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Original Article

Forward Head Posture and Cervical Muscle Echo Intensity: Associations with Cervicothoracic Sagittal Alignment: A Cross-Sectional Study

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Abstract

Objective: To explore whether adults with craniovertebral angle (CVA)-defined forward head posture (FHP) differ in cervicothoracic sagittal alignment and ultrasound echo intensity (EI). **Methods**: In this exploratory cross-sectional study, 60 adults aged 18–50 years underwent photogrammetric assessment of CVA, HPA, HTA, and FSA and ultrasound EI analysis of selected cervical muscles. Unadjusted between-group comparisons and adjusted linear regression analyses were performed. **Results**: Twenty-four participants had FHP. The FHP group had lower HTA ($p = 0.017$), whereas HPA and FSA were similar. EI was higher in the FHP group for longus colli ($p = 0.021$; FDR $q = 0.032$), splenius capitis, semispinalis capitis, and rectus capitis posterior major (all $p < 0.001$; $q < 0.001$). CVA correlated negatively with longus colli and rectus capitis posterior major EI ($\rho = -0.314$, $p = 0.015$ for both), but not after adjustment. In adjusted group-based analyses, semispinalis capitis showed a nominal difference ($\beta = 20.647$, 95% CI 3.266–38.029, $p = 0.020$), but no EI difference remained significant after multiple-testing correction (all $q \geq 0.119$). **Conclusions**: Adults with CVA-defined FHP showed higher unadjusted EI in selected muscles and lower HTA, but adjusted analyses did not support an independent CVA-EI association.

Keywords: Cervicothoracic Sagittal Alignment, Craniovertebral Angle, Echo Intensity, Forward Head Posture, Ultrasound Imaging

Introduction

Forward head posture (FHP) is a common postural deviation characterized by anterior translation of the head relative to the trunk and is frequently discussed in relation to modern sedentary and screen-based behaviors. Observational studies in younger populations report that forward head and related postural alterations are common and may co-occur with neck symptoms or disability risk, supporting the clinical relevance of objective postural assessment in young and middle-aged adults[1,2]. Despite its prevalence, the biomechanical and muscular correlates of FHP are heterogeneous, and not all individuals with a reduced craniovertebral angle (CVA) present with the same cervicothoracic alignment pattern or muscle characteristics[3].

Photogrammetry is widely used as a practical, non-radiographic approach to quantify FHP, with the CVA being one of the most frequently reported metrics. A systematic review of non-radiographic methods highlights that CVA-based assessment is commonly applied, while also emphasizing variability in protocols and thresholds across studies, underlining the importance of standardized measurement procedures[4]. In addition, photogrammetric approaches can quantify related cervicothoracic alignment angles (e.g., sagittal head tilt, head position, and shoulder-related angles), which may add information beyond CVA alone[5,6].

The authors have no conflict of interest.

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From a functional and morphological perspective, the literature suggests that FHP may be accompanied by changes in cervical muscle behavior, particularly in stabilizing musculature. For example, comparisons of individuals with and without FHP have demonstrated differences in neck extensor muscle thickness change during contraction and reduced extensor strength in FHP, supporting the concept that postural alignment can be linked to altered neuromuscular performance[7]. However, other work—especially in chronic neck pain populations—suggests that head posture alone may not fully explain pain, disability, or muscular performance, reinforcing that FHP is likely one component within a broader biopsychosocial and biomechanical framework[3].

Beyond muscle size or activation, muscle quality has gained attention as a complementary construct. Ultrasound-derived echo intensity (EI), computed via grayscale analysis, is commonly interpreted as a surrogate marker of increased intramuscular fat/connective tissue and therefore reduced muscle quality; a foundational methods paper describes standardized EI quantification using ImageJ-style ROI-based grayscale analysis[8]. In the cervical region specifically, EI has been applied to compare women with and without FHP, illustrating both feasibility and the potential for mixed or muscle-dependent findings[9].

Given these gaps and inconsistencies, there is a rationale to examine FHP using a combined alignment–muscle quality approach: (i) quantify CVA and additional cervicothoracic sagittal angles to characterize posture beyond a single metric, and (ii) quantify EI across multiple cervical muscles to capture muscle quality changes that may not be reflected in thickness/CSA alone. Therefore, the present study explored, in a cross-sectional clinic-based sample, whether adults classified as having CVA-defined FHP differed from those without FHP in cervicothoracic sagittal alignment angles and ultrasound EI of selected cervical muscles. As a secondary exploratory analysis, we also examined whether continuous CVA was associated with EI before and after adjustment for age, sex, and BMI. Accordingly, the study was designed to identify exploratory posture-related patterns rather than to establish a robust independent posture-specific effect.

Methods

Study design and setting

This cross-sectional observational study investigated the association between FHP, cervicothoracic sagittal alignment angles, and cervical muscle echo intensity (EI) in adults. Recruitment was conducted between November 2023 and November 2024 in a Physical Medicine and Rehabilitation (PM&R) outpatient clinic. Potential participants were adults aged 18–50 years who attended the clinic for complaints other than neck or postural problems. As part of the screening procedure, patients were asked whether they had experienced neck pain within the previous 6 months. Only those who answered no and agreed to participate were included in the study. No missing or unusable photogrammetric or ultrasound measurements occurred in the final dataset; thus, all 60 enrolled participants were included in the analyses. Figure 1 illustrates participant recruitment and classification.

