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Craniocervical Posture and Cervical Curvature Variations in Adult Females with Different Vertical Facial Patterns: A Cross-Sectional Study

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Abstract: This study aimed to determine whether there are relationships between vertical facial patterns, cervical posture, and cervical curvature types. Ninety-two adult females with skeletal Class I relationships were retrospectively analyzed and divided into hypodivergent, normovergent, and hyperdivergent groups based on the mandibular plane angle to the nasion–sella line. Variables representing craniocervical posture (sagittal vertical axis, SVA; cervical inclination angle, CIA) and cervical curvature were measured. Differences in craniocervical posture among the groups were assessed. Cervical curvatures were classified into lordotic, straight, kyphotic, or sigmoid categories. The distribution of cervical curvature types among the groups was compared, and correlations between vertical facial patterns, craniocervical postures, and cervical curvature measurements were calculated. The results indicated that the hyperdivergent group exhibited increased SVA and decreased CIA compared to the normovergent and hypodivergent groups. Significant differences in cervical curvature types were observed among the groups. Lordotic curvature was most common in the normovergent group, while straight curvature was predominant in the hypodivergent and hyperdivergent groups. A significant correlation was found between an increased mandibular plane angle and a forward head position (increased SVA and decreased CIA). In conclusion, there are relationships between vertical facial patterns, cervical posture, and cervical curvature types. Therefore, careful assessment of craniocervical posture and cervical curvature is necessary in lateral cephalograms for orthodontic evaluation. However, cervical curvature measurements show minimal correlation with the mandibular plane angle.

Keywords: craniocervical posture; cervical curvature; vertical facial pattern; mandibular plane angle

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1. Introduction

Cervical lordosis is the anterior convexity of the cervical spine, which extends from the foramen magnum to the first thoracic vertebra. Normal cervical curvature is lordotic, and proper cervical curvature is important for good posture and function of the head and neck area [1,2].

Loss of normal cervical curvature is relatively common. Previous studies have reported that only one-third of the adult population shows lordotic cervical curvature, while the rest show straight, kyphotic (curved in the opposite direction of lordosis), or sigmoid (which has both lordotic and kyphotic curves) cervical curvature [3–5]. Loss of the normal cervical curvature can cause neurological symptoms, neck and shoulder pain, headaches, and other disorders, thus causing functional disability [1,6–9]. Although there are many studies on the biomechanical changes that alter cervical curvature, the exact pathophysiology has not been established. It has been reported that cervical curvature can be affected by numerous factors, such as age, sex, trauma, congenital defects, cervical muscle weakness, tumors, infection, and psychosocial factors [2,4,10–12]. Recently, interest has been focused on the relationship between cervical curvature and posture because forward head posture is common with the use of smartphones [13,14]. Forward head posture is a habitual neck posture defined by forward translation of the cervical spine and is thought to be related to cervical curvature malalignment. As the head tilt is more forward in relation to the cervical spine, the axial load moves anteriorly. Consequently, increased compressive force can trigger a progressive degenerative process and potentially result in poor alignment of the cervical curvature [15].

Few studies have investigated the relationship between craniofacial characteristics and cervical posture [16,17]. Hellsing et al. [16] reported that subjects between ages 8 and 15 years with dolichocephalic faces had a forwardly inclined cervical column. Similarly, Solow and Tallgren [17] investigated adult males between the ages of 18 and 30 and reported that forward head posture was frequently associated with a large anterior facial height, maxillary and mandibular retrognathism, and large mandibular plane inclination. However, to our knowledge, there have been no studies on the relationship between vertical facial patterns and craniocervical posture in adult females.

Cervical curvature can be associated with craniocervical posture and vertical facial patterns. A few studies have investigated cervical curvature variations according to vertical facial patterns, and the results are controversial [8,16–18]. No studies have compared the distribution of cervical curvature type according to different vertical facial patterns. Our study is the first to establish a relationship between cervical curvature and vertical facial patterns. The purposes of this study were to (1) compare the craniocervical posture of adult females with different vertical facial patterns, (2) compare the distribution of cervical curvature variations with different vertical facial patterns, and (3) determine any correlation between the vertical facial pattern, craniocervical posture, and cervical curvature measurements.

2. Materials and Methods

This study was approved by the Institutional Review Board of the Gangnam Severance Dental Hospital (No. 3-2023-0088).

