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RESEARCH

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The impact of forward head posture on neck muscle endurance and thickness in women with chronic neck pain: a cross-sectional study

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Abstract

Background Forward head posture (FHP) is a common postural deviation that has been linked to neck pain and dysfunction. The impact of FHP on neck muscle endurance and thickness in individuals with chronic neck pain remains unclear. This study aimed to compare neck muscle endurance and thickness between women with chronic neck pain and FHP versus those with chronic neck pain but normal head/neck posture.

Methods Forty women with chronic non-specific neck pain were divided into two groups based on craniovertebral angle assessment, 20 with FHP and 20 with normal posture in each group. Neck pain, disability, neck flexor and extensor muscle endurance, and neck muscle normalized thickness (sternocleidomastoid, upper trapezius (Utrap), longus coli and total neck extensors) measured via ultrasound were compared between the groups.

Results Women with FHP demonstrated significantly lower endurance of the extensor muscles, normalized thickness of the Utrap muscle, and significantly higher Neck Pain and Disability Scale (NPDS) and Neck Disability Index (NDI) scores compared to the Non-FHP group ($p < 0.05$). Craniovertebral angle (CVA) was positively correlated with extensor muscle endurance ($p = 0.002$, $r = 0.481$).

Conclusions Our findings indicate that the endurance of neck extensor muscles decreases, and neck pain and disability increase in women with chronic neck pain and FHP. This emphasizes the importance of addressing FHP in patients with chronic neck pain and considering the improvement of neck extensor muscle endurance as part of their treatment. These findings may also serve as indicators of the severity of neck pain and assist in patient monitoring.

Keywords Forward head posture, Muscle endurance, Muscle thickness, Neck pain, Ultrasonography

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Introduction

Weakening and atrophy of neck muscles play a significant role in neck pain, which is among the most prevalent and disabling musculoskeletal issues [1, 2]. Worldwide, neck pain ranks as the fourth leading contributor to the burden of musculoskeletal conditions [3].

The relationship between neck pain and Forward Head Posture (FHP) is multifaceted, as the posture may influence the mechanical, muscular, and neurological aspects of neck health [4, 5]. Prolonged FHP can lead to nerve sensitization and increased sensitivity to pain, meaning that even minor stressors may result in significant discomfort [6]. FHP often leads to upper cervical extension combined with lower cervical flexion [7], causing the head to be positioned ahead of the body's weight-bearing axis. This increases the length of the moment arm and results in biomechanical movement abnormalities. Continuous exposure to this excess stress can lead to musculoskeletal damage or pain [8, 9]. FHP appears to affect the endurance and length of the neck muscles and resulting in an inability to contract and tension the muscles effectively [1, 2, 10]. As it is often associated with specific muscles imbalances like weakness and reduced endurance in the deep neck flexors and extensors, coupled with tightness and increased tension in the superficial neck flexor such as the sternocleidomastoid (SCM), and upper trapezius muscles (Utrap) [8].

The degree of FHP, measured by the craniovertebral angle (CVA), is a useful and reliable indicator of functional neck disability [11].There appears to be a connection between CVA and the development of neck pain, with pain intensity related to the level of functional disability [12–15]. A systematic review and meta-analysis in 2019 showed that adults with neck pain had a higher degree of FHP compared to asymptomatic adults, and FHP was significantly correlated with neck pain indices [16].

Clinical and paraclinical evaluations are crucial in determining the underlying causes of chronic nonspecific neck pain and in characterizing the appropriate treatment plan for each patient. The neck flexor and extensor endurance tests are valid clinical tools used to evaluate neck function and endurance [11, 17, 18]. Despite similar results from ultrasonography (US) and magnetic resonance imaging (MRI) for measuring muscle thickness, US offers a more cost-effective and widely available alternative [19–21].The.