Participants

Individuals aged 18–50 years were eligible. Participants were excluded if they reported neck pain within the previous 6 months, or if they had known neurological or musculoskeletal conditions affecting the cervical region or other conditions that could interfere with posture or ultrasound imaging. Age, sex, body mass index (BMI), and other demographic variables were recorded.

Sample size

Sample size planning was informed by prior studies that classified FHP using CVA thresholds around 48° and reported sample sizes around 29 participants[10]. Assuming a medium effect size (d=0.6), a minimum of 52 participants would provide 80% power at $\alpha=0.05$ for between-group comparisons. In the present dataset, this yielded n = 24 in the FHP group and n = 36 in the no-FHP group based on the CVA < 48° definition.

Photogrammetric assessment of head and neck posture

Head and neck posture was assessed in standing using a digital camera positioned 1.5 m from the participant and fixed on a tripod. Natural standing posture was standardized by asking the participant to move the head and neck through full extension and flexion and then progressively reduce the movement amplitude until stopping at a comfortable neutral position. After this procedure, the participant maintained the natural posture for image capture.

For CVA measurement, the examiner marked the tragus of the right ear and the spinous process of the seventh cervical vertebra (C7). Three lateral photographs were taken on each side. Photogrammetric angle measurements were additionally verified using a freely available, web-based online protractor (Çevrimiçi İletki; Ginifab, angle measurement tool). CVA was defined as the angle between (i) the line connecting the tragus to C7 and (ii) the horizontal line passing through C7. Forward head posture was defined as a mean CVA < 48° (FHP group), whereas participants with mean CVA ≥ 48° were classified as the no-FHP group, in line with previous reports using a CVA threshold of 48°. For analytic purposes, CVA served as the defining classification variable for group allocation (FHP vs no-FHP), whereas the associations between continuous CVA and muscle echo intensity were examined separately in secondary exploratory analyses.

