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Assessment of Radiographic Craniovertebral Angle in Relation to Sagittal Skeletal Pattern, Vertical Growth Pattern, and Sella Turcica Morphology: A Retrospective Cephalometric Study

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Abstract

Aim: Craniocervical posture has been investigated in relation to dentofacial morphology, yet existing literature remains conflicting due to varied assessment methods. This study aimed to evaluate whether the radiographic craniovertebral angle (CVA) differs according to sagittal skeletal classification, vertical growth pattern, sella turcica morphology, and sex.

Methods:

In this retrospective cross-sectional study, standardized lateral cephalograms of 594 untreated individuals (375 females and 219 males; mean age: 17.05 ± 3.56years, range: 15–25 years) were evaluated. Sagittal skeletal relationship was classified into Class I, Class II, and Class III based on the ANB angle ($n = 198$ per group). Vertical growth pattern was determined using the Jarabak ratio (hyperdivergent $< 62\%$, normodivergent 62%–65%, hypodivergent $> 65\%$), and sella turcica morphology was categorized into six types according to Axelsson et al. Radiographic CVA was measured as the posterior angle between McGregor's plane and the longitudinal axis of the second cervical vertebra (odontoid process to the anteroinferior border of C2). Group comparisons were analyzed using one-way ANOVA and independent-samples t-tests ($\alpha = 0.05$).

Results:

The overall mean CVA was 86.96° ± 8.84°. No statistically significant differences in CVA were found among sagittal skeletal classes (Class I: 88.05° ± 8.44°; Class II: 86.26° ± 8.77°; Class III: 86.56° ± 9.23°; F = 2.345, P = 0.097, η^2 = 0.008), vertical growth patterns (hyperdivergent: 85.04° ± 8.25°; normodivergent: 85.78° ± 8.58°; hypodivergent: 87.39° ± 8.92°; F = 2.426, P = 0.089, η^2 = 0.008), or sella turcica morphological types (F = 0.769, P = 0.572, η^2 = 0.007). CVA also did not differ significantly between males (86.48° ± 8.18°) and females (87.24° ± 9.20°; t = −1.010, P = 0.313, Cohen's d = 0.09).

Conclusions:

Within the limitations of this retrospective radiographic assessment, craniovertebral angle did not show statistically significant variation across ANB-defined sagittal skeletal classes, vertical growth patterns, sella turcica morphology variants, or sexes in individuals aged 15–25 years. These findings suggest that within this static cephalometric sample, variations in sagittal skeletal pattern and cranial base morphology were not associated with detectable differences in radiographic craniocervical angulation. Further dynamic, functional, and longitudinal studies are warranted to better understand the complex interplay between craniofacial morphology and head posture.

Keywords: Cephalometric Analysis, Craniovertebral Angle, Skeletal Malocclusion, Vertical Growth Pattern.

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Background

Head and neck posture has been investigated in relation to craniofacial morphology, with reported associations involving cervical vertebral morphology and craniocervical orientation (1). Coordinated jaw and neck muscle activity also supports a functional relationship between the masticatory and cervical neuromuscular systems (2). However, a literature review highlighted methodological limitations and conflicting findings concerning the relationship between temporomandibular disorders (TMD) and craniocervical posture (3). In an adult cephalometric sample, differences in selected cervical and craniocervical angular measurements were reported between sagittal skeletal classes (4).

Temporomandibular disorders (TMDs) may coexist with cervical pain without detectable differences in cephalometrically assessed craniocervical posture, as reported in a study comparing women with and without TMD (5). The radiographic craniovertebral angle (CVA), defined by the intersection of McGregor's plane and the odontoid plane, provides a measure of head flexion and extension relative to the upper cervical spine (6). Clinical reviews also list neck pain as a symptom that may accompany TMD (7,8). The relationship between sagittal jaw position and craniocervical posture has been investigated, although methodological heterogeneity and the limited number of studies constrain interpretation of the available evidence (9). Findings in adults with skeletal Class II malocclusion have also varied according to TMD status and the statistical method used, indicating that this relationship requires cautious interpretation (10).

