J. Phys. Ther. Sci. 33: 689–694, 2021

The Journal of Physical Therapy Science

Original Article

# The study of respiratory muscles activation during respiratory muscle strength effort in adult females with chronic neck pain

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**Abstract.** [Purpose] This study aimed to compare maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP) values and muscle activity during MIP and MEP between chronic neck pain and healthy participants. [Participants and Methods] Twenty chronic neck pain and 20 non-symptomatic females participated in this study. Maximal airway pressure (MIP and MEP) and surface electromyography (sEMG) for both sides of the upper trapezius, anterior scalene, pectoralis major and 6th intercostal muscles were recorded simultaneously. [Results] Significant differences of MIP and MEP values were found between the groups. The muscle activities of both sides of upper trapezius and 6th intercostal muscles during MEP were significantly higher in the chronic neck pain group than the healthy group except both sides of anterior scalene and pectoralis major muscles. During MIP, the activities of upper trapezius, 6th intercostal muscles and anterior scalene were significantly different between the two studied groups. Higher activity of left pectoralis major was found in the chronic neck pain group. [Conclusion] Decreasing values of MEP and MIP as well as muscles activities elevation in chronic neck pain participants were clearly demonstrated. Besides the musculoskeletal treatment, we suggest breathing exercise training to be considered in treatment programs.

**Key words** : Chronic neck pain, Muscle activity, Respiratory muscle strength

*(This article was submitted Mar. 30, 2021, and was accepted Jun. 11, 2021)*

## INTRODUCTION

Neck pain is considered a common musculoskeletal disorder. It can cause adaptive musculoskeletal and motor control changes in the cervical region and related structures[1, 2)]. In the Global Burden of Disease 2019 study, neck pain was in the top five ranking amongst musculoskeletal disorders with 223 million affected people worldwide and 22 million who live for years with a disability[3)]. The recurrence of neck pain can be found in the working population with 60–80% having repeated symptoms within one year[4)]. The prevalence is usually higher in women (5.8%) than men (4.0%) even when the symptoms change to chronic conditions. The prevalence of this condition increases accordingly with age[5)].

Musculoskeletal problems of the neck region in office workers, especially those working with computers, are very common. Various factors concerning neck pain have been elucidated, such as prolonged duration of computer usage and sustained awkward posture during visual display unit utilization[6, 7)]. For these workers, a forward head posture is usually related to higher biomechanical compressive loading on the cervical spine and surrounding structures[8)]. Excessively low threshold motor unit activity due to low-load repetitive work can cause pain that is associated with the overloading of cervical and shoulder girdle muscles[9)]. The role of other mechanisms like nociceptor sensitization by intra-muscular shear forces is also

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involved[10]. According to the phenomena mentioned earlier, the anterior scalene, sternocleidomastoid and upper trapezius muscles were found to have increasd electromyographic activity when compared to deeper postural stabilizer muscles like the deep cervical flexors[11].

However, rehabilitation of neck pain is considered as a musculoskeletal treatment. The cervical region and thoracic spine is connected to musculoskeletal and also neural connections so that neck pain may cause changes in the thoracic spine and rib cage and thus pulmonary function is affected[12]. The factors involved with respiratory dysfunction in neck pain cases include decreased strength and endurance of deep neck flexors and extensors. An increase in muscle activity and exhaustion of superficial neck muscles, particularly sternocleidomastoid (SCM) and anterior scalene (AS) are required as accessory muscles for breathing[11, 13, 14]. Moreover, cervical mobility changes, forward head posture support to changes in force-length curves, imbalance of muscles and segmental instability potentially affect the function of the thoracic cage and rib cage mechanism[12, 15]. Besides the musculoskeletal and structural connection of the cervical and thoracic spine, individuals with neck pain could have respiratory disturbances.