Only a limited number of studies have explored how FHP impacts endurance of neck muscles in individuals with this condition, as well as how these factors relate to the pain and disability associated with FHP. There is no clear consensus on how these elements connect to pain in people with FHP. Previous research has yielded inconsistent findings regarding the relationship between neck extensor and flexor muscle endurance and FHP. One study has indicated a decrease in the endurance of deep flexor muscles, while others have reported a decline in the endurance of extensor muscles [22]. Conversely, some studies have failed to detect any correlation between muscle endurance and FHP [23, 24].To address these gaps, our study focused on women with chronic neck pain, dividing them into two groups based on the presence or absence of FHP. In both groups, we measured the endurance of neck flexor and extensor muscles, as well as the thickness of these muscles, and compared the results between the two groups.

We hypothesized that women with chronic neck pain and FHP would have lower endurance in neck flexor and extensor muscles and reduced thickness in these muscles compared to women with chronic neck pain without FHP.

Materials and methods

Subjects

Forty women with chronic non-specific neck pain, aged between 18 and 65 years, participated in this cross-sectional study. The patients were referred to the sports medicine clinic of Rasool Akram Hospital during 2021–2022 and were divided into two groups based on the craniovertebral angle (CVA). Group 1 consisted of 20 patients with chronic neck pain without forward head posture (FHP), and Group 2 included 20 patients with chronic neck pain with FHP [14, 25].

The inclusion criteria were as follows: chronic nonspecific neck pain (persistent neck pain for at least three months with a severity of at least 3 on the Visual Analog Scale (VAS) from 0 to 10), female sex, aged 18–65 years, body mass index (BMI) of 30 or less, and a balanced mental state [26, 27]. The exclusion criteria included the presence of acute traumatic injury to the spine confirmed by a specialist, a history of previous surgery or injury to the neck or upper limb joints in the last year, pregnancy, concurrent shoulder pain, a recent fracture in the upper limbs within the last year, malignant tumors, inflammatory diseases such as ankylosing spondylitis, rheumatoid arthritis, fibromyalgia, myelopathy, cervical radiculopathy, participation in exercise therapy, manipulation programs, acupuncture, physiotherapy within the last three months, and congenital spinal malformation.

Neck pain and disability were assessed using the Neck Pain and Disability Scale (NPDS) and the Neck Disability Index (NDI) questionnaires, under the supervision of two investigators at the hospital. The NPDS specifically focuses on pain intensity and its impact on daily activities, providing a precise evaluation of neck pain, while the NDI assesses the degree of disability related to neck pain, encompassing a broader range of functional activities and quality of life aspects. The NPDS consists of 20 questions related to neck pain and its interference with daily life, with each question scored between 0 and 5, for a total score range of 0 to 100. Higher scores indicate more severe pain [28]. The NDI includes 10 sections covering pain intensity, personal tasks, lifting objects, reading, headaches, concentration, work, driving, sleep, and recreational activities, each with six statements describing the absence of pain or disability to the most severe possible level. The questions are measured on a 6-point scale from 0 (no disability) to 5 (full disability). The numeric response for each item is summed for a score varying from 0 to 50, which can also be translated to a percentage score of 0-100% [29]. Data on the number of hours participants spent working with laptops and mobile devices each day was also collected.

Assessment of the craniovertebral angle

To assess head and neck posture, the CVA was measured using digital photography. The angle between the line connecting the tragus of the ear and the spinous process of the seventh cervical vertebra with the horizontal plane was measured. Participants performed neck flexion and extension three times while standing to relax the neck muscles, then placed their heads in a comfortable position. The camera was fixed on a stand at a distance of 1.5 m from the subject and adjusted to its shoulder height. An image was taken from the right side of subject, and the angle between the lines was measured using Paint.NET software for Windows, version 5.0.13. A CVA less than 50 degrees was considered indicative of FHP, while a CVA of 50 degrees or more was considered normal [14, 25, 30] (Fig. 1).

