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Research Article

Inter-relationships Between Cervical Angles, Muscle Activity Levels and Mechanical Neck Pain

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Abstract

Background and Objective: Mechanical neck pain (MNP) is common musculoskeletal disorder, that has been repeatedly shown to correlate with sedentary life as well as our dependence on technology in work place. The purpose of this study was to evaluate three cervical angles and root mean square (RMS) activities of cervical muscles in individuals with mechanical neck pain (MNP) and pain-free individuals. **Materials and Methods:** A total of 77 participants were recruited in this study, including 43 subjects complaining of MNP and 34 pain-free subjects. Outcome measures included 3 cervical angles (Oc-C_2, C_1-C_2 and C_2-C_7) measured via X-ray imaging. Additionally, electromyographic activity was recorded for the upper trapezius (UT), cervical erector spinae (CE), sternocleidomastoid (SCM) and anterior scalene (AS) muscles. Statistical analysis was performed using Mann-Whitney U-test and Pearson correlation methods. **Results:** There were significant differences between MNP and pain-free individuals with respect to the C_2-C_7 angle ($p = 0.001$) and RMS activity for the left SCM ($p<0.005$). However, no significant differences between these two groups of participants were found for the Oc-C_2 and C_1-C_2 angles ($p = 0.712$ and $p = 0.870$, respectively). Pearson correlation analysis revealed that the Oc-C_2 angle was strongly directly correlated with RMS activity for the left trapezius ($p = 0.002$, $r = 0.502$) and weakly directly correlated with the C_1-C_2 angle ($p = 0.004$, $r = 0.484$) in pain-free individuals. There was a strong direct correlation between the Oc-C_2 and C_1-C_2 angles ($p = 0.000$, $r = 0.649$) for MNP participants. **Conclusion:** Relative to pain-free individuals, MNP individuals had reduced cervical lordosis and greater SCM activity. Moreover, the upper cervical vertebral angles were directly related to UT and SCM activities.

Key words: Mechanical neck pain, cervical muscles, cervical angles, musculoskeletal disorder, electromyography

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In the general population, neck pain is commonly observed in clinical settings, where it is the second most common condition after low back pain[1-4]. It has been estimated that 45–54% of all individuals will suffer from mechanical neck pain (MNP) during their lives[5]. According to Vernon and Humphreys[3], approximately 15% of females and 10% of males will suffer from chronic neck pain (CNP) during their lives. Chronic MNP (CMNP) involves nonspecific pain lasting more than 3 months[3,6] combined with referred pain in the upper limbs or head that increases in association with static posture or repetitive movement[7]. Chronic conditions are observed in almost one third of patients who seek medical help for neck pain[7]. The CMNP affects quality of life by impacting the occupational and vocational activities of daily living[3] and is costly with respect to treatment expenses and time lost[4].

The exact cause of MNP is unclear, although MNP is related to musculoskeletal and neural tissue dysfunctions[5]. Identifying risk factors for MNP is helpful for avoiding initial neck injuries and intervening to address major factors that lead to recurrent or persistent manifestations[6].

One important anatomical characteristic that is strongly related to MNP is the natural sagittal alignment of the cervical spine, which functions to maintain a lordotic shape induced by the wedge-shaped cervical vertebrae and is vital to compensate for the kyphotic curvature of the thoracic spine[8]. Cervical curvature is affected by a sedentary lifestyle and dependence on technology, which can lead to issues such as sitting for prolonged periods in front of a computer, a TV, games and/or static work[9].

Deviations from the normal sagittal alignment of the cervical curve, such as flattening of the cervical curve or cervical kyphosis, lead to pain and disability[8,10-12]. Cervical kyphosis is the most common deformity in the cervical spine and causes forward shifting of the head and neck[10,13]. One serious consequence is spinal cord compression and loss of horizontal gaze. Even in the absence of neurological symptoms, pain combined with cervical kyphosis leads to functional disability[10,13,14]. The primary function of the upper cervical spine, particularly occipitoatlantal (OA) alignment, is maintaining horizontal gaze. Many studies have reported that normal OA angulation is related to the alignment of the lower cervical spine, particularly the cervical and thoracic spine[15-19]. To maintain horizontal gaze, the OA is commonly hyper-extended with subaxial kyphosis[19]. Changes in horizontal gaze affect quality of life by impacting activities of daily living[20].