The respiratory muscles function to produce adequate ventilation and gas exchange. A negative pressure gradient resulting from these muscle contractions will give rise to an inflow of air into the lungs. The diaphragm plays a major role in inspiratory work in a person's body. The scalenes and the intercostal muscles are recruited for primary inspiratory muscles during tidal breathing. During higher levels of inspiration, the inspiratory muscles are considered to be accessory muscles. These provide a considerable contribution to the sternocleidomastoid and scalene muscles with the respiratory pump[16]. Maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) values are usually used for respiratory function evaluation. Therefore, this study aimed to study the respiratory muscles activation during respiratory muscle strength efforts between females with chronic neck pain and healthy females with no chronic neck pain.

## PARTICIPANTS AND METHODS

A cross-sectional study was performed with 20 female office workers who had chronic neck pain and 20 non-symptomatic persons. Volunteers were recruited using comparative age and BMI match controls.

Participants in the experimental group were females aged between 20 and 45 with a history of intermittent work-related neck pain lasting for more than 6 months prior to the study. They worked with a computer for at least 4 hours each working day. The pain level at the time of examination exceeded 30 mm on a visual analogue scale of 0–100 mm. Participants were excluded if they had neck or shoulder pain from non-musculoskeletal causes, demonstrated neurological signs, had a history of spinal or chest surgery, or a history of smoking or pregnancy at the time of examination. Participants who met the inclusion criteria were asked to participate in the study. They provided written informed consent before participating in this project.

This study was approved by the Research Ethics Review Committee for Research involving Human Research Participants, Health Sciences Group, Chulalongkorn University, Thailand. It was constituted in accordance with Belmont Report, Declaration of Helsinki (COA No.225/2019). All participants gave their signatures in the consent forms after receiving both verbal and written information about the study protocol.

Muscle activity was recorded during the respiratory muscle strength effort measurement. The 8-channels surface electromyography (sEMG) device (Naroxon Inc, Scottsdale, AZ, USA) was chosen to measure muscle activities. The EMG signals were read using bipolar Ag-AgCl surface electrodes. The position of electrodes for the upper trapezius (UT) activities were equidistance between the acromion arch and the C7 spinous process[17, 18]. The electrodes on anterior scalene (AS) were placed in the posterior triangle of the neck at the level of the cricoid cartilage to lie over the lower portion of the anterior scalene muscle[19]. Surface electrodes of the upper portion of pectoralis major and the 6th intercostal (IC6) muscles were placed on a midclavicular line and anterior axillary line, respectively[17]. Each volunteer was told to comfortably sit with their back supported on a chair. The sEMG electrodes were attached to the skin at an inter-electrode distance of 1 cm using hypoallergenic adhesive; the inter-electrode impedance was set below 2 kΩ[17].

Maximal airway pressure and surface electromyography (sEMG) for respiratory muscles were recorded simultaneously. A portable respiratory pressure meter (MicroRPM Medical, Yorba Linda, CA, USA) was used to assess maximum inspiratory pressure (MIP) and maximal expiratory pressure (MEP). After the correct procedure was demonstrated, the participants were told to perform maximal inspiratory for 3 times at least 30 sec intervals between the trials. The expiratory efforts were also performed with similar conditions. During the maximal respiratory measurements, the participants were instructed to close their mouths tightly around the flanged mouthpiece and air leakage was prevented using a nose clip. The MEP was assessed after the participants had taken a full deep breath and exhaled maximally for at least 1 sec. against the resistance gauge. The MIP was recorded after participants completed the process of full exhalation and then inhaled maximally for at least 1 sec. against the resistance gauge. The highest values of the inspiratory and expiratory efforts were recorded as the MIP and MEP, respectively.

The data from the study were analyzed with SPSS software version 22.0. The values of MIP, MEP and root mean square (RMS) of sEMG obtained from participants with and without chronic neck pain symptoms were calculated using independent t-test for their statistical differences at p-value $<0.05$.

## RESULTS

The demographic data are shown in Table 1. No significant differences by means of age, height, weight or BMI were identified between both studied groups (p>0.05). At the beginning of this study, 20 participants have been suffering from neck pain symptom with varying duration ranged from 9 to 21 months and the average of pain duration was 13 months.