2.1. Participants

We retrospectively analyzed the cephalometric radiographs of 1032 patients examined at the Department of Orthodontics, Gangnam Severance Dental Hospital, Yonsei University, between 2006 and 2010. Assuming that excessive smartphone use can affect the natural head posture, the period was limited to before 2010, when smartphones were not widely used [13,19]. Cephalometric radiographs were taken in the natural head position (self-balanced position) by a single technician using PMPROMAX (Planmeca, Helsinki, Finland) [20]. Previous studies reported significant gender differences in the intrinsic shape of the cervical curvature [2,10]; therefore, male subjects were excluded to prevent skewing the measurements with sex-related differences, and only female subjects were included in this study. To exclude the influence of growth on cervical curvature, we selected adult subjects aged 18–35. According to previous studies [2,21,22], only small changes in the size and curvature of the cervical spine are expected after 15 years of age, and the cervical spines of adults over the age of 50 are known to be more lordotic than those of adults under the age of 35. The inclusion criteria were (1) females aged 18–35 with a skeletal Class I relationship (0° < ANB angle < 4°), (2) no history of congenital defects, (3) no history of orthodontic treatment or surgery in the head and neck, (4) no craniofacial pathologies, and (5) a cephalometric radiograph that included at least the upper five cervical vertebral bodies, with the middle aspect of the sixth cervical vertebral body (C6) visible. In the entire cohort, 101 lateral cephalometric radiographs were obtained from subjects who met the inclusion criteria. The subjects were divided into three groups according to the mandibular plane angle (the angle between the nasion–sella line and the mandibular plane, NSL/MP): the hypodivergent group (NSL/MP < 29°), the normovergent group (NSL/MP 31–39°), and the hyperdivergent group (NSL/MP > 41°) [23]. The sample between the reference values of each vertical facial group was excluded, and 92 radiographs were selected as the final sample. The demographic data of the three study groups are presented in Table 1.

Table 1. Demographic data of the subjects.

Variables	Hypodivergent (n = 29)	Normovergent (n = 34)	Hyperdivergent (n = 29)	Total (n = 92)	p-Value
Age (y)	24.6 ± 5.0	24.0 ± 6.2	22.1 ± 3.7	23.6 ± 5.2	0.228
ANB (°)	2.1 ± 1.2	2.4 ± 1.0	2.8 ± 1.0	2.5 ± 1.1	0.085
NSL/ML (°)	26.4 ± 2.8	35.2 ± 2.1	43.9 ± 3.3	35.2 ± 7.5	0.000 ***

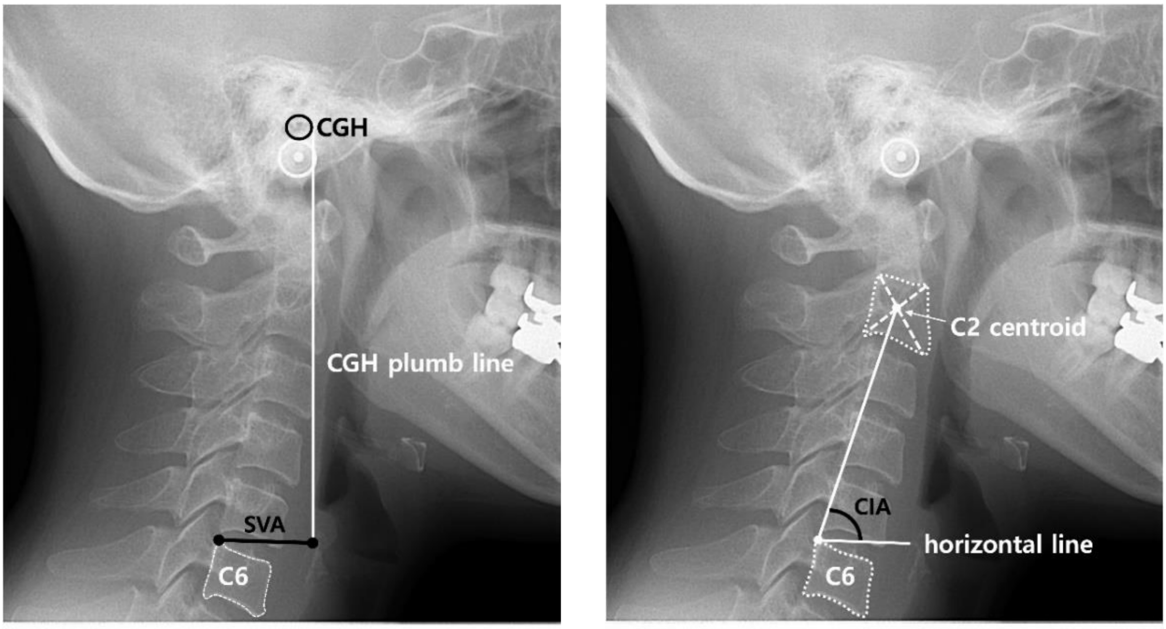
Values are presented as mean ± one standard deviation. ANB—angle between A point-nasion-B point; NSL/ML—angle between the nasion–sella line and the mandibular plane. The Kruskal–Wallis test was performed to compare the three groups (*** $p < 0.001$).