In addition to CVA, cervicothoracic sagittal alignment

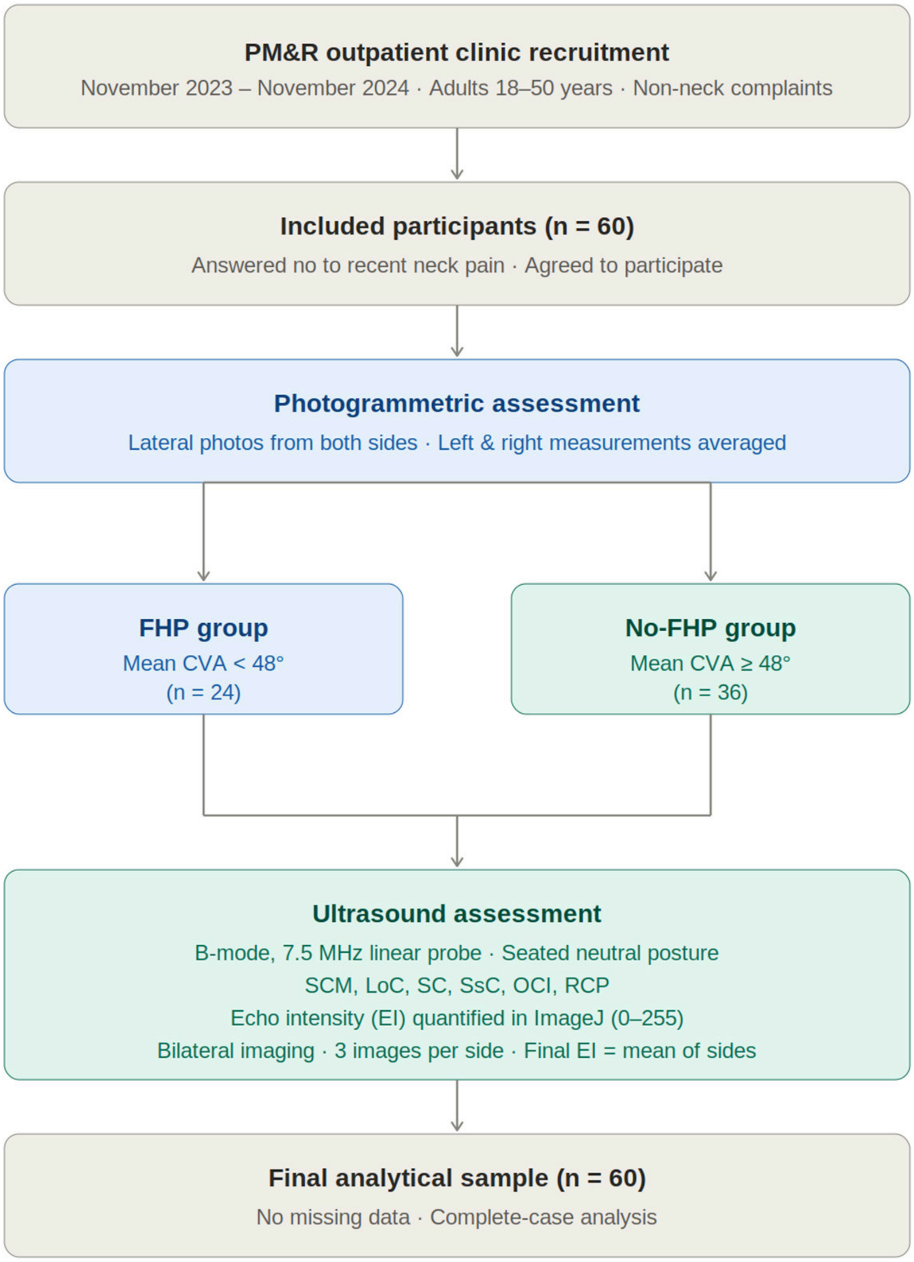

Figure 1. Study flowchart and ultrasound acquisition summary. Recruitment was conducted in a PM&R outpatient clinic between November 2023 and November 2024. Adults aged 18–50 years without self-reported neck pain within the previous 6 months and agreeing to participate were included (n = 60). All participants completed the photogrammetric and ultrasound assessments, with no missing or unusable measurements. Numbers of non-included patients and reasons for non-inclusion were not recorded prospectively.

angles were recorded, including head position angle (HPA), head tilt angle (HTA), and forward shoulder angle (FSA), using the standardized photogrammetric approach described above. For photogrammetric analysis, anatomical landmarks were identified for each angle measurement. The tragus and spinous process of C7 were used for craniovertebral angle (CVA); the external canthus and tragus were used for head tilt angle (HTA); the tragus, mentum, and manubrium were used for head position angle (HPA); and the midpoint

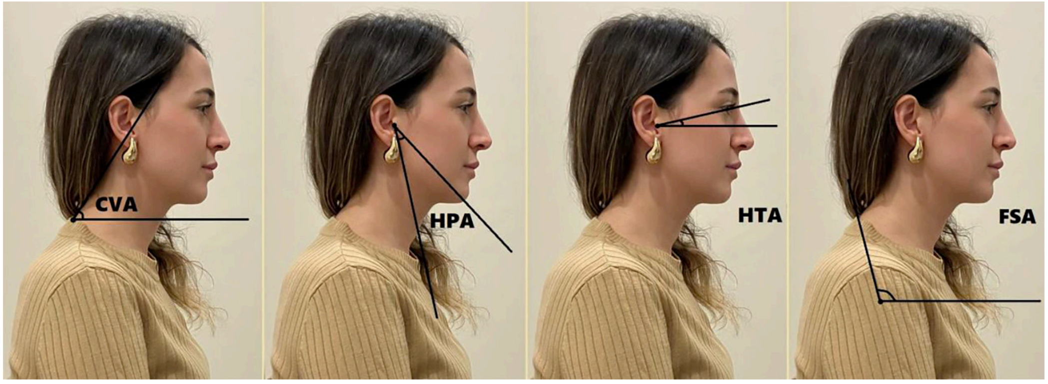

Figure 2. Photogrammetric measurement of cervicothoracic sagittal alignment angles. Representative lateral-view photographs illustrating angle definitions used for postural assessment: craniovertebral angle (CVA), head position angle (HPA), head tilt angle (HTA), and forward shoulder angle (FSA). Written informed consent for publication of the identifiable photograph was obtained from the individual shown.

of the humerus together with C7 was used for forward shoulder angle (FSA), in accordance with previously described photogrammetric definitions. HTA was defined as the angle between the line connecting the tragus to the external canthus and a horizontal line passing through the tragus. HPA was defined as the angle between the tragus–manubrium line and the tragus–mentum line. FSA was defined as the angle formed by the line connecting the midpoint of the humerus to C7 and a horizontal line passing through the midpoint of the humerus. Three lateral photographs were taken from each side, and angle measurements were performed bilaterally. For each angle, repeated measurements were first averaged within side, and the final value used in the statistical analysis was the mean of the left- and right-side measurements. This bilateral approach was adopted because previous photogrammetric work has shown that some postural angles may differ across sides and has recommended consideration of both sides during assessment. Photogrammetric angle extraction was performed by an assessor who was blinded during image analysis. The overall photogrammetric procedure and angle definitions were based on previously published protocols, and prior studies have reported acceptable to excellent intra- and inter-rater reliability for cervical, head, and shoulder sagittal posture angles measured from photographs[10-12] (Figure 2)

Ultrasound imaging and echo intensity quantification

Ultrasound assessments were performed in B-mode using a Logiq A5 ultrasound system (General Electric) equipped with a 7.5 MHz linear transducer. To improve consistency of echo intensity (EI) acquisition across participants, the gain was fixed at 48%, the dynamic range was fixed at 93 dB, and time compensation was set to a neutral position for all image depths. The depth setting was adjusted as needed for each muscle to visualize its superior and inferior margins while preserving the standardized imaging protocol.

Transverse images were acquired bilaterally from the sternocleidomastoid (SCM), longus colli (LoC), splenius capitis (SC), semispinalis capitis (SsC), obliquus capitis inferior (OCI), and rectus capitis posterior major (RCP). For each muscle, three images were obtained from each side under standardized probe pressure and orientation. Echo intensity was quantified separately for each image. For each muscle, EI was first averaged across the three repeated images within each side, and the final value used in the statistical analyses was the mean of the left and right sides (Figure 3).

Echo intensity (EI) was quantified offline using ImageJ. For each image, a region of interest (ROI) was defined as the largest possible rectangular area within the muscle belly, excluding bone and surrounding fascia. The image analyst was blinded to group allocation and photogrammetric measurements during EI quantification. The mean grayscale pixel value within the ROI was recorded as EI and expressed on a scale from 0 (black) to 255 (white).