All participants completed the respiratory strength effort and surface electromyography measurements with no dropouts. Significant differences of MIP and MEP values were found between the group of participants with and without chronic neck pain (p<0.001) (Table 2).

For the upper trapezius and 6th intercostal, an examination of both left and right sides of these muscles revealed the differences of root mean square (RMS) values during MEP activities between the groups of participants with and without chronic neck pain (p<0.001) (Table 3).

When various muscles were examined for RMS values during MIP efforts, it was found that the chronic neck pain participants had significantly higher RMS values for both sides of the upper trapezius (p<0.001), anterior scalene (p=0.01) and 6th intercostal muscles (p<0.001). Only the left pectoralis major muscle of the chronic neck pain subjects was found to have higher RMS values (p=0.03). This evidence was not observed with the right pectoralis major muscle (p=0.17) (Table 4).

**Table 1.** Characteristics of participants

| Characteristics | Chronic neck pain (n=20) Mean ± SD | Healthy (n=20) Mean ± SD | p-value |
|---|---|---|---|
| Age (years) | 29.84 ± 3.51 | 29.90 ± 3.22 | 0.608 |
| Weight (kg) | 51.89 ± 6.14 | 52.50 ± 5.91 | 0.932 |
| Height (cm) | 161.00 ± 3.48 | 161.30 ± 3.48 | 0.873 |
| BMI (kg/m$^2$) | 20.11 ± 2.71 | 20.20 ± 2.52 | 0.674 |

Data are expressed in mean ± SD.

**Table 2.** Maximum Inspiratory Pressure (MIP) and Maximum Expiratory Pressure (MEP) values

| Values | Chronic neck pain (n=20) Mean ± SD | Healthy (n=20) Mean ± SD | Mean difference | p-value |
|---|---|---|---|---|
| MIP (cm$H_2O$) | 75.26 ± 6.24 | 88.40 ± 6.46 | −13.14 | 0.001* |
| MEP (cm$H_2O$) | 84.00 ± 5.70 | 94.30 ± 7.22 | −10.30 | 0.001* |

Data are expressed in mean ± SD, MIP: Maximum inspiratory pressure; MEP: Maximum Expiratory Pressure.
*p>0.05.

**Table 3.** The root mean square (RMS) values of muscles during maximum expiratory pressure (MEP)

| Muscles | Side | RMS values | | p-value |
|---|---|---|---|---|
| | | Chronic neck pain (n=20) | Healthy (n=20) | |
| Upper trapezius (UT) | Rt | 36.78 ± 9.14 | 24.69 ± 4.67 | 0.001* |
| | Lt | 28.67 ± 7.69 | 20.75 ± 4.24 | 0.001* |
| Anterior scalenes (AS) | Rt | 21.62 ± 5.62 | 18.89 ± 4.15 | 0.091 |
| | Lt | 23.98 ± 5.05 | 22.01 ± 4.11 | 0.19 |
| Pectoralis major | Rt | 23.56 ± 4.81 | 21.34 ± 5.24 | 0.177 |
| | Lt | 26.77 ± 7.23 | 24.31 ± 3.93 | 0.201 |
| 6th intercostal muscle | Rt | 46.43 ± 8.07 | 30.69 ± 8.31 | 0.001* |
| | Lt | 47.13 ± 7.63 | 30.93 ± 7.02 | 0.001* |

Data are expressed in mean ± SD. RMS: Root Mean Square; Rt: Right; Lt: Left; MEP: Maximum Expiratory Pressure.
*p>0.05.

**Table 4.** The root mean square (RMS) values of muscles during maximum inspiratory pressure (MIP)

| Muscles | Side | RMS values | | p-value |
|---|---|---|---|---|
| | | Chronic neck pain (n=20) | Healthy (n=20) | |
| Upper trapezius (UT) | Rt | 60.88 ± 11.88 | 43.84 ± 8.97 | 0.001* |
| | Lt | 60.22 ± 10.35 | 44.93 ± 9.97 | 0.001* |
| Anterior scalenes (AS) | Rt | 54.82 ± 11.75 | 47.22 ± 5.88 | 0.018* |
| | Lt | 60.35 ± 13.27 | 48.12 ± 4.78 | 0.001* |
| Pectoralis major | Rt | 18.75 ± 3.95 | 17.13 ± 3.29 | 0.171 |
| | Lt | 20.42 ± 4.37 | 17.71 ± 3.29 | 0.035* |
| 6th intercostal muscle | Rt | 23.95 ± 5.11 | 18.36 ± 3.61 | 0.001* |
| | Lt | 26.28 ± 5.66 | 18.03 ± 3.26 | 0.001* |