2.2. Radiographic Analysis

All cephalometric radiographs were traced by one investigator who was blinded to the clinical information using V-ceph 7.0 (Cybermed, Seoul, Republic of Korea). Craniocervical posture and cervical curvature were analyzed. The lower aspects of the sixth and seventh cervical vertebral bodies (C6 and C7) were not included in the analysis because these parts were not visible on most routine orthodontic lateral cephalometric radiographs [24].

2.2.1. Craniocervical Posture

The craniocervical posture in the sagittal plane can be evaluated using two different configurations [25]: (1) the position of the head in relation to the cervical spine and (2) the inclination of the cervical spine. The sagittal vertical axis (SVA) [26] is the most commonly used measure of cervical sagittal balance. SVA is defined as the horizontal distance between a plumb line dropped from the anterior margin of the external auditory meatus and the posterior superior corner of C6 (Figure 1a). The increased distance represents a more forward shift of the head position. The cervical inclination angle (CIA) [27] is defined as the angle formed by the line connecting the posterior–superior corner of C6 with the centroid of the second cervical vertebra (C2) and the horizontal line. The centroid of C2 is the point at which the lines drawn between the opposing corners within C2 intersect (Figure 1b). A more acute angle indicates a more forward inclination of the cervical spine.



(a) (b)

Figure 1. (**a**) Sagittal vertical axis. This is the horizontal distance between a plumb line dropped from the anterior margin of the external auditory meatus (CGH) and the posterior–superior corner of C6. (**b**) Cervical inclination angle. This is the angle formed by the line connecting the posterior superior corner of the sixth cervical vertebra with the centroid of the second cervical vertebra (C2) and the horizontal line. The centroid of C2 is the point where the lines drawn between the opposing corners within the C2 intersect. SVA, sagittal vertical axis; CGH, the center of gravity of the head; C6, sixth cervical vertebra.

2.2.2. Cervical Curvature

Classification

For our study, we classified cervical curvature into four categories suggested by Beltsios et al. [4]. One linear measurement method and two angular measurement methods were used to evaluate cervical curvature.

1. C2–C6 Ohara method (Figure 2) [27]: A line was constructed to connect the midpoint of the C2 inferior endplate and the C6 superior endplate. The centroids of C3–C5 were defined as the points of intersection of lines drawn from opposite corners of the vertebral body. The four types of cervical curvature were defined based on the relative positions of the C3–C5 centroids to line AB. If all centroids were anterior to line AB and the maximum distance was >1 mm but <2 mm, it was classified as 'lordotic'. If the distance between line AB and each centroid was <1 mm, the line was classified as 'straight'. If all centroids were posterior to line AB and the maximum distance was >1 mm, it was classified as 'kyphotic'. If some centroids were anterior to and some posterior to line AB but the maximum distance was >1 mm, it was classified as 'sigmoid'.
2. C2–C6 Cobb method (Figure 3) [28]: The Cobb angle is the angle between the two perpendicular lines made from the inferior margin of C2 and the superior margin of C6. The angle is considered to be positive when the superior margin of C6 was more clockwise than the inferior margin of C2. The cervical spine types are classified according to the following criteria: If the Cobb angle is >7° but <20°, it is a 'lordotic' curvature type; if it is >−7° but <7°, it is a 'straight' curvature type; and if it is −7° or less, it is a 'kyphotic' curvature type.

3. C2–C5 Harrison posterior tangent method (Figure 4) [28]: The lines are drawn parallel to the posterior surface of each cervical vertebral body from C2 to C5, and angles from C2 to C3, C3 to the fourth cervical vertebra (C4), and C4 to C5 is added. When the posterior surface line of the lower vertebral body opens more clockwise than the upper vertebral body, the angle is considered positive. In this study, if the summed angle was >10° but <30°, it was classified as a 'lordotic.' If the summed angle was <10° but >−5°, it was classified as 'straight.' If the summed angle was <−5°, it was classified as 'kyphotic'. Because this study analyzed data from the middle of C6 to the upper part of the cervical vertebral bodies, measurements were extended only up to C5 in this method.