Studies comparing mouth-breathing children with controls have reported differences in photographically assessed cervical posture (11) and selected anthropometric orofacial measurements (12). The functional role of cervical musculature in supporting head posture supports examining the relationship between craniofacial morphology and cervical alignment (13).

In a randomized controlled trial involving 30 patients with TMD, Arslan et al. reported higher cervical muscle performance after eight weeks in patients receiving cervical stabilization training in addition to education and home exercises than in those receiving education and home exercises alone; however, cervical posture did not differ significantly between the groups (14).

Recent studies continue to report differing results. Peng et al. found that craniocervical associations varied with growth period and the angular measure assessed (13). Salazar-Lara et al. reported an association between sagittal skeletal relationship and a McGregor–odontoid plane angle in children aged 6–12 years (15), whereas Ertem Arslan et al. found no significant differences in photographic postural parameters between skeletal malocclusion groups in 10–15-year-old adolescents (16). Together with the methodological heterogeneity identified by Peng et al. in their systematic review, these findings support further evaluation using clearly defined postural measures and study populations (17).

This study aimed to retrospectively evaluate whether CVA differs by sagittal skeletal malocclusion, vertical growth pattern, sella turcica morphology, and sex using lateral cephalometric radiographs. The null hypothesis was that CVA would not differ significantly across these demographic and craniofacial categories. By examining these relationships in a single cephalometric dataset, this study sought to improve understanding of the associations between craniofacial morphology and craniovertebral posture.

Methods

This study was approved by the Non-Interventional Research Ethics Committee of Van Yuzuncu Yil University (Approval No: 2025/03-19). It was designed as a retrospective study using only anonymized lateral cephalometric radiographic data. All personal identifiers were removed, and no personal data were used at any stage of the study, ensuring participants' confidentiality and privacy. This research was conducted as a retrospective cross-sectional analysis of lateral cephalometric radiographs obtained for orthodontic assessment at the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Van Yuzuncu Yil University, between January 1, 2017, and January 1, 2025.

Study Population and Sample Selection

An a priori power analysis was performed for a one-way analysis of variance (ANOVA) comparing mean CVA values between three sagittal skeletal groups. Based on previously reported inter-group differences in cervical postural measurements, an effect size of Cohen's f=0.37 was specified (18). A minimum total sample size of 74 participants was required to achieve 80% statistical power at a significance level of α=0.05. Because the retrospective archive contained substantially more eligible radiographs, the final sample was expanded to improve estimate precision and facilitate

balanced subgroup comparisons. An initial pool of 1,018 lateral cephalometric radiographs was screened for eligibility. After applying the predefined inclusion and exclusion criteria, eligible radiographs were grouped according to sagittal skeletal classification. To obtain balanced groups for comparison, 198 eligible individuals were selected from each skeletal class, resulting in a final sample of 594 participants. The eligibility criteria were as follows:

Inclusion Criteria

- Aged between 15 and 25 years
- Lateral cephalometric radiographs with clearly identifiable skeletal reference landmarks (e.g., Sella, Nasion)
- No history of orthodontic treatment
- No congenital anomalies, syndromes, or systemic diseases affecting the head and neck region

Exclusion Criteria

- Radiographs in which skeletal landmarks or cervical vertebrae were not clearly distinguishable
- Images containing metal artifacts or falling outside the imaging field of view (FOV)
- History of orthodontic treatment
- History of trauma to the head or neck
- Presence of structural disorders such as cervical anomalies, torticollis, or craniovertebral malformations

Demographic information such as age and sex was recorded for further subgroup analyses.

Image Acquisition

All lateral cephalometric radiographs were acquired using an ORTHOPHOS XG imaging system (Sirona Dental Systems GmbH, Bensheim, Germany) at 60 kV and 3 mA, with an exposure time of 14.1 seconds. During image acquisition, the participants' heads were positioned by aligning relevant anatomical structures with the cephalometric unit's reference markers. An experienced radiologic technician obtained all radiographs using the same positioning and acquisition protocol to ensure standardization. The images were exported in Digital Imaging and Communications in Medicine (DICOM) format, and radiomorphometric measurements were performed using ImageJ software (National Institutes of Health, Bethesda, USA).