Neck flexor & extensor endurance test

Both of neck endurance tests are clinical methods that has been used in many studies related to neck pain and headaches of neck origin and their validity have been proven [17]. For the neck flexor endurance test, the patient lay supine with their hands by their sides and knees bent. For the neck extensor endurance test, the patient lay prone with their hands by their sides. During the neck flexor endurance test, the patient performed cranio-cervical flexion (chin tuck), lifting their head 2.5 cm from the bed while maintaining the chin tuck position. Using a ruler, an imaginary line was drawn from the forehead hairline perpendicular to the bed surface. The distance between the bed surface and the head was measured with the ruler to confirm it was exactly 2.5 cm. In the neck extensor endurance test, the patient positioned their head and neck outside the bed and tried to keep them in a horizontal position while maintaining the chin tuck position [27, 31]. The duration that the patient could hold these positions was measured with a stopwatch. Patients were instructed on the test and practiced for 5 s, followed by a 5-minute rest. The test was then performed twice, with a 5-minute rest between trials. The average time was recorded to assess muscular endurance (Fig. 1). The tests were discontinued if the subject was unable to maintain the correct posture, experienced separation of skin folds due to loss of chin tuck, or expressed a desire to stop because of fatigue or pain.

Ultrasonography protocol

This study used the Chison ultrasound system model i3 (China Jiangsu, CHISON Medical Technologies Co.) with a frequency of 7.5 MHz and a 5 cm linear probe. Before the ultrasound evaluation, the patient was asked to lie on the bed and rest for 10 min. Ultrasound was performed on the non-dominant side of the patients. In this study, the sternocleidomastoid (SCM), longus colli (LCo), upper trapezius (Utrap), and total neck extensor muscles were examined. To evaluate the SCM and LCo muscles, the patient lay in a supine position with a rolled towel placed under their neck to maintain a neutral position. First, the thyroid cartilage was located by palpation, which is at the C5-C6 level. The probe was then placed transversely 2 cm below and 5 cm lateral to the midline. The longus colli muscle is positioned with the common carotid artery

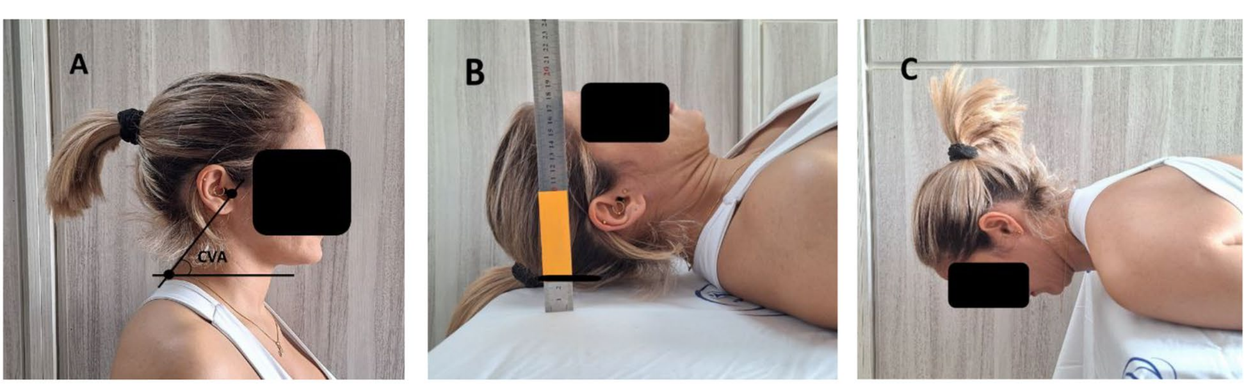

Fig. 1 the CVA (**A**), the neck flexor endurance test (**B**), the neck extensor endurance test (**C**)