Within-day intra-rater reliability of ultrasound EI measurements was assessed in all 60 participants (n = 60) within a single session at 30-minute intervals. After each scan, the probe was removed from the target site and then repositioned over the same anatomical area for the subsequent scan. Reliability was quantified using a two-way mixed-effects ICC model for absolute agreement [ICC(3,1)]. The ICC values were 0.9990 (95% CI 0.9983–

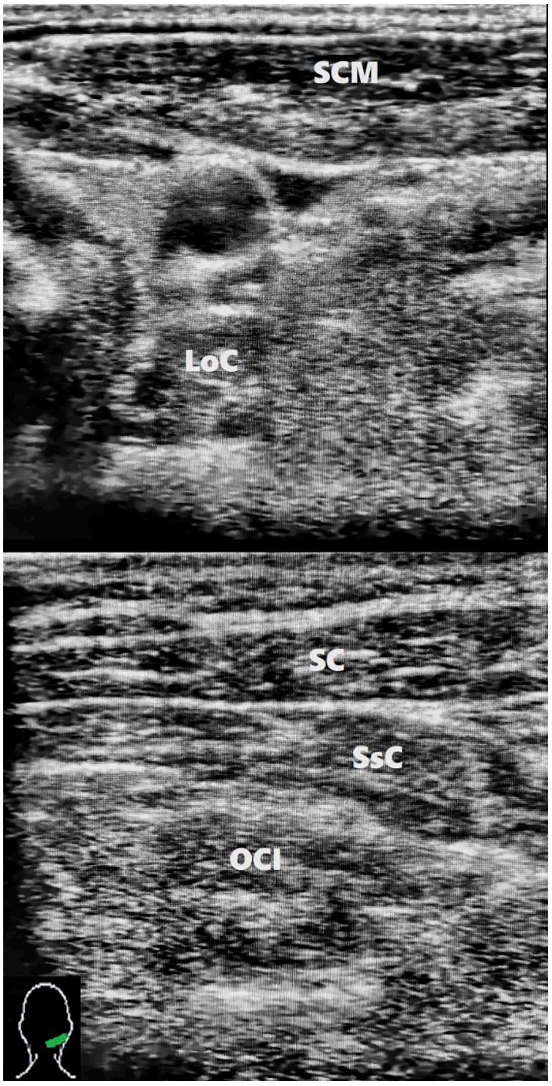

Figure 3. Representative ultrasound images and regions evaluated for echo intensity. Representative B-mode ultrasound images illustrating selected cervical muscles assessed for echo intensity (EI). The figure shows a subset of the analyzed muscles, including the sternocleidomastoid (SCM), longus colli (LoC), splenius capitis (SC), semispinalis capitis, and obliquus capitis inferior (OCI). Rectus capitis posterior major (RCP) was also included in the analyses but is not shown in this illustrative figure. EI was quantified from standardized regions of interest within the muscle belly, excluding fascia and bone, and expressed as grayscale values from 0 to 255.

0.9994) for SCM, 0.9975 (95% CI 0.9959–0.9985) for LoC, 0.9978 (95% CI 0.9963–0.9987) for SC, 0.9983 (95% CI 0.9972–0.9990) for SsC, 0.9981 (95% CI 0.9968–0.9989) for OCI, and 0.9983 (95% CI 0.9972–0.9990) for RCP.

Statistical Analysis

Continuous variables are summarized as mean ± standard deviation (SD) when normally distributed, or median [interquartile range] otherwise; categorical variables are presented as counts and percentages. Normality was assessed using the Shapiro–Wilk test and visual inspection of histograms and Q–Q plots. All analyses were conducted on complete-case data, and all 60 participants had complete data for the posture and EI variables included in the analyses.

Because this study was designed as an exploratory cross-sectional analysis, no single confirmatory primary EI endpoint was prespecified. The primary grouped analyses compared participants with and without CVA-defined FHP in terms of additional cervicothoracic sagittal alignment angles and EI outcomes. Secondary exploratory analyses examined the association between continuous CVA and EI across all participants. Sample size planning was based on an anticipated medium between-group effect size and should therefore be interpreted as supporting exploratory group comparisons rather than definitive multivariable modeling.

Between-group comparisons (FHP vs no-FHP) were performed using independent-samples t tests for normally distributed variables or Mann–Whitney U tests for non-normal variables. Categorical variables were compared using Fisher's exact test. Effect sizes were reported as Cohen's d for t tests or rank-biserial correlation for Mann–Whitney U tests, as appropriate.

Associations between CVA and EI were examined using Spearman rank correlations. To evaluate the independent association of CVA with EI while accounting for potential confounding, linear regression models were fitted for each muscle EI with CVA as the primary predictor and age, sex, and BMI as covariates. In addition, adjusted group-based linear regression models were fitted with group status (FHP vs no-FHP) as the main predictor and age, sex, and BMI as covariates. Heteroscedasticity-consistent (HC3) robust standard errors were used. To improve transparency, model diagnostics included assessment of multicollinearity using variance inflation factors (VIFs), inspection of influential observations using Cook's distance, and evaluation of residual and model behavior using residual plots, Q–Q plots, and functional-form checks. To control the false discovery rate across the set of EI outcomes, p values were adjusted using the Benjamini–Hochberg procedure; a two-sided $p < 0.05$ was considered statistically significant.