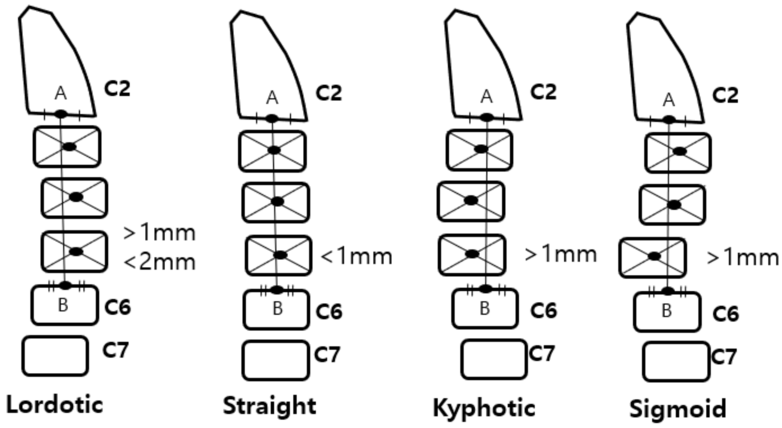


Figure 2. Ohara method. A line is constructed to connect the midpoint of the inferior endplate of the second cervical vertebra (C2) (A point) and the midpoint of the superior endplate of the sixth cervical vertebra (C6) (B point). The centroids of the third, fourth, and fifth cervical vertebrae (C3, C4, and C5) are the points of intersection of lines drawn from opposite corners within the vertebral body. The four types of cervical curvature are defined based on the relative positions of the C3–C5 centroids to line AB. Lordotic: All centroids are anterior to line AB, and the maximum distance is >1 mm but <2 mm. Straight: The distance between line AB and each centroid is <1 mm. Kyphotic: All centroids are posterior to line AB, and the maximum distance is greater than 1 mm. Sigmoid: Some centroids are anterior to and some posterior to line AB, but the maximum distance is >1 mm.

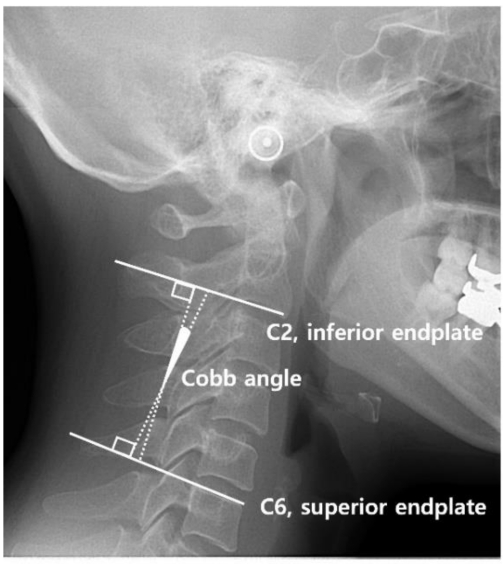


Figure 3. Cobb angle. This is the angle between the two perpendicular lines made from the inferior margin of C2 and the superior margin of C6. When the superior margin of C6 is rotated more clockwise than the inferior margin of C2, the angle is positive.

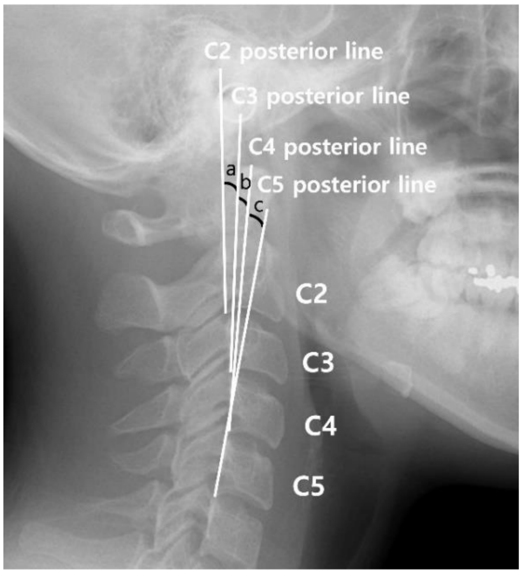


Figure 4. Harrison posterior tangent method. The lines are drawn parallel to the posterior surface of each cervical vertebral body from C2 to C5 and each angle from C2 to C3, C3 to C4, and C4 to C5 is added. a, angle between C2 and C3; b, angle between C3 and C4; c, angle between C4 and C5.

The Ohara, Cobb, and Harrison posterior tangent methods used two or more matching types to determine each sample's final curvature spine type. If the results of all the three methods were inconsistent, the sample was excluded. The sigmoid group was classified using only the Ohara method because it could not be identified using the Cobb and Harrison posterior tangent methods. Therefore, the sample classified as 'sigmoid' curvature type with the Ohara method was classified as sigmoid regardless of the results from other angular methods.

Distribution

The distribution of cervical curvature types in each vertical facial group was examined. We compared the differences in the overall cervical curvature distribution in the three vertical facial groups.