Data are expressed in mean ± SD. RMS: Root Mean Square; Rt: Right; Lt: Left; MIP: Maximum Inspiratory Pressure.
*p>0.05.

# DISCUSSION

The results of this study revealed reduction of MEP and MIP values in individuals with chronic neck pain and these findings agreed with previous studies[12)]. In individuals with chronic neck pain, faulty breathing patterns were found to affect respiratory functions[20)]. The faulty breathing of the upper chest in the chronic neck pain was related to the lifting upward of clavicles with more muscle activity of sternocleidomastoid, anterior scalene and trapezius muscles. This pattern contributed to the muscle imbalance, which may result in a forward head posture for office workers with chronic neck pain[8)]. From this reason, superficial neck flexors muscles such as anterior scalene become tight and deep neck flexor muscles appear to be lengthened and weakened. The upper trapezius and pectoralis major muscles responsible for forced inspiration also become tightened[21)]. These imbalances may cause upper rib cage dysfunction, leading to the lesser MEP and MIP values in chronic neck pain subjects when compared with healthy participants.

The assessment of respiratory muscles function can be measured directly by the pressure developed throughout the maximal expiratory and inspiratory effort. The results of this study showed that multi-muscle recruitment patterns during MEP and MIP effort in chronic neck pain were significantly different from subjects in the healthy group. Chronic neck pain participants have demonstrated greater activity in all muscle testing (upper trapezius, anterior scalene, 6th intercostal and pectoalis major muscles of both sides). These results indicate that chronic neck pain participants may have lower airway pressure generation during MEP and MIP efforts than healthy participants have. In chronic neck pain patients, strength and endurance impairments were reported with deep neck flexors and extensors muscles[13, 22)]. These alterations may influence kinetic control for either a specific area or for articulations related to shoulder and thoracic spine[23, 24)]. Fatigability of anterior scalene and upper trapezius muscles was also found to be related with increasing muscle activation in chronic neck pain cases[25, 26)]. Function length alteration due to fatigability resulted in abnormal over pull and under pull during respiratory motion, which led to length tension discrepancies. In addition, increasing activities of upper trapezius and intercostal muscles during maximal expiratory effort were related to breathing pattern alterations in females. It has also been found that during maximal inspiratory effort, the upper trapezius and anterior scalene activities were associated with greater reliance on the extradiaphragmatic inspiratory muscles[27)].

Decrease in neck muscles strength and muscle length deficit was found in people with chronic neck pain when compared with healthy individuals[28)]. Therapeutic exercises include neck muscles strengthening especially deep and superficial neck flexor muscles and stretching exercise around the neck and scapular area such as upper trapezius, scalene, levator scapulae, pectoralis major and pectoralis minor. These exercises are always suggested for the chronic neck pain treatment cases[29, 30)]. Moreover, respiratory dysfunction is developed in chronic neck pain people[12)]. Since cervical and thoracic spines are connected to musculoskeletal and also neural connections. The decreasing strength of deep neck flexor and extensor muscles may also cause changes in the thoracic spine and rib cage and thus respiratory function is affected. Breathing exercise is therefore important and should be considered for respiratory function improvement. From these reasons, further study is necessary to investigate the effect of neck muscles exercise training and breathing exercise for individuals with chronic neck pain. According to the findings, chronic neck pain subjects have reduced strength of respiratory muscles but increased muscle activities of extradiaphragmatic inspiratory muscles than healthy participants have. Even though interesting information is clearly demonstrated, further investigation in males with chronic neck pain as well as more participants for both genders is still critical to support our findings.