Results

Participant characteristics

A total of 60 adults aged 18-50 years were included. All adjusted analyses were conducted on complete-case data, and all 60 participants had complete data for the

Table 1. Participant characteristics by FHP group (CVA < 48°).

Variable	No FHP	FHP	Effect size	p-value
Male, n (%)	6 (16.7%)	3 (12.5%)		0.729
Age (years)	27.00 [25.00, 27.25]	30.50 [27.00, 38.75]	0.64	<0.001
Weight (kg)	56.00 [54.50, 62.50]	65.50 [60.75, 74.50]	0.56	<0.001
Height (m)	1.62 [1.62, 1.67]	1.65 [1.64, 1.67]	0.18	0.246
Body mass index (kg/m^2)	21.47 [19.74, 23.08]	23.84 [23.14, 26.63]	0.58	<0.001

Note: *FHP was defined as CVA < 48°. Continuous variables are presented as median [IQR]. Effect sizes are reported as rank-biserial correlation for Mann–Whitney U comparisons. Sex is reported as n (%) and was compared using Fisher's exact test.*

Table 2. Cervicothoracic sagittal alignment angles by FHP group (CVA < 48°).

Variable	No FHP	FHP	Effect size	p-value
Head position angle (°)	31.50 [27.75, 32.00]	28.50 [23.00, 34.75]	-0.12	0.416
Head tilt angle (°)	20.00 [16.00, 23.25]	15.50 [10.00, 20.25]	-0.36	0.017
Forward shoulder angle (°)	122.00 [112.75, 124.50]	121.00 [120.00, 124.25]	0.09	0.544

Note: *CVA was used as the defining classification variable for FHP group allocation and is therefore not presented here as an inferential between-group outcome. Angles are presented in degrees (°) as median [IQR]. Effect sizes are reported as rank-biserial correlation for Mann–Whitney U comparisons.*

posture and EI variables included in the models. Forward head posture (FHP) was defined as CVA < 48°, resulting in 24 participants in the FHP group and 36 in the no-FHP group. Sex distribution did not differ between groups (12.5% vs 16.7% male, $p = 0.729$). Compared with the no-FHP group, the FHP group was older (median 30.5 [27.0–38.8] vs 27.0 [25.0–27.3] years, $p < 0.001$) and had higher body weight (median 65.5 [60.8–74.5] vs 56.0 [54.5–62.5] kg, $p < 0.001$) and BMI (median 23.84 [23.14–26.63] vs 21.47 [19.74–23.08] kg/m^2, $p < 0.001$). Height was similar between groups ($p = 0.246$) (Table 1).

Cervicothoracic sagittal alignment angles

Because CVA was the classification variable used to define the study groups, it is presented descriptively rather than as an inferential between-group outcome. Among the additional cervicothoracic sagittal alignment angles, head tilt angle (HTA) was lower in the FHP group (median 15.50° [10.00–20.25] vs 20.00° [16.00–23.25], $p = 0.017$), whereas head position angle (HPA) (median 28.50° [23.00–34.75] vs 31.50° [27.75–32.00], $p = 0.416$) and forward shoulder angle (FSA) (median 121.00° [120.00–124.25] vs 122.00° [112.75–124.50], $p = 0.544$) did not differ between groups (Table 2).

Ultrasound echo intensity (EI)

Echo intensity differed between groups for several cervical muscles. The FHP group showed higher EI in the longus colli (LoC) (median 137.87 [129.60–152.47] vs 129.74 [112.47–142.65], $p = 0.021$), splenius capitis (SC) (median 159.19 [149.87–167.87] vs 137.32 [123.53–142.11], $p < 0.001$), semispinalis capitis (median 165.51 [150.25–168.88] vs 130.63 [128.46–148.05], $p < 0.001$), and rectus capitis posterior major (RCP) (median 141.46 [136.01–144.62] vs 121.07 [109.99–128.79], $p < 0.001$). EI did not differ significantly for the sternocleidomastoid (SCM) ($p = 0.176$) or the obliquus capitis inferior (OCI) ($p = 0.791$) (Table 3).

Association between CVA and EI

In correlation analyses across all participants, lower CVA was associated with higher EI in LoC (Spearman $\rho = -0.314$, $p = 0.015$) and RCP (Spearman $\rho = -0.314$, $p = 0.015$) (Table 4). In multivariable linear regression models with HC3 robust standard errors adjusting for age, sex, and BMI, continuous CVA was not independently associated with EI for any muscle (all $p \geq 0.139$) (Table 5). These analyses were conducted as secondary exploratory models to examine whether continuous CVA, beyond its role as the grouping variable, was independently

Table 3. Ultrasound echo intensity (EI) by FHP group (CVA < 48°).

Variable	No FHP	FHP	Effect size	p-value	FDR q-value
Sternocleidomastoid echo intensity (EI)	109.62 [98.40, 115.77]	114.09 [101.69, 120.09]	0.21	0.176	0.211
Longus colli echo intensity (EI)	129.74 [112.47, 142.65]	137.87 [129.60, 152.47]	0.35	0.021	0.032
Splenius capitis echo intensity (EI)	137.32 [123.53, 142.11]	159.19 [149.87, 167.87]	0.65	<0.001	<0.001
Semispinalis capitis echo intensity (EI)	130.63 [128.46, 148.05]	165.51 [150.25, 168.88]	0.60	<0.001	<0.001
Obliquus capitis inferior echo intensity (EI)	131.01 [122.50, 141.72]	140.56 [119.32, 143.72]	0.04	0.791	0.791
Rectus capitis posterior major echo intensity (EI)	121.07 [109.99, 128.79]	141.46 [136.01, 144.62]	0.60	<0.001	<0.001

***Note**: EI values are presented as median [IQR]. Effect sizes are reported as rank-biserial correlation for Mann–Whitney U comparisons. FDR q-values are Benjamini–Hochberg adjusted across the six EI comparisons.*

Table 4. Spearman correlations: CVA vs EI (all participants).