2.3. Statistical Analysis

Twenty lateral cephalometric radiographs were randomly selected, and the same examiner traced and measured them at 2-week intervals to determine the magnitude of the measurement errors using Dahlberg's formula [29]. The intraclass correlation coefficients (ICCs) for the reliability of the variables were all greater than 0.97. All analyses were performed using SPSS software (version 23; IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$. Descriptive statistics were calculated for all variables, including means and standard deviations. Differences in the lateral cephalometric variables for craniocervical posture and cervical curvature among the three groups were tested using a one-way analysis of variance with the Bonferroni post hoc test. The difference in the overall distribution of cervical curvature types between the three vertical facial groups and the difference in the proportion of each cervical curvature type were assessed using Fisher's exact test with the Bonferroni post hoc test. First, an overall comparison was conducted. Second, cervical curvature was categorized into two groups: lordotic and non-lordotic (straight, kyphotic, or sigmoid curvature). The analysis was conducted to determine whether there were differences in the distribution of the cervical type according to the vertical facial pattern. Pearson's correlation coefficient was calculated to investigate the correlation between the measured values. Despite the more severe conditions with the sigmoid curvature samples, they were excluded from the correlation analysis because the measured values did not differentiate this group from the lordotic and straight groups [30]. Because the Ohara method has a nominal variable, this group was excluded from the descriptive statistics and correlation analysis.

3. Results

3.1. Craniocervical Posture and Cervical Curvature

Differences in craniocervical posture among the three groups are presented in Table 2. The hyperdivergent group showed a larger SVA than the hypodivergent group. Likewise, the hyperdivergent group showed smaller CIA than the normovergent and hypodivergent groups. In contrast, the cervical curvature measurements did not show any statistical differences.

Table 2. Comparisons of craniocervical posture and cervical curvature measurements according to vertical facial patterns.

	Hypodivergent (n = 29)	Normovergent (n = 34)	Hyperdivergent (n = 29)	p-Value
Craniocervical posture				
Sagittal vertical axis (mm)	14.4 ± 4.5^{a}	$17.3 \pm 4.8^{a,b}$	20.0 ± 5.5^{b}	0.000 ***
Cervical inclination angle (°)	85.3 ± 4.2^{a}	84.5 ± 2.9^{a}	79.7 ± 3.9^{b}	0.000 ***
Cervical curvature				
Cobb angle (°)	−0.8 ± 9.8	−3.9 ± 12.0	−6.4 ± 8.0	0.123
Harrison posterior tangent angle (°)	2.1 ± 8.8	1.7 ± 11.6	−2.7 ± 9.1	0.134

Values are presented as mean ± one standard deviation. Analysis of variance was performed to compare the variables among three facial patterns. A post hoc test was conducted with the Bonferroni method. [a,b] Different superscript letters indicate statistical difference among three groups. The same letter means there is no difference between groups (*** $p < 0.001$).

3.2. Cervical Curvature Classification

In the overall sample, the straight cervical type was the most common (48.9%), followed by kyphotic (25.0%), lordotic (19.6%), and sigmoid (6.5%) types.

3.3. Distribution of Cervical Curvature by Vertical Facial Pattern

In the hypodivergent group, the ratio of straight curvature was the highest (65.5%), followed by lordotic (17.2%), kyphotic (13.8%), and sigmoid (3.4%) curvatures. In the normovergent group, lordotic curvature showed the highest ratio (32.4%), straight and kyphotic curvatures showed the same ratio (29.4%), and sigmoid curvature showed the lowest ratio (8.8%). In the hyperdivergent group, the ratio of straight curvature was highest (55.2%), followed by kyphotic curvature (31.0%). The ratios of the lordotic and sigmoid curvatures were similar (6.9%) (Table 3).

Table 3. Classification of cervical curvature.

Curvature Measurement Method	Cervical Curvature Classification			
	Lordotic	Straight	Kyphotic	Sigmoid
Ohara method	17 (18.5%)	47 (51.1%)	22 (23.9%)	6 (6.5%)
Cobb method	15 (16.3%)	44 (47.8%)	27 (29.3%)	6 (6.5%)
Harrison posterior tangent method	16 (17.4%)	47 (51.1%)	23 (25.0%)	6 (6.5%)
Final curvature	18 (19.6%)	45 (48.9%)	23 (25.0%)	6 (6.5%)

Significant differences were found in the distribution of cervical curvature types between the groups (p = 0.035). Even though the post hoc test did not reveal any significant pairwise difference (p > 0.05), based on the difference between the expected and observed frequencies, it can be inferred that there was a higher incidence of lordotic curves and a lower incidence of straight curves in the normovergent group. In contrast, the hypodivergent group showed a higher incidence of straight curves (Table 4).

