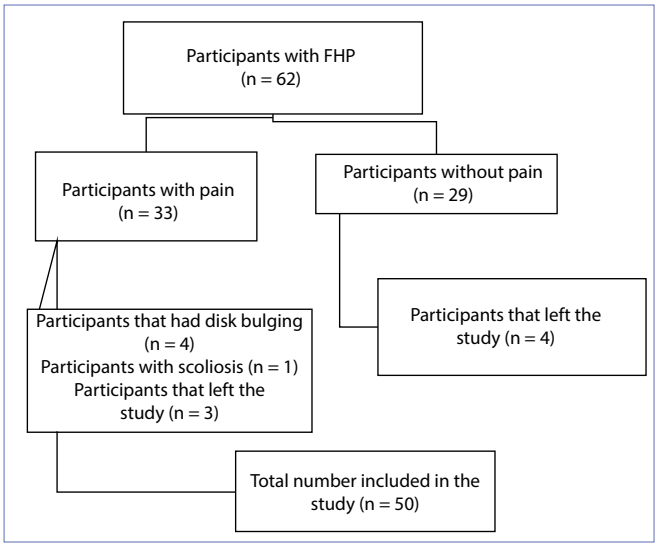

Figure 4. Flowchart of how participants entered the study.

The Kolmogorov-Smirnov test showed demographic and baseline data were normal (**table I**). The independent t-test revealed a significant difference between groups in SECM thickness at contraction (MVIC) ($p = 0.024$) and the thickness difference of the SECM ($p = 0.043$) (**table II**, **figures 5**, **6**). The two groups had no significant difference in SECM thickness at rest ($p = 0.24$).

Table II. Mean and SD of subjects' demographic data and muscle size between both two groups.

Variables	FHP group with pain	FHP group without pain	P-value	95%Confidence Interval
Age	42.56 ± 1.33	39.44 ± 1.91	0.187	(-1.56-7.80)
Weight (kg)	78.36 ± 3.82	78.52 ± 3.24	0.975	(-10.24-9.92)
Height (cm)	159.88 ± 1.883	166.04 ± 1.77	0.21	(-11.36-0.95)
BMI	30.82 ± 1.63	28.61 ± 1.25	0.28	(-1.93-6.36)
Gender (m/f)	3/22	6/22	/	/
CVA (degree)°	44.92 ± 1.11	45.60° ± 0.97	0.649	(-3.66-2.30)
Normalized rest SECM thickness (mm)	0.07 ± 0.004	0.07 ± 0.003	0.243	(-0.018-0.004)
Normalized contracted SECM thickness (mm)	0.09 ± 0.004	0.10 ± 0.005	0.043**	(-0.029-0.0004)
Normalized SECM thickness difference (mm)	0.015 ± 0.0019	0.026 ± 0.002	0.024**	(-0.015-0.001)

FHP: Forward Head Posture; BMI: Body Mass Index; CVA: Cranio Vertebral Angle; SECM: Semi-Spinalis capitis muscle; **P-value is significant.

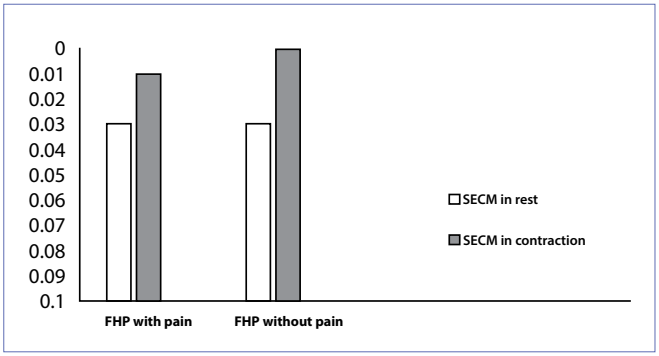

Figure 5. Semispinalis capitis muscle size in rest and contraction between FHP subjects with and without pain.

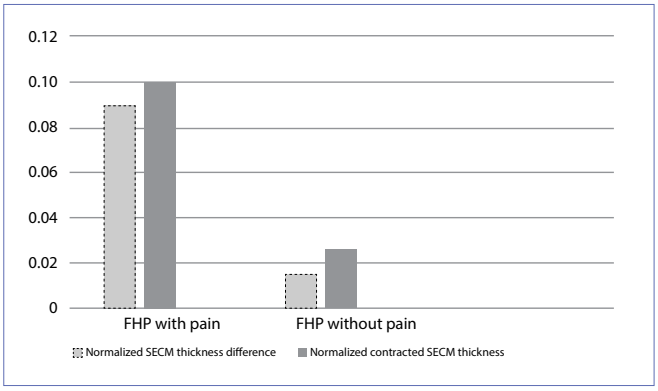

Figure 6. Semispinalis capitis normalized muscle size in contraction (MVIC and thickness differences) between FHP subjects with and without pain.