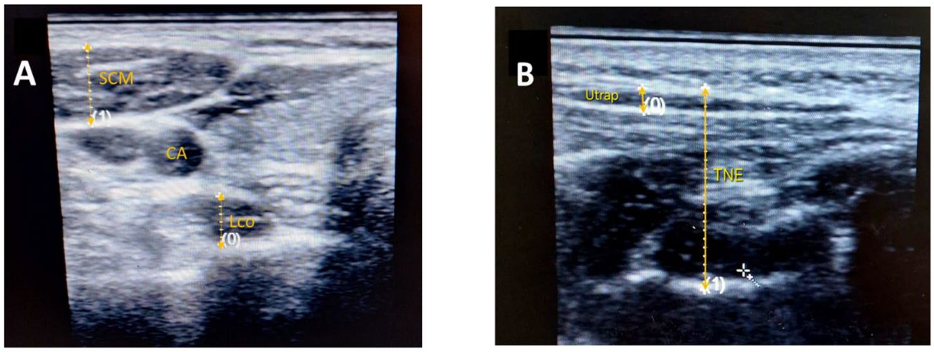

Fig. 2 The anterior-posterior dimension (APD) or thickness of thesternocleidomastoid (SCM), longus colli (LCo), carotid artery (CA) (**A**), upper trapezius (Utrap), and total neck extensor muscles(TNE) (**B**)

and internal jugular vein on its anterolateral side, while the thyroid gland and C5 vertebral body are located on its anteromedial side [32]. To examine the extensor muscles, the patient was placed prone with a pillow under their chest. Their hands were placed under their forehead, and their head and neck were kept in a neutral position. The probe was initially placed transversely on the spinous process of the C5 vertebra. After observing the lamina, the probe was moved to the non-dominant side of the patient, approximately 2 cm lateral to the spinous process of the vertebra, to capture images of the muscles [33, 34] (Fig. 2). The anterior-posterior dimension (APD) or thickness of the muscles, defined as the greatest distance between the anterior and posterior edges of the muscle, was measured and recorded. For standardization, normalized muscle thickness (muscle thickness divided by patient weight) was used in this study [34–36]. Ultrasound measurements were performed by a sports medicine resident with three years of experience in musculoskeletal ultrasonography. Intrarater reliability was assessed in 14 patients with chronic neck pain (7 with FHP and 7 without), across two sessions conducted 3 to 7 days apart.

Table 1 Comparison of demographic characteristics of two groups FHP, Non FHP

Variable	Chronic neck pain patients		*P* value
	With FHP Mean (SD)	Without FHP Mean (SD)	
Age(y)	37.15(8.19)	35.90(6.52)	0.56
Weight(kg)	64.50(9.27)	65.15(7.86)	0.81
Height(cm)	162.75(6.12)	164.75(7.04)	0.34
BMI(kg/m2)	24.29(2.77)	24.07(3.10)	0.80
Working with laptop and mobile (hours per day)	7.80(1.90)	7.75(1.91)	0.93
Pain (VAS)	6.10(1.48)	5.40(1.69)	0.17

BMI: body mass index; FHP: forward head posture; VAS: visual analogue scale (0–10)

Statistical analysis

Data were analyzed using SPSS software for Windows, version 23. The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Depending on the normality results, the independent t-test or the Mann-Whitney U test was used to compare quantitative data between the two groups. Comparison of the endurance of neck flexor muscles, endurance of neck extensor muscles, NDI, and normalized Utrap muscle thickness between the two groups was performed using the non-parametric Mann-Whitney U test. Comparisons of other variables were conducted using the parametric independent t-test.

The Fisher exact test was employed to compare qualitative data. Correlations between variables were examined using the Pearson or Spearman correlation test. A p-value of less than 0.05 was considered statistically significant. Correlation coefficients were classified as follows: values between 0.20 and 0.39 indicated a weak correlation, values between 0.40 and 0.59 indicated a moderate correlation, and values between 0.60 and 0.79 indicated a strong correlation [37, 38]. A p-value of less than 0.05 was considered statistically significant.

Result

In total, 40 female patients participated in the study (age = 36.52(7.24), weight = 64.82(8.38), height = 163.75(6.51), BMI = 24.18(2.87)). As shown in Table 1, there were no significant differences between the two groups of participants.