The cervical muscles provide approximately 80% of the mechanical stability of the cervical region[21], thus, the muscular system has a substantial role in stabilization of this region. Inadequate recovery of cervical muscles after injury may lead to the chronicity of certain MNP dysfunctions[22]. One characteristic of CMNP is increased activity in the superficial cervical flexor muscles, particularly the sternocleidomastoid (SCM) and anterior scalene (AS) muscles. This finding has been reported in multiple studies[23-25].

Multiple investigations have indicated that in patients with neck pain, the upper trapezius (UT) muscle exhibits greater activity on the symptomatic side than on the non-symptomatic side under conditions involving stress or mental effort[26] and during functional tasks[25]. Impairments of the cervical extensor muscles have been identified in patients with MNP disorders[27].

A literature review revealed that a few studies have investigated the association between cervical spine curvature and neck pain[28-30] but that relationships between cervical angles and MNP have not previously been studied. A recent study investigated relationships between facial morphology and activities of head, neck and trunk muscles[31] but did not examine the effects of different cervical angles on muscle activity. In the available literature, there is a gap in authors understanding of the relationships between muscle activity levels and cervical angles and how such relationships affect the incidence of mechanical pain.

The purposes of this study were (1) To demonstrate the differences between MNP and pain-free individuals with respect to three cervical angles and the root mean square (RMS) activities of cervical muscles and (2) To correlate muscle activities with cervical angles in MNP and pain-free individuals. It was hypothesized that the two types of individuals did not differ with respect to cervical angles or RMS activities of cervical muscles and that there were no relationships between cervical angles and RMS activities of muscles.

MATERIALS AND METHODS

Study design: This investigation was an observational cross-sectional study.

Participants: A total of 100 subjects of both genders sought to participate in the current study and 77 of these individuals were eligible (Fig. 1). The study included 43 participants with MNP and 34 pain-free participants. The participants' ages ranged from 18-23 years (19.8±1.27 years) and their body mass index (BMIs) ranged from 21-25 (23.9±4.23). They were recruited from students in various fields by the Faculty of the

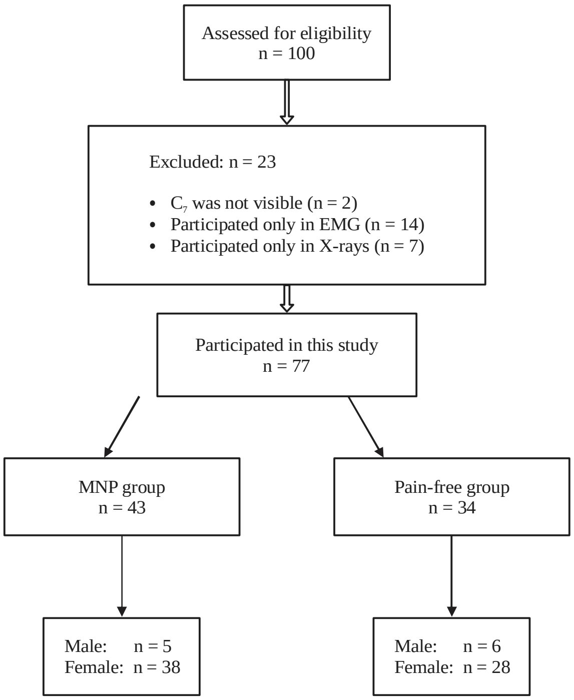

Fig. 1: Flow chart of study participants

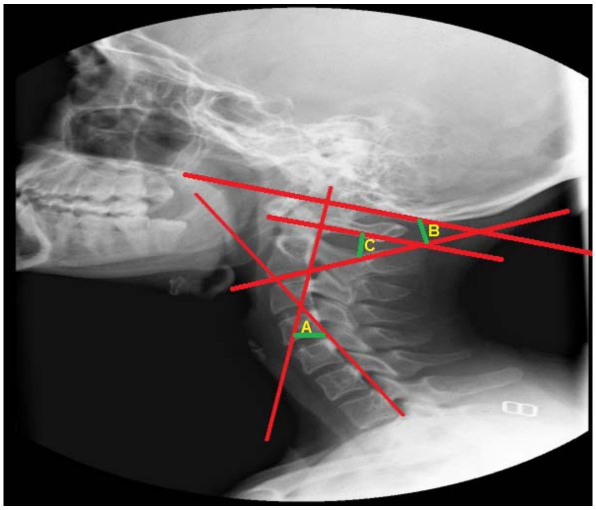

Fig. 2: X-ray image to calculate angles of cervical spine using CorelDRAW program, A: Absolute rotation angle (ARA) (C_2-C_7 angle), B: Occipital to 2nd cervical (Oc-C_2) angle and C: 1st and 2nd cervical (C_1-C_2) angle

School of Physical Therapy at Cairo University. This study was conducted between March, 2016 and July, 2017.