Table 4. The distribution of cervical curvature by the vertical facial type in the sample.

	Lordotic	Straight	Kyphotic	Sigmoid	***p*-Value** [†]
Hypodivergent (n = 29)	5	19	4	1	0.035 *
Normovergent (n = 34)	11	10	10	3	
Hyperdivergent (n = 29)	2	16	9	2	
Post hoc p-value [‡]	Hypodivergent vs. Normovergent				0.119
	Hypodivergent vs. Hyperdivergent				0.884
	Normovergent vs. Hyperdivergent				0.146

[†] Fisher's exact test was performed to compare among 5 types of cervical curvature in each facial types. [‡] The Bonferroni post hoc test was conducted. Bonferroni p-values are shown in the table. * p < 0.05.

After categorizing the cervical curvatures into normal (lordotic) and abnormal (straight, kyphotic, and sigmoid) curves, the normovergent group showed the highest percentage of lordotic curvature (32.4%), followed by the hypodivergent (17.2%) and hyperdivergent (6.9%) groups. There was a difference in distribution between the normovergent and hyperdivergent groups. A higher incidence of lordotic curvature and a lower incidence of non-lordotic curvature were observed in the normovergent group (Table 5).

Table 5. Comparison of the distribution of lordotic versus non-lordotic [a] cervical curvature types for each vertical facial pattern.

	Lordotic	Non-Lordotic	***p*-Value** [†]
Hypodivergent (n = 29)	5	24	0.037 *
Normovergent (n = 34)	11	23	
Hyperdivergent (n = 29)	2	27	
Post hoc p-value [‡]	Hypodivergent vs. Normovergent		0.741
	Hypodivergent vs. Hyperdivergent		1.000
	Normovergent vs. Hyperdivergent		0.039 *

[a] Non-lordotic cervical curvature included straight, kyphotic, and sigmoid curves. [†] Fisher's exact test was performed to compare among 5 types of cervical curvature in each facial type. [‡] The Bonferroni post hoc test was conducted. Bonferroni p-values are shown in the table. * p < 0.05.

3.4. Correlation Among Vertical Facial Patterns, Craniocervical Posture, and Cervical Curvature

There was a moderate correlation between the craniocervical postures and vertical facial patterns (p > 0.05) (Table 6). SVA was positively related to NSL/ML and negatively related to CIA. This indicates that the more vertical the facial type, the greater the increase in the forward position of the head and forward inclination of the cervical column. However, a weak correlation was found between NSL/ML and cervical curvature measurements. The craniocervical posture and cervical curvature measurements also showed a weak correlation. The Cobb angle showed weak correlations with SVA and CIA. In contrast, the Harrison posterior tangent angle showed no significant correlation with SVA or CIA (p > 0.05). The SVA and CIA were strongly correlated, and the Cobb angle and Harrison angle were also highly correlated.

Table 6. Pearson's correlation coefficient between measurements.

Variables	NSL/ML	Sagittal Vertical Axis	Cervical Inclination Angle	Cobb Angle (°)	Harrison Posterior Tangent Angle (°)
NSL/ML		0.391 **	−0.468 **	−0.238 **	−0.192
(*p*-value)		(0.000)	(0.000)	(0.022)	(0.066)
Sagittal vertical axis			−0.845 **	−0.299 **	−0.184
(*p*-value)			(0.000)	(0.004)	(0.079)
Cervical inclination angle				0.250 **	0.182
(*p*-value)				(0.016)	(0.082)
Cobb angle					0.901 ***
(*p*-value)					(0.000)

NSL/ML—angle between the nasion–sella line and the mandibular plane. Pearson correlation analysis was performed to evaluate the relationship between the variables. ** $p < 0.01$, and *** $p < 0.001$. Subjects with sigmoid curvature were excluded.

4. Discussion

The relationship between the sagittal facial patterns and the type of cervical curvature remains controversial [16,17,31]. To exclude the effects of the anteroposterior skeletal discrepancy on the type of cervical curvature, we only investigated patients with a skeletal Class I relationship.

This study used two measurements of craniocervical posture (SVA and CIA) and three methods of cervical curvature (Ohara, Cobb, and Harrison posterior tangent methods). Introduced in 1889, SVA is the most commonly used method to measure the anteroposterior head position. However, it has the limitation of being affected by individual size differences [21]. Therefore, the CIA method, which measures the degree of head tilt, was used. However, the CIA considers only the position of the cervical vertebrae and does not use any reference to the head. Both methods were employed to evaluate craniocervical posture for a more accurate analysis. The Cobb method is the most widely used method for cervical curvature measurement because of its ease of use and good intra- and interrater reliability. The Harrison posterior tangent method is the most accurate method for measuring cervical curvature [1,28]. However, as angular methods primarily assess overall curvature, they cannot effectively distinguish segmental reversed curvatures (sigmoid) from lordotic or straight alignments; therefore, the Ohara method, which can distinguish regional kyphotic curvatures, was also utilized [32].