The average CVA angle in the FHP group was 43.8 degrees, compared to 53.7 degrees in the Non-FHP group, a difference that was statistically significant ($p < 0.001$).

The FHP group had significantly lower endurance of the extensor muscles, normalized thickness of the Utrap muscle, and significantly higher NPDS and NDI scores compared to the Non-FHP group Table 2.

Table 2 Comparison of variables between two groups of FHP and Non-FHP

Variable	Chronic neck pain patients		*P* value
	With FHP Mean (SD)	Without FHP Mean (SD)	
Endurance of cervical flexor muscles(s)	16.68(4.63)	20.17(12.13)	0.91
Endurance of cervical extensor muscles(s)	22.6(6.66)	33.12(14.21)	0.011
NDI score	27.10(8.92)	21.35(9.47)	0.013
NPDS score	60.35(12.71)	49.8(17.70)	0.037
Normalized thickness of SCM muscle (mm/kg)	0.132(0.015)	0.126(0.015)	0.19
Normalized thickness of LCo muscle (mm/kg)	0.073(0.014)	0.075(0.010)	0.76
Normalized thickness of Utrap muscle (mm/kg)	0.036(0.014)	0.043(0.009)	0.047
Normalized thickness of neck extensor muscles (mm/kg)	0.295(0.048)	0.305(0.032)	0.053

FHP: forward head posture; LCo: longus colli; NDI: neck disability index; NPDS: neck pain and disability scale; SCM: sternocleidomastoid; Utrap: upper trapezius; A p-value of less than 0.05 was considered statistically significant

Table 3 Correlation between variables

Variable	Correlation Coefficient (*r*)	*p*-value	Interpretation
Age			
- Flexor Muscle Endurance	-0.562	< 0.001	Moderate negative correlation
- Extensor Muscle Endurance	-0.438	0.006	Moderate negative correlation
- Normalized LCo Thickness	-0.381	0.018	Moderate negative correlation
NDI / NPDS			
- CVA	-0.477/-0.403	0.002/0.010	Moderate/ Moderate negative correlation
- Flexor Muscle Endurance	-0.375/-0.402	0.017/0.010	Weak/Moderate negative correlation
- Extensor Muscle Endurance	-0.438/-0.401	0.005/0.010	Moderate negative correlation
- Normalized LCo Diameter	-0.545/0.494	< 0.001/0.001	Moderate negative correlation
CVA			
- Extensor Muscle Endurance	0.481	0.002	Moderate positive correlation
Flexor and Extensor Muscle Endurance			
- Correlation Between Endurances	0.613	< 0.001	Strong positive correlation
Normalized LCo Muscle Diameter			
Flexor Muscle Endurance	0.416	0.008	Moderate positive correlation
Extensor Muscle Endurance	0.513	0.001	Moderate positive correlation
Normalized Total Extensor Muscles Diameter			
- Normalized SCM Muscle Thickness	0.489	0.001	Moderate positive correlation
- Normalized LCo Muscle Thickness	0.415	0.008	Moderate positive correlation

CVA: craniovertebral angle; LCo: longus colli; NDI: neck disability index; NPDS: neck pain and disability scale; SCM: sternocleidomastoid

Investigating the correlation between study variables, age was negatively correlated with flexor ($p < 0.001$, $r = -0.562$) and extensor ($p = 0.006$, $r = -0.438$) muscle endurance, and normalized LCo thickness ($p = 0.018$, $r = -0.381$).