DISCUSSION

The current study's findings revealed a significant difference in SECM thickness during contraction and an SECM thickness difference between FHP individuals with and without pain. According to the results of this study, there was no significant difference in SECM thickness at rest between FHP people with and without pain.

Pain and neck extensor muscle thickness in contraction

In the current study, FHP individuals with pain had a smaller APD (anterior-posterior measurement) of SECM muscle in isometric contraction than those without pain. This can be the primary finding to examine the relationship between neck pain and cervical muscle thickness through ultrasonography in MVIC. In any case, previous studies looking at the strength of the neck extensor muscles in people with mechanical neck pain, whether or not they have FHP, have found changes in physical muscle structure, cross-sectional area (35-39) and the isometric neck extensor muscles strength (11, 15, 17). Research that explored the other muscles, except SECM, revealed a generalized diminished cervical multifidus muscle CSA in females with respective neck pain by Fernandez *et al.* (37). Kristjansson detailed a smaller CSA of cervical multifidus in neck pain patients (38). In another study on the longus colli muscle, Javanshir *et al.* documented smaller CSA and APD in subjects with persistent mechanical neck pain, possibly related to cervical muscle weakness (39). The results of these studies follow our findings.

Moreover, as said within the presentation, a few ponder appeared to indicate that the strength of the neck extensor muscles was diminished in patients with neck pain and cervicogenic pain compared to controls (11, 15-17). Measuring muscle strength during contraction could be one technique to discover the proper relationship between muscle size and muscular force (3). As a result, muscle shortcoming was induced by a diminution in muscle thickness using ultrasonography during MVIC (10). The results of the above studies are in agreement with our findings.

The SECM, a back neck muscle with one-of-a-kind physiological and mechanical highlights in cervical extension (7), has been found to have intermediary neck extensor muscle quality when subjects' heads and necks were in a neutral position (8). His muscle begins at the summit of the transverse process of the 6th or 7th thoracic vertebrae and the 7th cervical vertebra with an upward orientation. This muscle is embedded into the superior and inferior occiput nuchal lines with a broad ligament. Since this introduction, the semi-Spinalis Capitis could be an essential extensor within the neck. It can be longer modified in forward head posture than other suboccipital neck muscles (40).

The other muscles, such as the splenius capitis, begin in the spinous process of the third or fourth thoracic vertebrae and the seventh cervical vertebra and are coordinated medially to the SECM. It moves upward along the side and is embedded into the mastoid process (40). Subsequently, compared to SECM, these muscles are less likely to be influenced by FHP. Semispinalis cervices and multifidus are categorized as local and deep neck extensor muscles that stabilize the neck during neck and head movements (19, 20, 31, 38). These muscles are connected exceptionally close to the cervical spine and don't reach the occiput (40). Hence, it did not influence forward head posture. Neck muscle shortcomings showed up to cause distress on tendons and apophyseal joint capsules due to the pain (41, 42). The minor alteration in SECM thickness may be clarified by neural inhibition created by pain at rest (16). So, maximal muscle execution is prohibited (15).

Pain and neck muscles thickness at rest

The current study revealed no significant difference in SECM thickness at rest across groups. Other investigations have found

a difference in results in SECM size at rest in people with neck pain *versus* healthy people with or without FHP (11, 12, 43). Rezasoltani *et al*. found that in people with constant non-specific neck pain, the SECM at the level of the third cervical spine decayed at rest (11, 12). Jull *et al*. found significant decay and a lower thickness of SECM at the level of the second cervical vertebrae ipsilateral to the side of migraine (43).

The results of these studies disagree with our findings. This disparity emerges from the reality that the present research normalized muscle thickness with body weight, but the mentioned studies did not (11, 12, 43). Researchers found no critical distinction when muscle estimates were normalized to body mass (34). In addition, participants in this study were both male and female and worked in various occupations. However, in other investigations (11, 12, 43), the participants were female employees and neck muscular strength is lower in women than in men (18). This could explain the discrepancy between our findings and those studies.

On the other hand, some studies agreed with our results (13, 14, 22). Bokaee *et al*. found that the estimate of the SECM in individuals without neck pain does not differ between FHP and non-FHP members (22). Moreover, Ghamkhar *et al*. in 2019 and Kahlaee *et al*. in 2017 found no critical difference in SECM thickness between individuals with and without neck pain (13, 14).