Based on SVA and CIA values, the hyperdivergent group was distinguished from the other groups. The hyperdivergent group showed a more anterior position of the head and increased anterior inclination of the cervical spine than the hypodivergent group. Our findings are similar to previous studies that reported a correlation between large vertical craniofacial dimensions and extended head posture [17,33–35]. This mechanism can be explained by 'neuromuscular feedback' and is termed the 'soft-tissue stretching hypothesis'. This hypothesis suggests that the soft tissue layer is passively stretched when the head is extended relative to the cervical vertebral column. This would increase forces on the skeletal structures and could redirect the mandibular growth more caudally [31]. Consequently, subjects with a hyperdivergent facial pattern or a retrognathic profile are likelier to exhibit a forward craniocervical posture.

The three groups had no significant differences in the Cobb angle and Harrison posterior tangent angle. As these angles serve as criteria for classifying cervical types, comparing these angles between the three groups when all cervical curvature types are intermixed seems to have no clinical significance. For this reason, it would be more meaningful to ascertain the distribution of cervical curvature types for each vertical facial pattern and compare the differences in these distributions.

Cervical curvature was classified into four categories within each group. It is well accepted that the physiological cervical curvature is lordotic in a natural head posture. However, our results showed that only 19.6% of the samples had lordotic cervical curvature. A straight cervical curvature was the most common (48.9%), followed by kyphotic (25.0%), lordotic (19.6%), and sigmoid (6.0%) curvatures. In previous studies, lordotic cervical curvature was not dominant. Beltsios et al. [4] conducted a study on 100 healthy adults and reported that approximately one-third of the population had a lordotic cervical spine, one-third had a straight spine, and the remaining third had either kyphotic or sigmoid curvatures. Yu et al. [3] reported that 28% of young asymptomatic Chinese adults have lordotic cervical spines, whereas 45% have straight spines. Nonetheless, compared to previous findings [3,4], our results indicate a lower proportion of lordotic cervical curvature.

This is the first study to describe the prevalence of each type of cervical curvature in different vertical facial patterns. In the hypodivergent and hyperdivergent groups, the straight curve was most prominent, whereas in the normovergent group, the lordotic curve was predominant. Fisher's exact test indicated an association between the vertical facial pattern and the type of cervical curve. The normovergent group had a higher frequency of lordotic curves and fewer straight curves, the hypodivergent group had a predominance of straight curves, and the hyperdivergent group had fewer lordotic curves. Compared with previous studies [3,4,36], the distribution of cervical curvature types in the normovergent group was similar, but the hypodivergent and hyperdivergent groups showed a higher proportion of non-lordotic cervical curvatures. In this study, although there were no significant differences in the mean values of cervical curvature measurements, the distribution of cervical curvature types showed a significant difference between the three groups. This may be linked to the observation that the hypodivergent group had the highest proportion of straight curves and the lowest proportion of kyphotic curves, whereas the normovergent group had an even distribution for each curvature type. As expected, there was a greater prevalence of non-lordotic cervical curvature in the hyperdivergent group, which tended to show a forward head posture. However, the hypodivergent group showed a greater prevalence of straight curvature. Fineman et al. [37] reported that subjects who changed from a neutral position to a military posture (backward craniocervical posture) often experienced the loss of cervical lordosis, leading to a straight cervical alignment. Variations in muscle tension around the shoulder and neck areas may contribute to this phenomenon [38]. In addition, craniofacial development is closely linked to stomatognathic functions, such as mastication, swallowing, and respiration, all of which influence craniocervical posture [39,40]. Further research is needed to investigate their biomechanical impact on cervical alignment, with biomechanical analysis and longitudinal studies providing further validation of these relationships.

