The Effects of Forward Head Posture on Neck Extensor Muscle Thickness: An Ultrasonographic Study

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Abstract

Objective: This study aimed to compare neck extensor muscle thickness, thickness changes, and strength between participants with forward head posture (FHP) and controls with normal head posture (NHP).

Methods: Twenty college students with FHP (mean age 21.30 ± 2.36 years) and 20 students with NHP (mean age 21.85 ± 2.78 years) participated in this case-control study. The thickness of neck extensor muscles was measured at rest and at maximal voluntary isometric contraction (MVIC). In addition, the craniovertebral angle (CVA) was calculated. To compare thickness changes between the 2 groups and among 5 muscles, a 2-way repeated measures analysis of variance was applied. In addition, Pearson's correlation test was performed to investigate the relationship between neck extensor MVIC and CVA.

Results: The FHP group demonstrated lower MVIC compared with the NHP group ($P = .03$). Semispinalis capitis showed the smallest thickness changes during neck extensor MVIC in FHP compared with the controls ($P < .001$). However, no significant difference in terms of muscle thickness was observed between the 2 groups at the state of rest ($P = .16$-.99). A positive association was also found between the MVIC and CVA ($P = .02$).

Conclusions: Semispinalis capitis had less thickness changes during MVIC of neck extensors in individuals with FHP compared with those with NHP. This indirectly implies lower activity of this muscle in FHP condition. This study finding may help researchers develop therapeutic exercise protocols to manage FHP. (J Manipulative Physiol Ther 2018;41:34-41)

Key Indexing Terms: *Muscle Contraction; Muscle Strength; Neck Muscles; Posture; Ultrasonography*

Introduction

One of the predisposing factors that cause occupational neck pain is irregular head and neck posture.[1] Forward head posture (FHP) is one of the most common deviations from normal cervical posture[2] and may lead to an increase in gravitational load and mechanical stress to cervical facet joints, altered neck extensor muscles activity, and length of cervical muscles.[3-6] Forward head posture is defined as leaning the head and the upper cervical spine anterior to the plumb line that passes the lateral malleolus in sagittal view.[7] It is expected that FHP should be typically accompanied by shortening of neck extensor muscles and lengthening of neck ventral muscles.[4] This length alteration could secondarily decrease neck muscles' tension during daily or work-related activities. Each muscle induces the largest tension in only an optimal resting length.[8] If a muscle passes its own optimal length by getting either lengthened or shortened, the tension produced by the muscle can be reduced. As such, it is expected that neck extensor muscles produce altered tension in individuals with FHP compared with individuals with normal head posture (NHP). Forward head posture is recognized as a risk factor for neck pain; therefore, studying neck muscle function and strength in individuals with FHP may reduce the incidence of neck pain.

Ultrasonographic studies on neck muscles have revealed that there is a correlation between thickness and strength of neck muscles.[9-15] In other words, reduced muscle thickness

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Paper submitted June 16, 2016; in revised form November 2, 2017; accepted July 28, 2017.

0161-4754

https://doi.org/10.1016/j.jmpt.2017.07.012

probably implies muscle weakness. Although such morphologic and physiologic changes have been reported in patients with neck pain,[10,14,16-18] there are limited studies on neck muscles in FHP. Evidence in the literature supports that poor postural orientation could predispose people to the risk of neck pain.[5,6] One of the most common postural deviations associated with suboccipital trigger points, headache, and neck pain is FHP.[19] This signals the need for a study to investigate neck extensor muscles and their strength in individuals with FHP compared with individuals with NHP. Thus, the present study was carried out to compare the thickness and strength of neck extensor muscles in individuals with FHP compared with individuals with NHP. The study also examined the possible relationship between the strength of neck extensor muscles and the degree of FHP. As such, the following hypotheses were formulated: (1) Neck extensor muscles could produce less tension during maximum voluntary isometric contraction (MVIC) in individuals with FHP compared with individuals with NHP; (2) Neck extensor muscles have less thickness in individuals with FHP compared with individuals with NHP; (3) Neck extensor muscles have altered thickness changes during an isometric neck extension task in individuals with FHP compared with individuals with NHP. Moreover, it was hypothesized that there is a direct relationship between the amount of forward head inclination and neck extensor muscle strength.