		Spearman rho	p-value	FDR q-value
CVA	Sternocleidomastoid echo intensity (EI)	-0.231	0.076	0.106
CVA	Longus colli echo intensity (EI)	-0.314	0.015	0.044
CVA	Splenius capitis echo intensity (EI)	-0.222	0.088	0.106
CVA	Semispinalis capitis echo intensity (EI)	-0.255	0.049	0.098
CVA	Obliquus capitis inferior echo intensity (EI)	0.115	0.381	0.381
CVA	Rectus capitis posterior major echo intensity (EI)	-0.314	0.015	0.044

***Note**: Spearman correlations computed across all participants (n=60). FDR q-values are adjusted across the six CVA–EI correlations.*

associated with EI.

In addition, adjusted group-based analyses were performed using multivariable linear regression models with group status (FHP vs no-FHP) as the main predictor and age, sex, and BMI as covariates (Table 6). After adjustment, the FHP group remained significantly associated with a lower head tilt angle (HTA) (β = -5.093, 95% CI -9.412 to -0.774, p = 0.021), whereas head position angle (HPA) and forward shoulder angle (FSA) did not differ between groups (all p ≥ 0.677). For ultrasound EI outcomes, the adjusted group coefficient was positive for all muscles, but only semispinalis capitis showed a nominally significant difference (β = 20.647, 95% CI 3.266 to 38.029, p = 0.020); however, this association did not remain significant after false discovery rate correction (q = 0.119). No other EI outcome demonstrated a statistically significant adjusted group difference (all p ≥ 0.114). Overall, these adjusted analyses indicate that most of the crude between-group EI differences were attenuated after accounting for age, sex, and BMI. Collinearity diagnostics did not suggest problematic multicollinearity in the adjusted models, with all variance inflation factors remaining below 2 (VIFs for continuous CVA models: 1.19–1.41/ VIFs for adjusted group-based models: 1.14–1.93). However, several EI models showed a small number of potentially influential observations and non-uniform residual/model-behavior patterns, indicating that the regression estimates should be interpreted cautiously. These findings support the exploratory interpretation of the adjusted models.

Discussion

In this exploratory clinic-based sample, participants classified as having forward head posture using a CVA cutoff of <48° showed higher unadjusted ultrasound EI in the

Table 5. Linear regression models for the association of continuous CVA with EI (HC3 robust standard errors).

Outcome	Model	Beta	Robust SE	95% CI low	95% CI high	p-value	R^2	N	FDR q-value
Sternocleidomastoid echo intensity (EI)	EI ~ CVA + age + sex + BMI (OLS, HC3 robust SE)	-0.382	0.272	-0.914	0.151	0.160	0.032	60	0.481
Longus colli echo intensity (EI)	EI ~ CVA + age + sex + BMI (OLS, HC3 robust SE)	-1.073	0.724	-2.493	0.347	0.139	0.287	60	0.481
Splenius capitis echo intensity (EI)	EI ~ CVA + age + sex + BMI (OLS, HC3 robust SE)	0.222	0.503	-0.764	1.207	0.659	0.245	60	0.659
Semispinalis capitis echo intensity (EI)	EI ~ CVA + age + sex + BMI (OLS, HC3 robust SE)	-0.442	0.577	-1.572	0.689	0.444	0.205	60	0.598
Obliquus capitis inferior echo intensity (EI)	EI ~ CVA + age + sex + BMI (OLS, HC3 robust SE)	-0.358	0.455	-1.250	0.534	0.431	0.064	60	0.598
Rectus capitis posterior major echo intensity (EI)	EI ~ CVA + age + sex + BMI (OLS, HC3 robust SE)	0.408	0.603	-0.773	1.590	0.498	0.270	60	0.598

Table 6. Adjusted group-based linear regression models: FHP vs no-FHP (HC3 robust standard errors).

Outcome	Model	Beta	Robust SE	95% CI low	95% CI high	p-value	R^2	N	FDR q-value
Head position angle (HPA), °	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	-0.646	1.548	-3.679	2.388	0.677	0.236	60	—
Head tilt angle (HTA), °	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	-5.093	2.204	-9.412	-0.774	0.021	0.162	60	—
Forward shoulder angle (FSA), °	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	0.510	1.651	-2.726	3.745	0.758	0.123	60	—
Sternocleidomastoid echo intensity (EI)	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	6.508	5.197	-3.679	16.695	0.211	0.036	60	0.253
Longus colli echo intensity (EI)	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	9.894	7.786	-5.366	25.154	0.204	0.239	60	0.253
Splenius capitis echo intensity (EI)	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	10.723	7.031	-3.058	24.504	0.127	0.272	60	0.253
Semispinalis capitis echo intensity (EI)	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	20.647	8.868	3.266	38.029	0.020	0.301	60	0.119
Obliquus capitis inferior echo intensity (EI)	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	12.906	8.158	-3.085	28.896	0.114	0.131	60	0.253
Rectus capitis posterior major echo intensity (EI)	Outcome ~ group + age + sex + BMI (OLS, HC3 robust SE)	7.858	8.293	-8.396	24.112	0.343	0.274	60	0.343