Inclusion criteria for MNP included pain involving the posterior or posterolateral aspect of the neck for more than 3 months[4], a score of 20% (or at least 10 points) on the neck disability index (NDI) (scored out of 50 points)[32] and an average cervical pain intensity of 5 or more on a visual analog scale (VAS) (scored out of 10)[7,33]. Participants were excluded if they had undergone postural control training, physical therapy during the preceding 12 months or spinal surgery, complained of any neurological signs, had any history of cervical spine disc herniation or cervical trauma, were pregnant, had congenital postural deformities or exhibited a definitive visual disorder. This study was approved by the ethical committee of the School of Physical Therapy of Cairo University (approval No. P.T. REC/012/001185) and registered in the Australian New Zealand Clinical Trials Registry (ID ACTRN12616000749404). Each participant provided informed consent.

Assessment of inclusion criteria

Pain assessment: The average intensity of cervical pain was assessed using a VAS. This VAS was a linear horizontal scale that ranged from 0-10, with 0 representing no pain or discomfort and 10 indicating the worst possible pain[34,35]. The VAS scores have been demonstrated to be reliable and valid measurements of chronic pain intensity[35,36].

Disability assessment: The NDI was used to calculate each patient's perceived impairment due to neck pain[9]. This index is a valid and reliable outcome measure for patients with neck pain[32].

Materials and outcome measures

Radiography: Lateral standard cervical radiographs were obtained for all participants. For these radiographs, the neck was in a neutral lateral cervical posture and the subject was looking straight ahead with open eyes and the right shoulder in contact with the cabinet, with a standard tube distance of 100 cm; the participants were asked to avoid moving during radiograph acquisition[15,37].

The following angles were measured using radiographs: A: The absolute rotation angle (ARA) (the C_2-C_7 angle), which was defined as the angle between two lines drawn along the posterior surfaces of the C_2 and C_7 vertebral bodies, B: The occipital to 2nd cervical (Oc-C_2) angle, which was defined as the angle between the McGregor line (the line from the posterior nasal spine to the most inferior point of the occiput) and the line passing through the inferior aspect of the C_2vertebral body and C: The 1st and 2nd cervical (C_1-C_2) angle: The angle between the inferior aspects of the C_1 and C_2 vertebral bodies[15,16]. The X-ray images were analyzed using the CorelDRAW program to calculate the angles of the cervical spine, as shown in Fig. 2. CorelDRAW measurements were repeated three times and average values were recorded[15].

Electromyography: A two-channel digital electromyogram device (Neuro-EMG-Micro, Neurosoft, Ivanovo, Russia) was used to detect myoelectric signals bilaterally from the UT, cervical erector spinae (CE), SCM (at the sternal head) and AS muscles. The ground electrode was strapped around the wrist and the surface recording bar electrodes (one of which was active and the other of which was the reference electrode, with a 2-3 cm distance between these electrodes) were positioned on parallel fibers of the examined muscles[38]. The skin overlying the examined muscle was carefully washed with alcohol[39]. The active electrodes were placed as follows: (1) In the SCM muscle at the sternal head, (2) In the AS muscle just posterior to the clavicular head of the SCM muscle[40], (3) In the UT muscle 2 cm lateral to the center of a line drawn between the C_7 spinous process and the posterolateral acromion[41] and (4) In the CE muscle with one electrode at the C_2 level just at the edge of the trapezius muscle or 35-40 mm lateral to the spinous process of C_2[42]. The electrodes were fixed using self-adhesive plastic wrap[40]. After electrode placement, the impedance was checked to ensure that it was at an acceptable level (<2 kΩ)[43].