Methods

Participants

Twenty college students with FHP (11 females, 9 males; mean age 21.85 ± 2.87 years) and 20 students with NHP (11 females, 9 males; mean age 21.30 ± 2.36 years) participated in this case-control study. The experimental setup is described in Figure 1. The sample size was estimated based on the following formula assuming $\propto = 0.05$ and $\beta = 0.2$. Based on the pilot study, the mean difference and standard deviation for the muscle thickness changes were expected to be 0.2 and 0.2, respectively.

$$N = 2\left[\frac{\left(Z\,1-\left(\frac{\alpha}{2}\right)+Z\,1-\beta\right)\delta}{\Delta\mu}\right]^2 = \left[\frac{(1.96+0.84\ \ )0.2}{0.2}\right]^2 = 16$$

Accordingly, the number of participants in each group was estimated to be 16 persons. To boost statistical power, 20 participants were included in each group. Participants were recruited from among healthy college students who had no history of any neck pain, trauma to the cervical spine, inflammatory or infectious diseases of the spine, or congenital spinal deformities.[7,20,21] The participants in both groups were statistically similar in terms of age, body mass index, and height. All the experimental procedures in this study were approved by the local Ethics Committee (IR.USWR.REC.1393.126) and conformed to the Declaration of Helsinki (1964).

The aims and objectives of the study were explained to the volunteers verbally prior to obtaining their written informed consent.

Procedure

Postural Assessment. To find out whether there was FHP, this study applied 2 different ways to carry out the postural assessment, including plumb line assessment and craniovertebral angle (CVA) measurement. First, all participants were asked to stand normally in their own relaxed position while the plumb line was passed anterior to their lateral malleolus. At this position, FHP was recognized by placing the ear tragus anterior to the plumb line.[7,22,23] To measure the CVA, participants were asked to stand relaxed with arms by their sides. The spinous process of C7 was

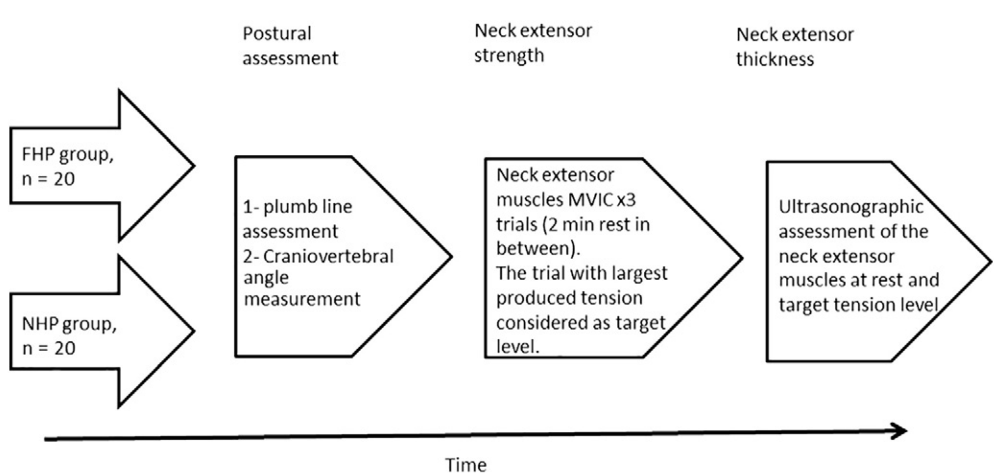

Fig 1. *Experimental setup for assessment of FHP, neck extensor muscle strength, and neck extensor muscle thickness.* FHP*, forward head posture;* MVIC*, maximal voluntary isometric contraction (kgf);* NHP*, normal head posture.*