Neck pain and disability scores measured by NDI and NPDS questionnaires, were negatively correlated with CVA ($p = 0.002$, $r = -0.477$and $p = 0.010$, $r = -0.403$), flexor muscle endurance ($p = 0.017$, $r = -0.375$ and $p = 0.010$, $r = -0.402$), extensor muscle endurance ($p = 0.005$, $r = -0.438$ and $p = 0.010$, $r = -0.401$) and normalized LCo diameter ($p < 0.001$, $r = -0.545$ and $p = 0.001$, $r = -0.494$). CVA was positively correlated with extensor muscle endurance ($p = 0.002$, $r = 0.481$). Flexor and extensor muscle endurance were positively correlated ($p < 0.001$, $r = 0.613$). Normalized LCo muscle diameter showed a moderate positive correlation with flexor and extensor muscle endurance ($p = 0.008$, $r = 0.416$ and $p = 0.001$, $r = 0.513$). Normalized total extensor muscles diameter was positively correlated with SCM and LCo muscle normalized thickness ($p = 0.001$, $r = 0.489$ and $p = 0.008$, $r = 0.415$) Table 3.

Discussion

As the results show the FHP group has significantly higher NPDS and NDI scores compared to the Non-FHP group and neck pain and disability scores measured by NDI and NPDS questionnaires, were negatively correlated with CVA. This might be due to the fact that in our study both groups had chronic neck pain. When this chronic neck pain is accompanied by FHP, this posture during the time could alter the biomechanics of neck muscle and pain perception more than FHP alone or FHP with acute neck pain. These findings align with the review by Mahmoudi et al. in 2019, which indicated that individuals with FHP and non-specific neck pain experience increased disability and pain [16]. Similarly, Kim's study confirmed severe neck pain and disability in individuals with FHP [39]. Conversely, Merinero's study found no connection between FHP and neck pain or disability, despite increased tissue mechanical sensitivity and a decrease in cervical range of motion in those with FHP [40]. This discrepancy may arise from the fact that the community studied by Merinero had FHP without any existing neck pain, suggesting that FHP alone does not cause neck pain but may exacerbate pre-existing pain and disability.

The study's findings revealed that cervical extensor muscle endurance was significantly lower in the Forward Head Posture (FHP) group compared to the non-FHP group. Additionally, neck pain and disability were negatively correlated with the endurance of both neck flexor and extensor muscles. Previous studies by Peolsson and Rezasoltani indicated that patients with chronic neck pain exhibit reduced cervical extensor muscle endurance compared to healthy subjects [36, 41].

In our study, both groups demonstrated decreased cervical extensor muscle endurance compared to healthy subjects in other studies. However, when FHP is combined with chronic neck pain, it leads to a significant reduction in cervical extensor muscle endurance between groups. This may be due to the fact that prolonged periods of FHP have been shown to decrease the number of sarcomeres and shorten muscle fibers, impairing muscular contraction [39]. Furthermore, the increased moment arm in FHP places a constant load on the craniovertebral extension muscles, resulting in heightened activity, transformation of muscle fiber types and subsequent fatigue in the cervical extensors, which further diminishes endurance [42].

Consistent with Torkamani's findings, this study also showed reduced endurance of cervical extensor muscles in individuals with FHP [43]. Edmondston's research demonstrated that while the difference in extensor muscle endurance among people with postural neck pain is clinically significant, it is not statistically significant [44]. Ghamkhar and colleagues found no association between neck muscle endurance and FHP [23]. None of the cited studies have compared individuals with neck pain who assume different head and neck positions.

The inconsistencies in these findings could be attributed to the impact of FHP on extensor endurance in chronic neck pain patients but not in individuals without pain. Variations in testing methods or the small sample sizes in studies like Edmondston's, which included only 13 and 12 participants in each group could also contribute to these mixed results.

Based on the results, the normalized thickness of Utrap muscle was significantly lower in the FHP group. As previously demonstrated, FHP can lead to the shortening of neck extensor muscles and lengthening of neck flexor muscles. Additionally, FHP with chronic neck pain can limit the range of motion in both neck flexion and extension [39]. FHP may induce over-activation of the upper trapezius not only in an upright posture but also while resting in a side-sleeping position [45]. Chronic over-activation of muscles can lead to increased proteolytic activity and muscle fatigue, potentially resulting in muscle atrophy [46]. We hypothesize that when FHP is combined with chronic neck pain, it specifically affects the thickness of superficial extensor muscles like the upper trapezius more than other neck muscles. Further studies are needed to evaluate this hypothesis in greater detail.