This study presented the evidence that MEP and MIP values to generate maximum airway pressure were reduced in chronic neck pain subjects. Moreover, the increasing of muscle activities of upper trapezius, anterior scalene, 6th intercostal and pectoralis major muscles were found to be greater than healthy subjects. This information should be taken into consideration for rehabilitation programs for people suffering from chronic neck pain. Not only should musculoskeletal treatment exercise be used to strengthen superficial or deep neck flexor or extensor muscles but also breathing exercise training should be added into the rehabilitation program.


## *Funding*

This paper was supported by the Faculty of Allied Health Sciences Projects Fund, Chulalongkorn University (AHS-CU 62002).

## *Conflict of interest*

No potential conflict of interest relevant to this article was reported.


## REFERENCES


1) Shahidi B, Curran-Everett D, Maluf KS: Psychosocial, physical and neurophysiological risk factors for chronic neck pain: a prospective inception cohort study. J Pain, 2015, 16: 1288–1299. [Medline] [CrossRef]
2) Falla D, Farina D: Neuromuscular adaptation in experimental and clinical neck pain. J Electromyogr Kinesiol, 2008, 18: 255–261. [Medline] [CrossRef]
3) Cieza A, Causey K, Kamenov K, et al.: Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet, 2021, 396: 2006–2017. [Medline] [CrossRef]
4) Keown GA, Tuchin PA: Workplace factors associated with neck pain experienced by computer users: a systematic review. J Manipulative Physiol Ther, 2018, 41: 508–529. [Medline] [CrossRef]
5) Safiri S, Kolahi AA, Cross M, et al.: Global, regional, and national burden of other musculoskeletal disorders 1990–2017: results from the Global Burden of Disease Study 2017. Rheumatology (Oxford), 2021, 60: 855–865. [Medline] [CrossRef]
6) Chen X, O'Leary S, Johnston V: Modifiable individual and work-related factors associated with neck pain in 740 office workers: a cross-sectional study. Braz J Phys Ther, 2018, 22: 318–327. [Medline] [CrossRef]
7) Kuo YL, Wang PS, Ko PY, et al.: Immediate effects of real-time postural biofeedback on spinal posture, muscle activity, and perceived pain severity in adults with neck pain. Gait Posture, 2019, 67: 187–193. [Medline] [CrossRef]
8) Kocur P, Wilski M, Lewandowski J, et al.: Female office workers with moderate neck pain have increased anterior positioning of the cervical spine and stiffness of upper trapezius myofascial tissue in sitting posture. PM R, 2019, 11: 476–482. [Medline] [CrossRef]
9) Hoyle JA, Marras WS, Sheedy JE, et al.: Effects of postural and visual stressors on myofascial trigger point development and motor unit rotation during computer work. J Electromyogr Kinesiol, 2011, 21: 41–48. [Medline] [CrossRef]
10) Visser B, van Dieën JH: Pathophysiology of upper extremity muscle disorders. J Electromyogr Kinesiol, 2006, 16: 1–16. [Medline] [CrossRef]
11) Jull G, Falla D: Does increased superficial neck flexor activity in the craniocervical flexion test reflect reduced deep flexor activity in people with neck pain? Man Ther, 2016, 25: 43–47. [Medline] [CrossRef]
12) Wirth B, Amstalden M, Perk M, et al.: Respiratory dysfunction in patients with chronic neck pain—influence of thoracic spine and chest mobility. Man Ther, 2014, 19: 440–444. [Medline] [CrossRef]
13) Bonilla-Barba L, Florencio LL, Rodríguez-Jiménez J, et al.: Women with mechanical neck pain exhibit increased activation of their superficial neck extensors when performing the cranio-cervical flexion test. Musculoskelet Sci Pract, 2020, 49: 102222. [Medline] [CrossRef]
14) Dimitriadis Z, Kapreli E, Strimpakos N, et al.: Hypocapnia in patients with chronic neck pain: association with pain, muscle function, and psychologic states. Am J Phys Med Rehabil, 2013, 92: 746–754. [Medline] [CrossRef]
15) Dimitriadis Z, Kapreli E, Strimpakos N, et al.: Respiratory dysfunction in patients with chronic neck pain: what is the current evidence? J Bodyw Mov Ther, 2016, 20: 704–714. [Medline] [CrossRef]
16) Ratnovsky A, Elad D, Halpern P: Mechanics of respiratory muscles. Respir Physiol Neurobiol, 2008, 163: 82–89. [Medline] [CrossRef]
17) AbuNurah HY, Russell DW, Lowman JD: The validity of surface EMG of extra-diaphragmatic muscles in assessing respiratory responses during mechanical ventilation: a systematic review. Pulmonology, 2020, 26: 378–385. [Medline] [CrossRef]
18) Szeto GP, Straker LM, O'Sullivan PB: Neck-shoulder muscle activity in general and task-specific resting postures of symptomatic computer users with chronic neck pain. Man Ther, 2009, 14: 338–345. [Medline] [CrossRef]
19) Cabral EE, Fregonezi GA, Melo L, et al.: Surface electromyography (sEMG) of extradiaphragm respiratory muscles in healthy subjects: a systematic review. J Electromyogr Kinesiol, 2018, 42: 123–135. [Medline] [CrossRef]
20) CliftonSmith T, Rowley J: Breathing pattern disorders and physiotherapy: inspiration for our profession. Phys Ther Rev, 2011, 16: 75–86. [CrossRef]
21) Kendall FP: Trunk and respiratory muscles. In: Muscles: testing and function with posture and pain, 5th ed. Baltimore: Lippincott Williams & Wilkins, 2005, pp 165–244.
22) Kumar S, Narayan Y, Prasad N, et al.: Cervical electromyogram profile differences between patients of neck pain and control. Spine, 2007, 32: E246–E253. [Medline] [CrossRef]
23) Tsang SM, Szeto GP, Lee RY: Movement coordination and differential kinematics of the cervical and thoracic spines in people with chronic neck pain. Clin Biomech (Bristol, Avon), 2013, 28: 610–617. [Medline] [CrossRef]
24) Key J, Clift A, Condie F, et al.: A model of movement dysfunction provides a classification system guiding diagnosis and therapeutic care in spinal pain and related musculoskeletal syndromes: a paradigm shift-Part 2. J Bodyw Mov Ther, 2008, 12: 105–120. [CrossRef]. [Medline]
25) Hsu WL, Chen CP, Nikkhoo M, et al.: Fatigue changes neck muscle control and deteriorates postural stability during arm movement perturbations in patients with chronic neck pain. Spine J, 2020, 20: 530–537. [Medline] [CrossRef]