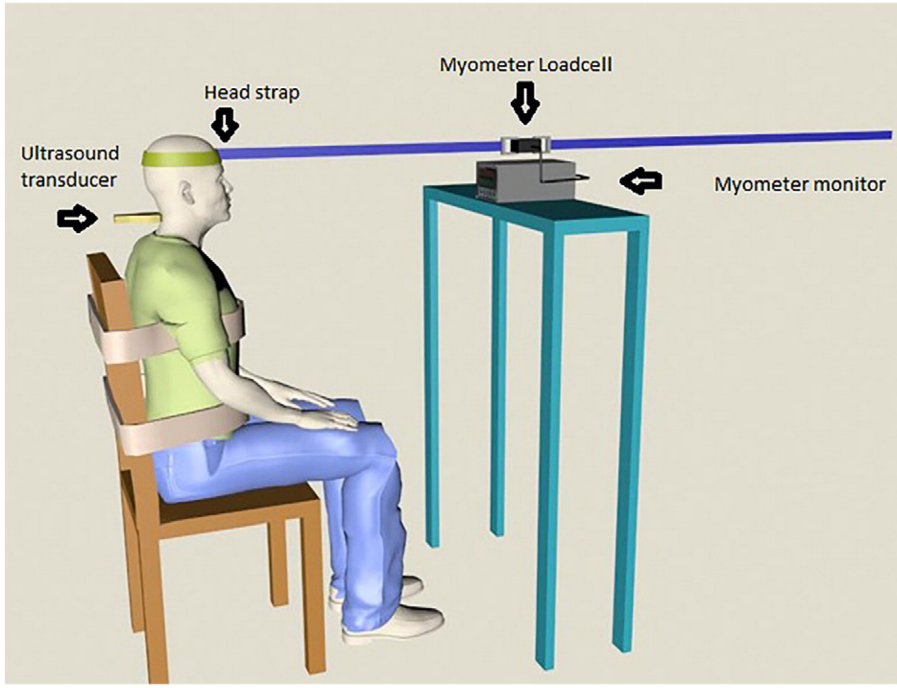

Fig 2. *Participant position during isometric neck extension.*

identified through palpation and marked with a conical adhesive marker. In the next step, participants were instructed to perform head flexion and extension 3 to 4 times so that their self-balanced head position could be obtained.[24] A digital camera (Canon model IXUS, Canon, Tokyo, Japan) was placed at a distance of 1.5 m from each participant's shoulder. Digital lateral view images from each participant's head, neck, and shoulder were captured for further measurement. The angle between the lines connecting the spinous process of C7 to the ear tragus and the horizontal line passing C7 was considered the CVA.[4,7] A CVA less than 49 degrees was considered the FHP.[24] The measurements were carried out using Autocad Software Version 12 (Autodesk, San Rafael, California).[25]

Neck Extensor Muscle Strength. A Multi-Analyzer Myometer (MIE Medical Research Ltd., Leeds, United Kingdom) was utilized to assess the MVIC of the neck extensor muscles.[12] Participants were instructed to sit relaxed on a chair while putting their hands on their legs and keeping their heads and necks in neutral position. Two belts were used to fasten the participant's trunk to the chair—1 at the level of scapular spine and the other at the level of iliac crest (Fig 2). A strap wrapped around the head was connected to the tensiometer located in front of participant's forehead[12] (Fig 2). Participants were asked to perform 2 to 3 submaximal contractions of the neck extensor muscles as a warm-up exercise. Then, the participants performed 3 trials of MVIC of neck extensor muscles.[21,26] They were instructed to avoid upward or downward movements of their chins to prevent craniocervical extension. Each trial took 4 seconds. There was a 2-minute rest period between the trials to prevent muscle fatigue.[27] The trial with maximum amount of force was chosen as participant's maximal neck extensor muscle strength.[9-11] Once participants' MVICs were identified, they were given 5 minutes of rest to prepare for the main procedure.[28] In the next step, participants were asked to perform the MVIC of neck extensor muscles and reach their force to the target MVIC. At the same time, the ultrasonic imaging of their neck extensor muscles was taken. Once they had kept their neck extensor MVIC for 4 seconds, the examiner froze the ultrasound image for further measurements.

Ultrasonography. Ultrasonographic imaging of neck extensor muscles was carried out using Ultrasonix ES 500 (Ultrasonix Medical Corporation, Vancouver, BC, Canada) with a linear 4.5-cm and 12 MHz transducer. The fourth cervical (C4) spinous process was identified through palpation.[26] This level was chosen as the level of ultrasound imaging because the muscle cross-sectional area is larger than C3 level and is very similar to the level of C5.[29] Thus, the transducer transversely was positioned at the level of C4 spinous process, sliding it slowly to the right, upward, and downward until the echogenic vertebral lamina could be identified clearly. The thickness of the neck extensor muscles comprising the trapezius, splenius capitis, semispinalis capitis, semispinalis cervicis, and multifidus muscles were measured at the same level at the state of rest and MVIC (Fig 3). The thickness of each muscle was measured by determining the maximal distance between the muscle's facial borders.[27,29] The measured muscle thickness was divided by the participant's weight to normalize