Normalization of EMG activity: The following procedures were performed to normalize the cervical muscles. (1) For the SCM and AS muscles, assessments were performed with the subject lying in a supine position, the participant was asked to raise his head and hold it isometrically, an activity that involved a combination of cranio-cervical and cervical flexion[34,40], (2) For the UT muscle, participants were asked to perform arm abduction at 90° and hold their arms isometrically with their elbows straight and their palms facing downwards while sitting and (3) For the CE muscle, each participant was asked to raise his head 20 mm above the bed and hold it isometrically while lying in a prone position[42]. The participants performed three isometric maximal voluntary contractions that were held for 5-7 sec each and separated by 30 sec of rest. The same verbal command was used for all normalization trials[44]. Normalized values were calculated as follows[45]:

$$\text{Normalized RMS (\%)} = \frac{\text{EMG amplitude during resting}}{\text{Average of EMG}_{\text{MAX}}\ \text{for the 3 trials}} \times 100$$

Statistical analysis: Numerical data were assessed for normality by evaluating the distribution of data, calculating mean and median values, drawing histograms and box plots and performing tests of normality (Shapiro-Wilk tests). Cervical angle data and EMG data showed non-parametric distributions. The Mann-Whitney U-test with p-value correction was used to determine whether the MNP and pain-free groups differed with respect to cervical angles or muscle activities. Spearman correlation coefficients were used to investigate relationships between cervical angles and EMG activities. Independent t-tests were used to compare demographic characteristics between groups. Quantitative data are presented as the means and standard deviations. The threshold for significance was set at $p \leq 0.0045$.The measured data were analyzed using the SPSS 18.0 (SPSS, Chicago, IL, USA) statistical program.

RESULTS

Among the 100 subjects who sought to participate in the current study, 77 participants were eligible, including 43 participants with MNP (5 males and 37 females) and 34 pain-free participants (6 males and 28 females). As shown in Table 1, there was no significant difference between these two groups with respect to age, weight, height or BMI ($p>0.05$ for all comparisons), although the groups had significantly different VAS and NDI scores ($p<0.05$ for both comparisons).

Table 1: Demographic and clinical data for the participants

Variables	MNP individuals (Mean±SD)	Pain-free individuals (Mean±SD)	p-value	CI (95%)	
				Lower	Upper
Age (years)	19.97±1.22	19.58±1.32	0.447	-0.96	0.19
Sex distribution within the group	5 males 37 females	6 males 28 females	0.141	-0.22	0.10
Weight (kg)	61.97±7.44	59.85±10.46	0.197	-6.19	1.94
Height (cm)	161.55±15.74	164.02±9.63	0.833	-3.65	8.59
BMI	23.08±2.16	21.78±2.59	0.208	-2.37	-0.217
VAS	6.02±1.26	0.23±0.49	0.001	-6.24	-5.33
NDI	14.76±5.41	1.47±1.10	0.001	-15.18	-11.41

SD: Standard deviation, p-value: Probability value, BMI: Body mass index, CI: Confidence interval, MNP: Mechanical neck pain, VAS: Visual analogue scale, NDI: Neck disability index

Table 2: Cervical angles and RMS activities of cervical muscles for MNP and pain-free individuals

	MNP individuals		Pain-free individuals				CI (95%)	
Variables	Mean	SD	Mean	SD	p-value	Z	Lower	Upper
Cervical angle								
Oc-C_2	22.45	8.59	22.77	6.59	0.712	-0.369	20.83	24.39
C_1-C_2	29.61	6.37	29.50	6.43	0.870	-0.164	28.09	31.02
C_2-C_7	19.28	12.68	29.80	11.74	0.001	-3.57	21.78	27.39
EMG activity								
RT UT muscle	0.076	0.105	0.024	0.026	0.015	-2.43	0.032	0.069
LT UT muscle	0.103	0.151	0.037	0.026	0.010	-2.57	0.045	0.097
RT CE muscle	0.124	0.098	0.094	0.054	0.268	-1.10	0.091	0.128
LT CE muscle	0.162	0.159	0.112	0.061	0.230	-1.20	0.109	0.167
RT SCM muscle	0.086	0.077	0.063	0.034	0.140	-1.47	0.060	0.089
LT SCM muscle	0.097	0.079	0.059	0.037	0.005	-2.83	0.064	0.093
RT AS muscle	0.105	0.125	0.073	0.056	0.186	-1.32	0.066	0.112
LT AS muscle	0.102	0.079	0.096	0.043	0.436	-0.78	0.084	0.114

SD: Standard deviation, p-value: Probability value, CI: Confidence interval, MNP: Mechanical neck pain, EMG: Electromyography, LT: Left, RT: Right, UT: Upper trapezius, CE: Cervical erector spinae, SCM: Sternocleidomastoids, AS: Anterior scalene muscles

Cervical angles: As shown in Table 2, the mean C_2-C_7 angle was significantly larger in MNP subjects than in pain-free individuals ($p<0.001$), but these two groups did not significantly differ with respect to the Oc-C_2 angle or the C_1-C_2 angle ($p = 0.712$ and $p = 0.862$, respectively).