Note: *Table 5 presents the independent association of continuous CVA with EI after adjustment for age, sex, and BMI. Table 6 presents adjusted group-based estimates comparing the FHP and no-FHP groups after adjustment for age, sex, and BMI. Beta values in Table 6 represent the adjusted mean difference for the FHP group relative to the no-FHP group. HC3 robust standard errors were used in all models. False discovery rate correction was applied across the six EI outcomes within each EI model family. All analyses were based on complete-case data (n = 60).*

LoC, SC, SsC, and RCP, whereas SCM and OCI did not differ between groups. These findings indicate crude between-group differences in both deep anterior and posterior cervical muscles; however, they should not be interpreted as evidence of a robust independent posture-specific effect. Although CVA showed small-to-moderate negative correlations with LoC and RCP EI, these associations did not remain statistically significant in multivariable linear regression models with HC3 robust standard errors adjusted for age, sex, and BMI. This pattern suggests that the observed posture–muscle echogenicity relationship may be influenced by shared variance with participant characteristics and by the multifactorial determinants of muscle echogenicity. Accordingly, the higher EI values observed in selected muscles in the FHP group are better interpreted as exploratory findings that may reflect a combination of postural status, anthropometric factors, and other unmeasured biological or behavioral contributors, rather than a clearly independent effect of head posture alone.

Our group differences in EI contrast with findings from Bokaee et al.[9] who reported no significant between-group differences in EI among women with and without FHP, using EI quantified from ultrasound images. A plausible explanation is that EI is highly sensitive to acquisition and processing conditions (gain, dynamic range, probe pressure/angle, ROI selection, and analysis pipeline). A technical reliability study in individuals with and without FHP reported only moderate within-day ICC values for EI (approximately 0.48–0.51 for LoC and a suboccipital muscle) and highlighted SEM/MDC ranges that can be substantial relative to expected between-group differences[13]. These observations support the possibility that subtle EI differences may be missed unless imaging settings and ROI procedures are tightly standardized and measurement error is accounted for.

From a mechanistic standpoint, the current pattern—higher EI in LoC together with higher EI in posterior muscles (SC/SsC/RCP)—aligns with prior evidence of functional/structural deficits in deep cervical stabilizers in FHP. For example, Moghadam et al.[14] found significantly smaller longus colli cross-sectional area responses during cranio-cervical flexion testing across multiple pressure levels in individuals with FHP compared with controls. Increased EI in LoC in our FHP group may represent reduced muscle quality (e.g., greater intramuscular fat/connective tissue), which could contribute to impaired activation and endurance of deep neck flexors. On the posterior side, increased EI in SsC and RCP is consistent with the clinical concept that FHP is accompanied by upper cervical extension and potential overuse/adaptation of suboccipital and posterior cervical muscles, which may manifest as qualitative tissue change over time.

Regarding postural alignment metrics, our use of CVA <48° as the FHP cut-off is consistent with prior work in healthy adults that explicitly categorized participants using the same threshold (mean CVA <48°). In addition, photogrammetry-based angle measurement approaches commonly report strong reliability for cranio-cervical alignment angles; for instance, one study reported excellent intra-rater reliability for CVA (ICC ≈0.99 with a small SEM)[15].

In addition to CVA, we evaluated HTA, HPA, and FSA to capture broader cervicothoracic sagittal alignment. In our cohort, only HTA was significantly lower in the FHP group, whereas HPA and FSA did not differ. This pattern is compatible with the idea that CVA-defined FHP may reflect primarily anterior head translation and altered cranio-cervical orientation, without necessarily producing a uniform or measurable shoulder protraction component in all individuals. Importantly, photogrammetric studies have long suggested that using multiple angles can improve characterization of FHP, but their discriminative value is not identical. For example, Salahzadeh et al.[6] explicitly compared CVA, head tilt angle, and head position angle as photogrammetric indicators of FHP, supporting the concept that angles beyond CVA are relevant but may behave differently across classification schemes and samples.

Our null finding for FSA is also consistent with evidence that shoulder-based angles may not reliably distinguish FHP severity when CVA is the primary defining metric. Mostafaee et al.[16] assessed the accuracy of CVA and FSA to discriminate slight vs moderate-to-severe FHP and reported that CVA performed well, whereas FSA did not significantly discriminate between FHP severity groups. This aligns with our observation that—even with a clinically meaningful CVA cut-off—FSA may remain unchanged in some adults, potentially because scapulothoracic/shoulder posture is influenced by other factors (thoracic kyphosis, upper-cross syndrome features, habitual activity, and anthropometrics) that do not obligatorily co-vary with CVA-defined head translation. Broader observational work in younger populations also supports that forward head and protracted shoulder can co-exist but are not perfectly coupled, suggesting that shoulder angle metrics may capture a partially independent postural domain[1].