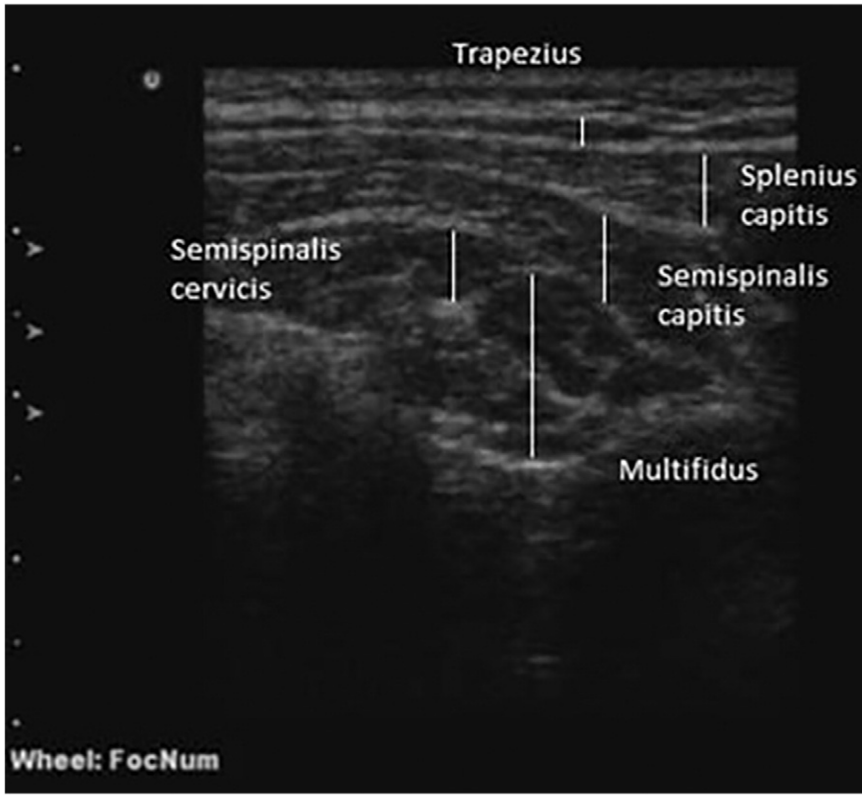

Fig 3. *Ultrasonic image of neck extensor muscles. The vertical lines indicate the thicknesses of different muscles.*

muscle thickness for both sexes.[30] The difference of each muscle normalized thickness at the level of MVIC minus its normalized thickness at rest was calculated and used in the data analysis.[26]

Reliability Study. The intrarater reliability was determined on 8 NHP participants and 8 FHP participants to estimate the reliability of muscle thickness measurements at rest and 100% of MVIC and of the muscle strength test. The required data were collected from 2 separate sessions within a period of 3 to 7 days.

Data Management and Statistical Analysis. SPSS software for Windows, version 20.0 (IBM, Armonk, New York) was applied to analyze the data. To test the normality, the Shapiro-Wilk test was performed. Additionally, independent *t* test was conducted to compare the demographic data, muscle thickness at rest, and target force between the 2 groups. For the estimation of the main and interaction effects of variables, 2-way repeated measures analysis of variance were performed with muscle (5 neck extensor muscles) as the within factor and group (FHP and NHP) as the between factor. Post hoc pairwise comparison was carried out using Bonferroni correction. Furthermore, to evaluate the homogeneity of variances for repeated measures analysis of variance, Leven's test was used. The homogeneity of variances was not violated for all variables except for multifidus muscle thickness changes with $\propto =$ 0.04, which was negligible and indicated equal variances for all variables across groups. To determine the relative and absolute reliability of the muscle thickness measurement and the neck muscle strength, intraclass correlation coefficient (ICC) and standard error of mean (SEM) were computed, respectively. Pearson's correlation test was performed to evaluate the strength of the relationship between the amount of forward head inclination and neck extensor muscle strength. Statistical significance was identified at the level of $P < .05$.