EMG activities: The mean RMS values obtained from bilateral measurements of four muscles in MNP and pain-free individuals are shown in Table 2. The MNP group and the pain-free group significantly differed with respect to the RMS activity of the left SCM muscle ($p = 0.005$) but not with respect to the RMS activities of the right SCM muscle ($p = 0.140$), the right or left CE muscle ($p = 0.268$ and $p = 0.230$, respectively), the right or left UT muscle ($p = 0.015$ and $p = 0.010$, respectively) or the right or left AS muscle ($p = 0.186$ and $p = 0.436$, respectively).

Correlations between cervical angles and RMS activities of muscles: In the control group, correlation analysis of the Oc-C_2, C_1-C_2 and C_2-C_7 angles revealed a weak but significant direct correlation between the Oc-C_2 angle and the C_1-C_2 angle ($p = 0.004$, $r = 0.484$) and a non-significant inverse correlation between the Oc-C_2 angle and the C_2-C_7 angle ($p = 0.556$, $r = -0.104$).

Correlation analysis for cervical angles and RMS activities of cervical muscles revealed a strong, significant, direct correlation between the Oc-C_2 angle and RMS activity for the left UT muscle ($p = 0.002$, $r = 0.502$) and weak but significant direct correlations with RMS activities for the right SCM ($p = 0.031$, $r = 0.370$) and the left SCM ($p = 0.028$, $r = 0.378$). There were also weak significant correlations between the C_1-C_2 angle and RMS activities for the left UT muscle ($p = 0.012$, $r = 0.427$), the right SCM muscle ($p = 0.055$, $r = 0.332$) and the left SCM muscle ($p = 0.007$, $r = 0.453$).

In the MNP group, correlation analysis for the Oc-C_2, C_1-C_2 and C_2-C_7 angles revealed a strong, significant, direct correlation between the Oc-C_2 angle and the C_1-C_2 angle ($p = 0.000$, $r = 0.649$) and a non-significant inverse correlation between the Oc-C_2 angle and the C_2-C_7 angle ($p = 0.242$, $r = -0.182$).

The correlation analysis for cervical angles and RMS activities of cervical muscles revealed a weak direct correlation between the Oc-C_2 angle and the RMS activity of the right SCM ($p = 0.037$, $r = 0.319$).

DISCUSSION

To authors' knowledge, this investigation was the first trial to address the Oc-C_2 and C_1-C_2 angles in MNP subjects and the relationships between these angles and muscle activity. The study results revealed that relative to pain-free patients, MNP patients had a smaller C_2-C_7 angle and increased muscle activity.

Regarding cervical angles, in the current study, the mean C_2-C_7 angle in the MNP group was less than 20°, which was smaller than the corresponding angle for the healthy control group (29.8°). These results agreed with those obtained by McAviney *et al.*[46], who found that cervical complaints arose in subjects with a C_2-C_7 angle of less than 20° or more than 40° but not in subjects with lordotic angles between 20° and 30°. The normal range of lordosis in the cervical region is 31-40°, a C_2-C_7 angle in this range contributes to maintaining biomechanical balance[29,47-49] and has important outcome-related consequences for clinical health[50]. Flattening of the cervical spine, cervical kyphosis or deviation from normal lordosis has been postulated to cause pain due to structural overload and muscle imbalance[47] as well as abnormal stresses in intervertebral discs (IVD) and vertebrae that lead to arthritis and IVD degeneration[50].

In the current study, there was an increase in the Oc-C_2 angle to 22° (relative to a normal value of 14°) to compensate for a decrease in the C_2-C_7 angle and thereby achieve balance in the cervical region. However, there was no difference in either the Oc-C_2 angle or the C_1-C_2 angle between the MNP group and the normal control group. This finding was attributed to a sedentary lifestyle in addition to increased use of cell phones and computers[51]. Prior studies had indicated that computer use, cell phone use and prolonged sitting were related to awkward postural characteristics such as head and neck flexion or forward head posture, which involved a combination of upper cervical lordosis and lower cervical kyphosis[52-56]. The alignments of the upper cervical spine, the occiput and the lower cervical spine were interrelated with respect to maintaining a level horizontal gaze[10,19]. For example, if the Oc-C_2 and C_1-C_2 angles are increased, resulting in greater lordosis, then the C_2-C_7 angle will decrease and vice versa[15].