Regarding the cervical muscle's anatomical relationship to the vertebrae, deep (local) muscles are thought to provide regional, inter-segmental stability and fine-tune intervertebral motions. In contrast, the superficial (global) muscles can provide the enormous torque needed for significant spine movements (6). The SECM stands for superficial muscles (6). Since the local muscles are responsible for keeping the cervical spine aligned in the rest posture seated on a chair with FHP, the SECM, as a superficial muscle, is inactive at rest (6). This can explain why the present study's SECM size did not change at rest.

This study showed that, in clinical practice, clinicians should first eliminate muscle weakness and then treat postural changes in the neck.

This study has some limitations. This study is a pilot study, so it is proposed that larger sample sizes be used in future investigations. We suggest calculating the amount of MVIC during the SECM ultrasonography in maximum contraction and measuring the relationship between them. During ultrasonography, other muscle dimensions should be recorded as well.

CONCLUSIONS

There is an alteration in SECM muscle size in maximum isometric contraction in FHP subjects with pain, while FHP people without pain didn't show this alteration. Both groups showed a similar alteration in the thickness of the SECM at rest. This study showed that neck pain is first related to SECM weakness, then FHP. In patients with neck pain, strengthening the SECM in a neutral position is recommended during exercise therapy.

FUNDINGS

This study was founded by vice President of research at Semnan University of Medical Sciences. The grant number is 1583.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

All authors contributed equally to this work.

ACKNOWLEDGMENTS

We thank the Neuromuscular Rehabilitation Research Center at Semnan University of Medical Sciences and Health Service.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Griegel-Morris P, Larson K, Mueller-Klaus K, Oatis CA. Incidence of common postural abnormalities in the cervical, shoulder, and thoracic regions and their association with pain in two age groups of healthy subjects. Phys Ther. 1992;72(6):425-31. doi: 10.1093/ptj/72.6.425.
2. Kim DH, Kim CJ, Son SM. Neck Pain in Adults with Forward Head Posture: Effects of Craniovertebral Angle and Cervical Range of Motion. Osong Public Health Res Perspect. 2018;9(6):309-13. doi: 10.24171/j.phrp.2018.9.6.04.
3. Kuo YL, Tully EA, Galea MP. Video analysis of sagittal spinal posture in healthy young and older adults. J Manipulative Physiol Ther. 2009;32(3):210-5. doi: 10.1016/j.jmpt.2009.02.002.
4. Silva AG, Punt TD, Sharples P, Vilas-Boas JP, Johnson MI. Head posture and neck pain of chronic nontraumatic origin:

a comparison between patients and pain-free persons. Arch Phys Med Rehabil. 2009;90(4):669-74. doi: 10.1016/j.apmr.2008.10.018.
5. Fernández-de-las-Peñas C, Alonso-Blanco C, Cuadrado ML, Pareja JA. Forward head posture and neck mobility in chronic tension-type headache: a blinded, controlled study. Cephalalgia. 2006;26(3):314-9. doi: 10.1111/j.1468-2982.2005.01042.x.
6. Bergmark A. Stability of the lumbar spine. A study in mechanical engineering. Acta Orthop Scand Suppl. 1989;230:1-54. doi: 10.3109/17453678909154177.
7. Rezasoltani A, Nasiri R, Faizei AM, Zaafari G, Mirshahvelayati AS, Bakhshidarabad L. The variation of the strength of neck extensor muscles and semispinalis capitis muscle size with head and neck position. J Bodyw Mov Ther. 2013;17(2):200-3. doi: 10.1016/j.jbmt.2012.07.001.
8. Mayoux-Benhamou MA, Wybier M, Revel M. Strength and cross-sectional area of the dorsal neck muscles. Ergonomics. 1989;32(5):513-8. doi: 10.1080/00140138908966121.
9. Rezasoltani A, Mälkiä E, Vihko V. Neck muscle ultrasonography of male weight-lifters, wrestlers and controls. Scand J Med Sci Sports. 1999;9(4):214-8. doi: 10.1111/j.1600-0838.1999.tb00236.x.
10. Goodarzi F, Rahnama L, Karimi N, Baghi R, Jaberzadeh S. The Effects of Forward Head Posture on Neck Extensor Muscle Thickness: An Ultrasonographic Study. J Manipulative Physiol Ther. 2018;41(1):34-41. doi: 10.1016/j.jmpt.2017.07.012.
11. Rezasoltani A, Ali-Reza A, Khosro KK, Abbass R. Preliminary study of neck muscle size and strength measurements in females with chronic non-specific neck pain and healthy control subjects. Man Ther. 2010;15(4):400-3. doi: 10.1016/j.math.2010.02.010.
12. Rezasoltani A, Ahmadipoor A, Khademi-Kalantari K, Javanshir K. The sign of unilateral neck semispinalis capitis muscle atrophy in patients with chronic non-specific neck pain. J Back Musculoskelet Rehabil. 2012;25(1):67-72. doi: 10.3233/BMR-2012-0303.
13. Kahlaee AH, Rezasoltani A, Ghamkhar L. Is the clinical cervical extensor endurance test capable of differentiating the local and global muscles? Spine J. 2017;17(7):913-21. doi: 10.1016/j.spinee.2017.01.014.
14. Ghamkhar L, Kahlaee AH. Is forward head posture relevant to cervical muscle performance and neck pain? A case-control study. Braz J Phys Ther. 2019;23(4):346-54. doi: 10.1016/j.bjpt.2018.08.007.
15. Ylinen J, Salo P, Nykänen M, Kautiainen H, Häkkinen A. Decreased isometric neck strength in women with chronic neck pain and the repeatability of neck strength measurements. Arch Phys Med Rehabil. 2004;85(8):1303-8. doi: 10.1016/j.apmr.2003.09.018.
16. Ylinen J, Takala EP, Kautiainen H, et al. Association of neck pain, disability, and neck pain during maximal effort with neck muscle strength and range of movement in women with chronic non-specific neck pain. Eur J Pain. 2004;8(5):473-8. doi: 10.1016/j.ejpain.2003.11.005.
17. Prushansky T, Gepstein R, Gordon C, Dvir Z. Cervical muscles weakness in chronic whiplash patients. Clin Biomech (Bristol, Avon). 2005;20(8):794-8. doi: 10.1016/j.clinbiomech.2005.05.003.
18. Cagnie B, Cools A, De Loose V, Cambier D, Danneels L. Differences in isometric neck muscle strength between healthy controls and women with chronic neck pain: the use of a reliable measurement. Arch Phys Med Rehabil. 2007;88(11):1441-5. doi: 10.1016/j.apmr.2007.06.776.
19. Rahnama L, Rezasoltani A, Khalkhali Zavieh M, Noori Kochi F, Akbarzadeh Baghban A. The effects of isometric contraction of shoulder muscles on cervical multifidus muscle dimensions in healthy office workers. J Bodyw Mov Ther. 2014;18(3):383-9. doi: 10.1016/j.jbmt.2013.11.011.
20. Rahnama L, Rezasoltani A, Zavieh MK, NooriKochi F, Baghban AA. Differences in cervical multifidus muscle thickness during isometric contraction of shoulder muscles: a comparison between patients with chronic neck pain and healthy controls. J Manipulative Physiol Ther. 2015;38(3):210-7. doi: 10.1016/j.jmpt.2014.11.008.
21. Rezasoltani A, Ylinen J, Vihko V. Isometric cervical extension force and dimensions of semispinalis capitis muscle. J Rehabil Res Dev. 2002;39(3):423-8.
22. Bokaee F, Rezasoltani A, Manshadi FD, Naimi SS, Baghban AA, Azimi H. Comparison of cervical muscle thickness between asymptomatic women with and without forward head posture. Braz J Phys Ther. 2017;21(3):206-11. doi: 10.1016/j.bjpt.2017.04.003.
23. Oliveira AC, Silva AG. Neck muscle endurance and head posture: A comparison between adolescents with and without neck pain. Man Ther. 2016;22:62-7. doi: 10.1016/j.math.2015.10.002.
24. Salahzadeh Z, Maroufi N, Ahmadi A, et al. Assessment of forward head posture in females: observational and photogrammetry methods. J Back Musculoskelet Rehabil. 2014;27(2):131-9. doi: 10.3233/BMR-130426.
25. Nam SH, Son SM, Kwon JW, Lee NK. The Intra- and Inter-rater Reliabilities of the Forward Head Posture Assessment of Normal Healthy Subjects. J Phys Ther Sci. 2013;25(6):737-9. doi: 10.1589/jpts.25.737.
26. Peolsson A, Brodin L, Peolsson M. A tissue velocity ultrasound imaging investigation of the dorsal neck muscles during resisted isometric extension. Man Ther. 2010;15(6):567-73. doi: 10.1016/j.math.2010.06.007.
27. Shaghayegh Fard B, Ahmadi A, Maroufi N, Sarrafzadeh J. Evaluation of forward head posture in sitting and standing positions. Eur Spine J. 2016;25(11):3577-82. doi: 10.1007/s00586-015-4254-x.
28. Rezasoltani A, Kallinen M, Mälkiä E, Vihko V. Neck semispinalis capitis muscle size in sitting and prone positions measured by real-time Ultrasonography. Clin Rehabil. 1998;12(1):36-44. doi: 10.1191/026921598673972662.
29. Lin YJ, Chai HM, Wang SF. Reliability of thickness measurements of the dorsal muscles of the upper cervical spine: an ultrasonographic study. J Orthop Sports Phys Ther. 2009;39(12):850-7. doi: 10.2519/jospt.2009.3005.
30. Lee JP, Tseng WY, Shau YW, Wang CL, Wang HK, Wang SF. Measurement of segmental cervical multifidus contraction by Ultrasonography in asymptomatic adults. Man Ther. 2007;12(3):286-94. doi: 10.1016/j.math.2006.07.008.
31. Lee JP, Wang CL, Shau YW, Wang SF. Measurement of cervical multifidus contraction pattern with ultrasound imaging. J