Results

Participants' Demographic Data

The Shapiro-Wilk test revealed normal distribution of all data. Therefore, parametric statistical tests were carried out to analyze the data. Participant demographic data, including age, weight, height, and body mass index, are presented in Table 1.

Reliability Study

The evaluated ICC and SEM varied from 0.82 to 0.94 and 0.11 to 0.69 for muscle thickness measurements. The ICC and SEM for neck extensor muscle strength were 0.94 and 0.19, respectively.

Table 1. *Means and Standard Deviations for Participant Demographic Data*

	NHP	FHP	*P* Value
Age, y	21.85 ± 2.78	21.30 ± 2.36	.51
Weight, kg	61.65 ± 8.18	61.12 ± 9.76	.85
Height, cm	170.35 ± 7.70	171.15 ± 7.08	.71
BMI, kg/m^2	21.19 ± 1.63	20.77 ± 2.38	.51

BMI, body mass index; *FHP*, forward head posture; *NHP*, normal head posture.

Muscle Strength

Participants with FHP showed statistically lower neck extensor muscle strength (MVIC) compared with individuals with NHP (Table 2).

Neck Extensor Muscle Thickness

The independent *t* test revealed no significant differences between the 2 groups in terms of muscles' normalized thickness at the state of rest (P = .16-.99) (Table 3).

Neck Extensor Muscle Thickness Changes During the Extension Task

A significant 2-way interaction of group by muscle was observed for neck extensor muscle thickness changes with P = .03. This could indirectly demonstrate different patterns of muscle activity in 2 groups while performing the extension task. Bonferroni's correction indicated that the semispinalis capitis muscle had significantly less thickness changes in individuals with FHP in comparison with those with NHP (P < .001). No other differences for any other muscle were observed between the 2 groups. However, multifidus showed the biggest thickness changes, whereas the trapezius muscle demonstrated the smallest changes among other muscles during the extension task in both groups (Fig 4).

CVA and Neck Extensor Muscle Strength

Participants with FHP showed statistically lower CVA compared with individuals with NHP (Table 2).

A significant positive correlation between the neck extensor muscle strength and the CVA was revealed (P = .02; r = 0.37). This indicates that the bigger the CVA is, the stronger the neck extensor muscles are (Fig 5).

Table 2. *Comparison of Neck Extensor Muscle MVIC Contraction and CVA Between the 2 Study Groups*

	NHP	FHP	*t*	*P* Value
MVIC, kgf	3.54 ± 0.92	2.96 ± 0.62	2.313	.03
CVA, degree	55.90 ± 2.25	43.43 ± 2.58	16.250	.0001

Values are mean ± standard deviation.
CVA, craniovertebral angle; *FHP*, forward head posture; *MVIC*, maximal voluntary isometric contraction; *NHP*, normal head posture.

Table 3. *Means and Standard Deviations for Normalized Muscle Thickness (Muscle Thickness/Participant's Weight) at Rest*

Muscle	NHP	FHP
Multifidus	0.1597 ± 0.02067	0.1577 ± 0.01724
Semispinalis cervicis	0.0889 ± 0.01987	0.0888 ± 0.02155
Semispinalis capitis	0.0905 ± 0.02018	0.0807 ± 0.02322
Splenius capitis	0.0657 ± 0.01314	0.0705 ± 0.01544
Upper trapezius	0.0209 ± 0.00798	0.0214 ± 0.00775

FHP, forward head posture; *NHP*, normal head posture.

Discussion

Neck Extensor Muscle Strength

The results of the present study indicate that participants with FHP demonstrated a significant reduction in neck extensor MVIC compared with those with NHP. Given that the length tension relationship of neck extensor muscles changes in FHP, it could produce a lower amount of extensor force compared with NHP. This finding is in line with the findings of a study by Lee et al in which less electromyographic activity of some neck extensor muscles was reported in individuals with FHP compared with those with NHP.[31] Another study also reported reduction in neck extensor strength during intended neck flexion and extension resembling FHP, supporting the findings of the current study.[12]

Neck Extensor Muscle Thickness

We hypothesized that the neck extensor muscles have less thickness in individuals with FHP compared with individuals with NHP, but this was not supported by the findings in this study. No significant differences on neck extensor muscle thickness were found between 2 groups at the state of rest. According to Rezasoltani et al, who evaluated the size of the semispinalis capitis muscle in 3 different head orientations, including extension, normal, and flexion, the size of the semispinalis capitis muscle is not a good indicator of muscle strength.[12] This could have been the reason for the lack of differences in neck extensor muscle thicknesses between the 2 groups at rest despite their different strengths. In contrast, Peolsson et al demonstrated a bigger deformation of neck extensor muscles at the state of rest in an intentional FHP compared with NHP.[21] Methodologic differences between these 2 studies may explain the conflicting results. In the current study, muscle thickness was measured, whereas Peolsson et al calculated the muscle deformation rate, which seems to be a more sensitive index for muscle activity.