In this study, we investigated the correlations among NSL/ML, craniocervical posture, and cervical curvature. The Pearson correlation suggests that the NSL/ML showed a moderate correlation with craniocervical posture, implying that head and cervical postures may vary according to the vertical facial pattern, aligning with the aforementioned soft-tissue stretching hypotheses. Thus, an increase in the mandibular plane angle was associated with a more anterior positioning of the head and neck. Our results showed a weak negative correlation between NSL/ML and cervical curvature measurements. This suggests that an increase in the mandibular plane angle corresponds to a decrease in cervical curvature; however, when examining the distribution of cervical curvature types, no difference was observed between the hyperdivergent and hypodivergent groups. Tecco et al. [8] found no significant differences in cervical curvature relative to vertical facial patterns. Their study was limited in not including kyphotic cervical curvature since kyphosis is not considered a physiological posture of the spine. Solow and Tallgren [17] observed a very weak negative correlation between the mandibular plane angle and cervical lordosis angle (the angle between odontoid process tangent and a line through the inferoposterior points of C2 and C4, CLA), noting reduced CLA in association with large vertical facial dimensions and increased CLA with a shorter vertical dimension. However, these studies were conducted with adult men; therefore, the results cannot be directly compared with those in our study. This indicates that the cervical curvature type cannot be explained solely by the magnitude of the mandibular plane angle. Examination of the relationship between craniocervical posture and cervical curvature measurements revealed that the Cobb angle had a weak correlation with craniocervical posture, whereas the Harrison posterior tangent angle showed no correlation. There are two possible explanations for this minimal correlation. First, a backward craniocervical posture may affect cervical curvature. Typically, a more lordotic curvature is expected with a more backward head position; however, this study found a prevalence of straight curvatures associated with such a posture. Second, cervical curvature may be influenced by multiple factors, with craniocervical posture being one of many potential influences. Previous studies suggest that factors such as muscle tension, lifestyle patterns, repetitive trauma, and congenital and developmental conditions may play a role [9,41–43], rather than craniofacial structure alone. This may explain the weak correlation observed in the present study. Additionally, the influence of environmental and social factors remains unclear, requiring further research on physical, psychosocial, and personal risk factors to better understand their impact on cervical alignment.

The mechanism underlying loss of cervical lordosis remains unclear. A recent hypothesis is that weakness of the neck extensor muscles is a risk factor for the development of cervical kyphosis [44]. A previous study has reported on the association between forward head posture and neck muscle imbalance [45]. Therefore, it is reasonable to assume that neck muscle imbalance according to different cervical postures may affect cervical spine curvature. To date, no trial has investigated the differences in neck extensor and flexor muscles according to vertical facial patterns. Only partial neck muscles were investigated, and they reported significant differences in the electromyographic activity of the sternocleidomastoid and trapezius when the vertical dimension varied [46]. Therefore, cervical muscle status according to vertical craniofacial factors should be considered in future studies.

Many dental clinicians are not familiar with methods for assessing cervical spine alignment. This study found that the simple Cobb method showed a strong correlation with the highly accurate Harrison method, making it a clinically accessible diagnostic tool. This correlation is likely due to both methods relying on angular measurements, which primarily evaluate overall cervical curvature. However, discrepancies between methods arise because angular measurements alone cannot differentiate segmental reversed curvatures, whereas the Ohara method, using linear assessments, is more sensitive to detecting regional kyphotic changes. Therefore, incorporating linear assessments alongside angular methods may enhance diagnostic accuracy in clinical practice.

This study had certain limitations. First, this study is limited to adult females aged 18–35 years, and further research is needed to explore cervical curvature in males and other age groups to improve generalizability. Second, the seventh cervical vertebrae were excluded from the analysis. In practice, seeing the lower cervical spine on routine lateral cephalometric radiographs is difficult. While three methods were used to address this limitation, the exclusion of C7 may impact the completeness of cervical curvature evaluation. To improve the evaluation of cervical curvature, future studies should consider adjusting imaging techniques to include the lower cervical spine. Third, various factors may influence cervical spine alignment, necessitating further investigation into biomechanical elements, such as daily life habits or job. Despite these limitations, this study is pioneering in illustrating the variance in cervical curvature types across vertical facial patterns. It has also been established that craniofacial features contribute to craniocervical posture and cervical curvature, although the exact nature of the cause-and-effect relationship remains unclear. Cervical posture is associated with facial soft-tissue aesthetics, while cervical spine curvature affects health-related quality of life [25]. Consequently, this study suggests that clinicians should meticulously evaluate craniocervical posture and cervical spine curvature using routine lateral cephalometric radiographs prior to orthodontic treatment.

5. Conclusions

1. The hyperdivergent facial pattern group demonstrated the most anterior head positioning and the greatest anterior inclination of the cervical spine.
2. A smaller population of lordotic cervical curvature was observed in our sample compared to the previous literature.
3. A clear association was established between vertical facial patterns and cervical spine curvature.
4. Upon categorization into lordotic and non-lordotic groups, the hyperdivergent group showed a notable decrease in lordotic curves compared to the normovergent group.
5. There is a moderate correlation between the vertical facial pattern and craniocervical posture, and a weak correlation with cervical curvature.

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