Goodarzi's study found that, contrary to their hypothesis, there was no significant difference in the normalized muscle thickness of the upper trapezius and other neck extensor muscles in the FHP group versus their control group. This discrepancy may be attributed to factors such as the younger age of their participants, the inclusion of both sexes in their groups, and the absence of neck pain in both groups [24].

Regarding muscle thickness, this study found that the normalized LCo muscle thickness did not have any difference between people who suffer from chronic neck pain with and without FHP in the resting state, consistent with the findings of Bokaee [47]. However, neck pain and disability based on the NDI and NPDS questionnaire negatively correlated with the normalized LCo muscle diameter. In a cadaver study, the three parts of the LCo exhibited different trends during varying degrees of FHP. No significant changes in muscle length were observed in slight FHP. However, in severe FHP, only the superior oblique part of the LCo lengthened significantly [48]. These findings highlight the complexity of LCo muscle changes during different degrees and durations of FHP, as well as the impact of concomitant chronic neck pain. This underscores the need for further investigation in this area to better understand the relationships and mechanisms involved.

The limitations of this study include the reliance on clinical tests to assess neck muscle endurance. While these tests have certain drawbacks, they remain commonly used in clinical settings due to their simplicity and practicality for evaluating and monitoring the treatment progress of patients with neck pain. On the other hand, the low endurance of cervical extensors in both groups compared to other studies may be attributed to chronic neck pain and its inhibitory effects, which both groups suffer from.

Additionally, our study included only female participants, which limits the generalizability of the findings. We suggest further studies that include both male and female participants to evaluate the effect of sex on these variables.

Furthermore, we recommend comparing neck muscle endurance and thickness in individuals with acute versus chronic neck pain. This comparison could provide valuable insights into how the duration of neck pain influences these variables, enhancing our understanding of muscle adaptations and potential treatment strategies.

Conclusion

It remains unclear whether FHP causes neck pain or if neck pain leads to FHP over time. However, a crucial finding of our study is the increased pain and disability in individuals with FHP compared to those with chronic non-specific neck pain and normal head posture. Our results indicate a decrease in neck extensor muscle endurance alongside an increase in neck pain and disability (based on the NDI and NPDS questionnaire) in the FHP group. These findings underscore the importance of evaluating and addressing FHP in managing chronic neck pain and highlight the need for further research to elucidate the causal relationships involved. Future studies should also explore the efficacy of targeted interventions, including ergonomic adjustments and specific exercise programs, to mitigate the impact of FHP on neck pain and disability.

Abbreviations

FHP	forward head posture
SCM	sternocleidomastoid
Utrap	upper trapezius
LCo	longus colli
CVA	craniovertebral angle
NPDS	Neck Pain and Disability Scale
NDI	Neck Disability Index
VAS	visual analogue scale

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Author contributions

Study conception and design: Sara Lotfian, Molood Jafari Fesharaki, Azar Moezy Data collection: Molood Jafari Fesharaki, Zahra SHahabbaspour Analysis and interpretation of results: Sara Lotfian, Molood Jafari Fesharaki Draft manuscript preparation: Sara Lotfian, Molood Jafari Fesharaki, Zahra SHahabbaspour, Haniseh Akbarzadeh All authors reviewed the results and approved the final version of the manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. It was approved by the Research Ethics Committee of the School of Medicine, Iran University of Medical Sciences, under ethics code IR.IUMS.FMD.REC.1399.619. Every patient included in the study voluntarily signed informed consent before participation.

Consent for publication

All participants provided written informed consent for the publication of their personal or clinical details, including any identifying images, in this study.

Competing interests

The authors declare no competing interests.

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