Neck Extensor Muscle Thickness Changes

The results of the present study revealed an altered pattern of neck extensor muscle thickness changes during an isometric neck extension task in individuals with FHP. The semispinalis capitis muscle showed less thickness change in participants with FHP compared with those with

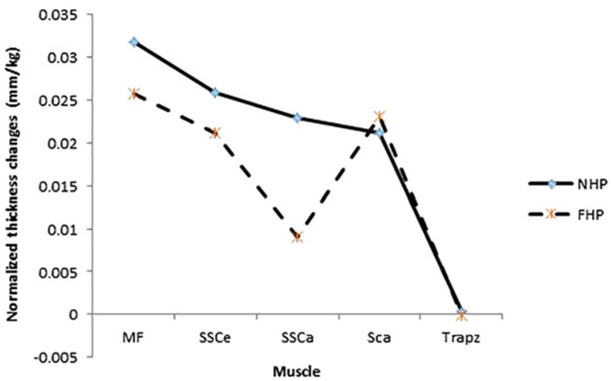

Fig 4. *Neck extensor muscle normalized thickness changes during isometric neck extension: NHP versus FHP. Normalized thickness changes = (muscle thickness at MVIC/body weight) – (muscle thickness at rest/body weight).* FHP*, forward head posture;* MF*, multifidus;* NHP*, normal head posture;* Sca*, splenius capitis;* SSCa*, semispinalis capitis;* SSCe*, semispinalis cervicis;* Trapz*, trapezius.*

NHP while performing an isometric neck extension task. This could indirectly indicate less activity of the semispinalis capitis muscle during a neck extension task in individuals with FHP compared with those with NHP. Semispinalis capitis is considered the main extensor of the neck.[11,12] It is worth noting that this muscle originates from the tips of the transverse processes of the upper 6 or 7 thoracic vertebrae and the seventh cervical vertebra, in addition to the articular processes of C6 to C4. These fibers then move upward and form a wide tendon connecting to the space between the superior and inferior occiput nuchal line.[32] Because of this fiber direction, semispinalis capitis plays a major role in neck extension. It is also very likely to be negatively affected in terms of altered muscle length by changing the head posture in FHP. Splenius capitis is positioned more medially. It ascends from the spinous processes of 3 or 4 thoracic vertebrae and the seventh cervical vertebra. It moves upward and in a laterally oblique direction and is attached to the mastoid process of the temporal bone.[32] Therefore, these fibers are less likely to be affected by FHP compared with the semispinalis capitis muscle. Even these fibers might be more activated to compensate for the decreased participation of semispinalis capitis. No significant differences were observed in splenius capitis thickness changes during a neck extension task between the 2 groups in this study. Semispinalis cervicis and multifidus are deep neck extensor muscles that are responsible for stabilizing the neck during neck and head movements.[9,10,17,26,29] These muscles are known as *local muscles* because their attachments are very close to the cervical spine. The anatomical view shows that these muscles do not reach the occiput. As a result, altered orientation of the head, similar to what is seen in FHP, could hardly affect their thickness during activities. Besides, these 2 muscles are located very close to the spine, and consequently deviation of the spine has a little impact on their length.