Electromyogr Kinesiol. 2009;19(3):391-7. doi: 10.1016/j.jelekin.2007.11.007.
32. Goodarzi F, Karimi N, Rahnama L, Khodakarim L. Differences in cervical extensor muscle thickness on subjects with normal head posture and forward head posture: an ultrasonography study. J Rehabil Sci Res. 2015;2(2):23-6. doi: 10.30476/JRSR.2015.41069.
33. Elliott JM, O'Leary SP, Cagnie B, Durbridge G, Danneels L, Jull G. Craniocervical orientation affects muscle activation when exercising the cervical extensors in healthy subjects. Arch Phys Med Rehabil. 2010;91(9):1418-22. doi: 10.1016/j.apmr.2010.05.014.
34. Rankin G, Stokes M, Newham DJ. Size and shape of the posterior neck muscles measured by ultrasound imaging: normal values in males and females of different ages. Man Ther. 2005;10(2):108-15. doi: 10.1016/j.math.2004.08.004.
35. Elliott J, Jull G, Noteboom JT, Galloway G. MRI study of the cross-sectional area for the cervical extensor musculature in patients with persistent whiplash-associated disorders (WAD). Man Ther. 2008;13(3):258-65. doi: 10.1016/j.math.2007.01.012.
36. Fernández-de-Las-Peñas C, Bueno A, Ferrando J, Elliott JM, Cuadrado ML, Pareja JA. Magnetic resonance imaging study of the morphometry of cervical extensor muscles in chronic tension-type headache. Cephalalgia. 2007;27(4):355-62. doi: 10.1111/j.1468-2982.2007.01293.x.
37. Fernández-de-las-Peñas C, Albert-Sanchís JC, Buil M, Benitez JC, Alburquerque-Sendín F. Cross-sectional area of cervical multifidus muscle in females with chronic bilateral neck pain compared to controls. J Orthop Sports Phys Ther. 2008;38(4):175-80. doi: 10.2519/jospt.2008.2598.
38. Kristjansson E. Reliability of Ultrasonography for the cervical multifidus muscle in asymptomatic and symptomatic subjects. Man Ther. 2004;9(2):83-8. doi: 10.1016/S1356-689X(03)00059-6.
39. Javanshir K, Rezasoltani A, Mohseni-Bandpei MA, Amiri M, Ortega-Santiago R, Fernández-de-Las-Peñas C. Ultrasound assessment of bilateral longus colli muscles in subjects with chronic bilateral neck pain. Am J Phys Med Rehabil. 2011;90(4):293-301. doi: 10.1097/PHM.0b013e31820173e5.
40. Gray H. Gray's Anatomy.
41. Deandrade Jr, Grant C, Dixon AS. Joint Distension And Reflex Muscle Inhibition In The Knee. J Bone Joint Surg Am. 1965;47:313-22. Available at: https://journals.lww.com/jbjsjournal/abstract/1965/47020/joint_distension_and_reflex_muscle_inhibition_in.8.aspx.
42. Stokes M, Young A. The contribution of reflex inhibition to arthrogenous muscle weakness. Clin Sci (Lond). 1984;67(1):7-14. doi: 10.1042/cs0670007.
43. Jull G, Amiri M, Bullock-Saxton J, Darnell R, Lander C. Cervical musculoskeletal impairment in frequent intermittent headache. Part 1: Subjects with single headaches. Cephalalgia. 2007;27(7):793-802. doi: 10.1111/j.1468-2982.2007.01345.x.