Finally, our HTA difference (FHP group lower HTA) suggests that, in this sample, FHP is accompanied by a measurable change in cranio-cervical angulation beyond simple head translation. Interventional work that includes these same angles provides indirect support that HTA and HPA can be responsive to cervicothoracic alignment changes: for instance, a Pilates-based program in individuals with upper-crossed syndrome reported improvements in CVA, HPA, and HTA following training[17]. While that study is not directly comparable to our cross-sectional design, it reinforces that HTA/HPA reflect modifiable aspects of alignment; therefore, the absence of an HPA group difference in our dataset may reflect heterogeneity of compensatory strategies (e.g., different combinations of upper cervical extension and lower cervical flexion), limited range of HPA variation in asymptomatic adults, or the fact that single-threshold dichotomization by CVA may not capture the full spectrum of head–neck positional relationships.

The observed unadjusted EI elevations in both anterior (LoC) and posterior (SC/SsC/RCP) muscle groups may indicate exploratory differences across multiple layers of the cervical stabilizing system; however, because these findings were attenuated in adjusted analyses, they should be interpreted cautiously. Clinically, these findings may be useful for hypothesis generation and for informing rehabilitation strategies targeting deep neck flexor activation/endurance, posterior cervical control, and movement retraining to reduce sustained forward head loading; however, they do not yet establish ultrasound EI as a posture-specific marker independent of participant characteristics. The absence of a between-group difference in SCM EI may indicate that SCM adaptations in FHP are more functional (activation strategy) than structural/qualitative in adults, or that SCM EI is less sensitive to postural variation at this stage.

Strengths and limitations

Key strengths include (1) simultaneous assessment of multiple cervicothoracic sagittal alignment angles and multiple cervical muscles, and (2) quantitative EI extraction using a consistent ROI-based grayscale method. Nevertheless, EI is influenced by acquisition parameters and can demonstrate only moderate reliability in some settings, making strict standardization essential. The cross-sectional design prevents causal inference—whether FHP leads to EI increases or whether pre-existing muscle quality differences predispose to FHP cannot be determined. An additional limitation is that a complete prospective screening log was not maintained. Although recruitment dates, the operational screening question regarding neck pain within the previous 6 months, and the absence of missing measurement data were available, the numbers of patients who reported neck pain, declined participation, or were otherwise not included were not recorded. Therefore, full participant-flow reporting could not be provided retrospectively. Also the sample size justification was based on exploratory between-group comparisons rather than formal power for the multivariable models. Although multicollinearity was low, some adjusted models showed potentially influential observations and non-uniform residual behavior, indicating that these regression estimates may be unstable. Therefore, the adjusted analyses should be interpreted as exploratory and hypothesis-generating. The loss of statistical significance in adjusted regression models suggests that future studies should consider larger samples, stratification by sex, and inclusion of behavioral/physical activity covariates to better isolate posture-specific effects.

Longitudinal studies examining whether correcting FHP changes EI over time would clarify causality and clinical responsiveness. Given the measurement properties of EI, future work should also report SEM/MDC and/or use repeated imaging to improve precision, as recommended by reliability-focused literature. Incorporating concurrent functional measures (deep neck flexor endurance, cranio-cervical flexion performance) may also help link EI-based muscle quality to clinically meaningful outcomes, building on evidence of altered LoC morphology/function in FHP.

In addition, because the primary between-group EI findings were unadjusted and the FHP group differed in age and BMI, the present results should be interpreted as exploratory rather than confirmatory. Larger studies with prespecified adjusted group-based analyses are needed to determine whether any observed EI differences remain after more rigorous control of confounding.

Conclusion

In this exploratory cross-sectional study, adults classified as having CVA-defined forward head posture showed higher unadjusted between-group echo intensity in selected deep and posterior cervical muscles and lower head tilt angle, while other sagittal alignment measures were similar between groups. These findings suggest crude muscle-specific differences accompanying CVA-defined postural classification; however, the absence of an independent association between continuous CVA and echo intensity after adjustment for age, sex, and BMI indicates that the observed relationship is not explained by posture alone. Accordingly, these results should be interpreted as preliminary and hypothesis-generating rather than confirmatory. Although ultrasound echo intensity may be of interest as an adjunctive descriptive measure in cervical muscle assessment, the present data do not support it as an independent marker of forward head posture. Larger, methodologically standardized longitudinal studies are needed to determine whether these unadjusted differences persist after adjustment and whether they are clinically meaningful or responsive to rehabilitation.

Ethics approval

Ethical approval for this study was obtained from Goztepe Prof Dr Suleyman Yalcin City Hospital Ethics Committee (Approval No:2022/0105 , Date: 23.02.2022). The study was conducted in accordance with the Declaration of Helsinki (1964) and its later amendments.

Consent to participate

All participants provided written informed consent prior to participation.

Consent for publication

Written informed consent for publication of the identifiable photograph shown in Figure 2 was obtained from the individual shown. The individual shown was not a study participant and appears solely as a model for demonstrating the photogrammetric angle definitions.

Authors' contributions

Conceptualization: BDK, BE, IHA. Methodology: BDK, BE, IHA. Data Acquisition: BDK, IHA.

Data Analysis and Interpretation: BDK, BE, IHA. Manuscript Drafting: BDK. Critical Revision: BDK, BE, IHA. All authors reviewed and approved the final manuscript and accept full responsibility for its content.

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AI-assisted tools were used only for language editing and grammar refinement. They were not used for data generation, data analysis, image interpretation, or scientific decision-making.

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