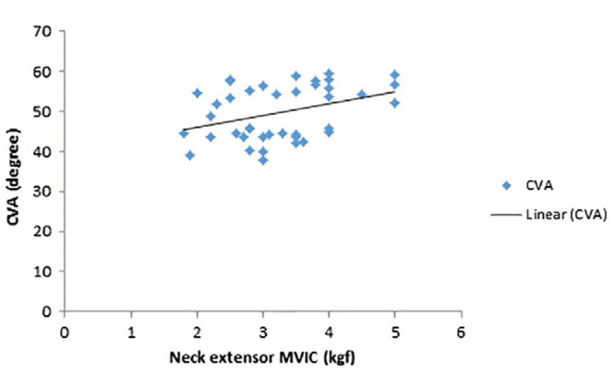

Fig 5. *The relationship between CVA and neck extensor muscles MVIC.* CVA*, craniovertebral angle (degree);* MVIC*, maximal voluntary isometric contraction (kgf).*

Superficial muscles, such as splenius capitis and semispinalis capitis, pass the upper cervical region. Therefore, craniocervical extension, observed in FHP, is more likely to influence them. In contrast, deep neck extensor muscles, such as semispinalis cervicis and multifidus, which do not have any anatomical attachments above the C2 level, may not be affected by FHP.

Trapezius muscles showed almost no significant thickness changes in both FHP and NHP. This might be explained by the fact that at the level of C4, trapezius is very thin compared with the bulky part on the shoulder.[33,34] As such, small thickness changes are to be expected at this level.

The findings of the present study are not in line with the results obtained by Elliot et al, who showed an increased activation of semispinalis capitis in a craniocervical extension task.[28] The underlying reason for such discrepancy could be the intentionally craniocervical hyperextension position taken by the participants in the mentioned study. However, the participants of the present study had had FHP for a long time. Thus, we believe that the long period of altered head posture could cause muscles to behave in a different way in terms of muscle activity. The current study findings are in accordance with the results of a study by Peolsson et al indicating a lower deformation of neck extensor muscles while performing a lifting task in intentional FHP compared with NHP.[33]

Correlation Between CVA and Neck Extensor Muscle Strength

A significantly positive weak to moderate relationship between CVA and extensor muscle strength was observed. Indeed, the lower neck extensor muscle strength coincides with a smaller CVA. This could be explained by the physiologic aspects of the muscle function. If FHP causes elongation or shortening of neck extensor muscles, this length alteration can lead to decreasing extensor force produced by these muscles. Based on length-tension relationship, more deviation from the optimal position results in more reduction in muscle tension.[8]

Study Limitations and Suggestions for Future Research

The findings in this study should be interpreted taking the following limitations into consideration. We only evaluated neck extensor muscles at the level of C4 without examining extensor muscle function in other cervical levels. Additionally, participants in this study were young (mean age approximately 22 years). Hence, the findings could not be generalized to older people. Given the limitations of the present study, further research is required to assess the neck extensor muscles at different levels of cervical spine to shed more light on the biomechanical and physiologic changes happening in the presence of FHP. Investigating the function of neck muscles in different age groups may also help researchers to understand the long-term effects of FHP on neck muscle function compared with NHP. Furthermore, patients with neck pain were excluded from the present study. Therefore, we did not evaluate the neck extensor muscles in patients experiencing chronic neck pain and FHP simultaneously. Future research on such individuals may reveal the effects of pain in the presence of FHP on the neck extensor muscles.

Clinical Implications

In the present study, individuals with FHP demonstrated lower neck extensor muscle strength compared with individuals with NHP. This finding may be of importance to clinicians attempting to strengthen these muscles during management of FHP. Future studies should evaluate patients experiencing both neck pain and FHP to determine the impact of FHP on neck pain.

Conclusions

The findings of this study indicate that FHP weakens the neck extensor muscles. Within these muscles, semispinalis capitis has less participation in an isometric neck extension task in FHP compared with NHP. Moreover, the strength of the neck extensor muscles is associated with the severity of FHP. However, no morphometric changes in terms of thickness were observed in any of the neck extensor muscles in participants with FHP at the state of rest.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): L.R., N.K.
Design (planned the methods to generate the results): L.R., N.K.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): L.R., N.K., S.J.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): F.G., R.B.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): L.R., F.G., N.K.
Literature search (performed the literature search): F.G., R.B.
Writing (responsible for writing a substantive part of the manuscript): L.R., F.G.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): L.R., N.K., S.J., F.G., R.B.

Practical Applications

- The present study showed that neck extensor muscle strength is significantly lower in FHP versus NHP.
- During isometric head extension, the semispinalis capitis muscle showed smaller thickness changes in individuals with FHP.
- A significant negative direct relationship was observed between the severity of FHP and neck extensor muscle strength.

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