Regarding muscle activity, increase in the activities of all tested muscles were observed in MNP subjects relative to pain-free individuals, including a significant increase in RMS activity of the left SCM muscle in the MNP group. These results were fully consistent with those reported by several authors; thus, there was strong evidence for increase in the activities of cervical muscles in participants with CMNP[22,25,43,57-61].

The increased activity in the UT muscle observed in the current study resulted from a combination of different factors. These factors may have included (1) Chronic pain that induced increased muscle activity, (2) Neural tissue sensitization, (3) Changes in motor control[58,62-64], (4) Direct effects of nociception on motor neuron output and (5) Changes in motor planning[65].

Increased activity in the superficial neck flexor (SCM and AS) muscles and the CE muscle could be attributed to compensation for activity in the deep neck flexor and extensor muscles[23-25] due to pain[59] and an altered motor strategy to compensate for impaired performance of the deep neck flexors and extensors[42].

Regarding relationships between different cervical angles, this study revealed a statistically significant direct correlation between the Oc-C_2 and C_1-C_2 angles. Negative but not significant correlations between the C_2-C_7 angle and the Oc-C_2 and C_1-C_2 angles were also identified. These results were in agreement with those of several prior studies[15-18]. Along these lines, a study of 313 asymptomatic volunteers (155 males and 158 females) revealed weak statistically significant negative correlations between the Oc-C_2 and C_2-C_7 angles and between the C_1-C_2 and C_2-C_7 angles, a strong coefficient was found for the correlation between the Oc-C_2 and C_2-C_7 angles[15]. A study of 518 asymptomatic volunteers (261 males and 257 females) also confirmed this result and proved that an increase in the Oc-C_2 angle will result in a decrease in the C_2-C_7 angle[16]. Although authors agreed with previous findings regarding a negative correlation between upper and lower cervical spinal angles, Guo *et al.*[17] found in their study of 414 asymptomatic volunteers a stronger negative correlation between the Oc-C_2 angle and the C_2-C_7 angle that contradicted prior results. Moreover, a study of 289 patients with atlantoaxial dislocation and atlas occipitalization revealed a statistically significant negative correlation between the Oc-C_2 and C_2-C_7 angles[18].

Regarding relationships between cervical angles and muscle activities, no correlations between the C_2-C_7 angle and cervical muscle activities were identified in the current study. This result is supported by Tecco *et al.*[39], who revealed that for 54 females between 25 and 35 years of age who were assessed at rest or during maximum voluntary muscle contraction, there was no correlation between cervical muscle activity and cervical posture. In contrast to the current study, an investigation by Pidcoe and Mayhew[66] concluded that the UT muscle extended the head and contributed to cervical lordotic posture.

Additionally, the SCM muscle has no direct attachment to the cervical spine and the Oc-C_2 and C_1-C_2 angles in the upper cervical region were correlated with the activities of the UT and SCM muscles in the current study. In contrast, as mentioned above, the UT muscle has been proven to extend the head and contribute to cervical lordotic posture. Pidcoe and Mayhew[66] explained that these muscles could affect head movement because the SCM muscle was attached to temporal bone and the UT muscle was attached to the superior nuchal line of the skull.

Gender was not regarded as an independent variable, although gender can affect spine posture via variations in muscles and passive tissue mechanics[67]. Another limitation was that for certain individuals, C_7 did not appear in X-rays; as a result, the researchers were forced to exclude these individuals from the study.

CONCLUSION

Participants with MNP had flattening in their cervical curves. Cervical muscles (the UT, SCM, CE and AS muscles) exhibited higher activities in participant with MNP than in pain-free individuals. Activity levels in the SCM and UT muscles were correlated with angles in the upper cervical region.

SIGNIFICANCE STATEMENT

This study revealed that there was increase inactivity of cervical muscles and decrease in the C_2-C_7 angle in participants with MNP. This investigation was the first trial to address the Oc-C_2 and C_1-C_2 angles in MNP subjects and the relationships between these angles and muscles activity which many researchers were not able to explore. Thus, best theory on it may be arrived at.

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