26) Falla D, Farina D, Graven-Nielsen T: Experimental muscle pain results in reorganization of coordination among trapezius muscle subdivisions during repetitive shoulder flexion. Exp Brain Res, 2007, 178: 385–393. [Medline] [CrossRef]
27) Mitchell RA, Schaeffer MR, Ramsook AH, et al.: Sex differences in respiratory muscle activation patterns during high-intensity exercise in healthy humans. Respir Physiol Neurobiol, 2018, 247: 57–60. [Medline] [CrossRef]
28) Miranda IF, Wagner Neto ES, Dhein W, et al.: Individuals with chronic neck pain have lower neck strength than healthy controls: a systematic review with meta-analysis. J Manipulative Physiol Ther, 2019, 42: 608–622. [Medline] [CrossRef]
29) Lytras D, Sykaras E, Christoulas K, et al.: Effects of an integrated neuromuscular inhibition technique program on neck muscle strength and endurance in individuals with chronic mechanical neck pain. J Bodyw Mov Ther, 2019, 23: 643–651. [Medline] [CrossRef]
30) Alfawaz S, Lohman E, Alameri M, et al.: Effect of adding stretching to standardized procedures on cervical range of motion, pain, and disability in patients with non-specific mechanical neck pain: a randomized clinical trial. J Bodyw Mov Ther, 2020, 24: 50–58. [Medline] [CrossRef]