Participants were classified into sagittal skeletal malocclusion types based on SNA (Sella–Nasion–A Point), SNB (Sella–Nasion–B Point), and ANB (A Point–Nasion–B Point) angular values as follows:

- Class I: ANB angle between 0° and 4°
- Class II: ANB angle >4°
- Class III: ANB angle <0° (Figure 1) (16).

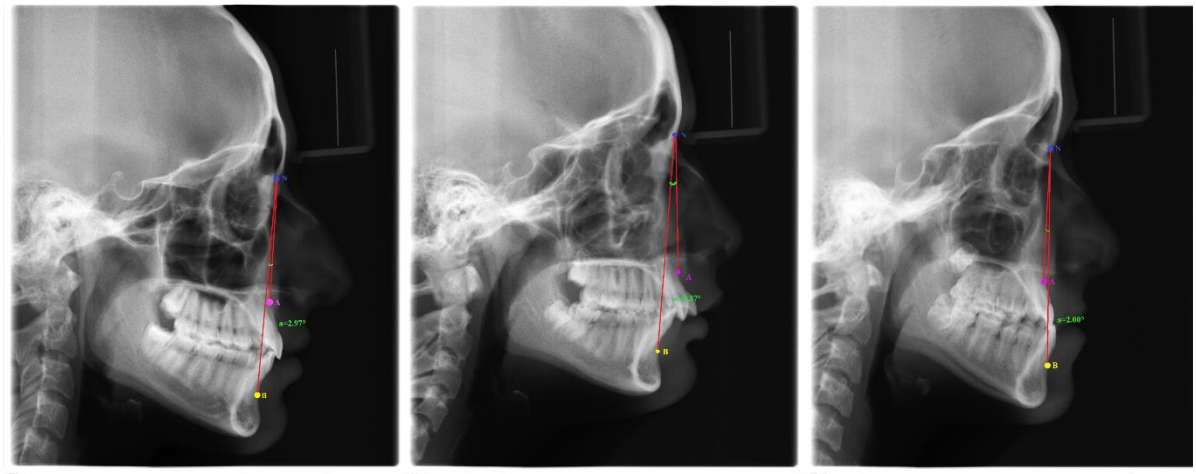


Figure 1: Lateral cephalometric images illustrating the ANB-based sagittal skeletal classification: (A) Class I, (B) Class II, and (C) Class III. The reference points marked in the images are as follows: N (Nasion): Represents the junction between the frontal bone and the nasal bone at the root of the nose. A (Point A): The most concave point on the anterior contour of the maxilla, indicating the position of the upper jaw. B (Point B): The most concave point on the anterior contour of the mandible, representing the position of the lower jaw.

Radiographic Evaluation and Consensus Procedure

All radiographic evaluations and measurements were independently performed by two investigators using ImageJ software. In cases of disagreement regarding landmark identification, sagittal skeletal classification, or sella turcica morphology, the relevant radiograph was jointly reassessed, and the final determination was reached by consensus. For continuous measurements, discrepant landmark placements were jointly reviewed, and the measurement was repeated using the agreed anatomical reference points. The consensus-based measurements and classifications were used in the final statistical analyses.

Measurement of the Craniovertebral Angle

The radiographic craniovertebral angle (CVA) was measured on lateral cephalograms as the posterior angle formed between McGregor's plane and the longitudinal axis of the second cervical vertebra (C2). McGregor's plane was defined as the line extending from the posterior nasal spine to the most caudal point of the occipital curve. The C2 axis was constructed by connecting the apex of the odontoid process to the most inferior anterior point of the C2 vertebral body. The posterior angle formed by the intersection of these two lines was recorded as the craniovertebral angle (Figure 2) (19).

Assessment of Sella Turcica Morphology

The morphology of the sella turcica was evaluated on lateral cephalograms according to the classification proposed by Axelsson et al. (2004) (20). Each participant was classified into one of six morphological categories: Type 1, normal sella turcica; Type 2, oblique anterior wall; Type 3, double contour of the floor; Type 4, pyramidal shape of the dorsum sellae; Type 5, irregularity of the posterior part of the sella turcica; or Type 6, sella turcica bridging (Figure 3).

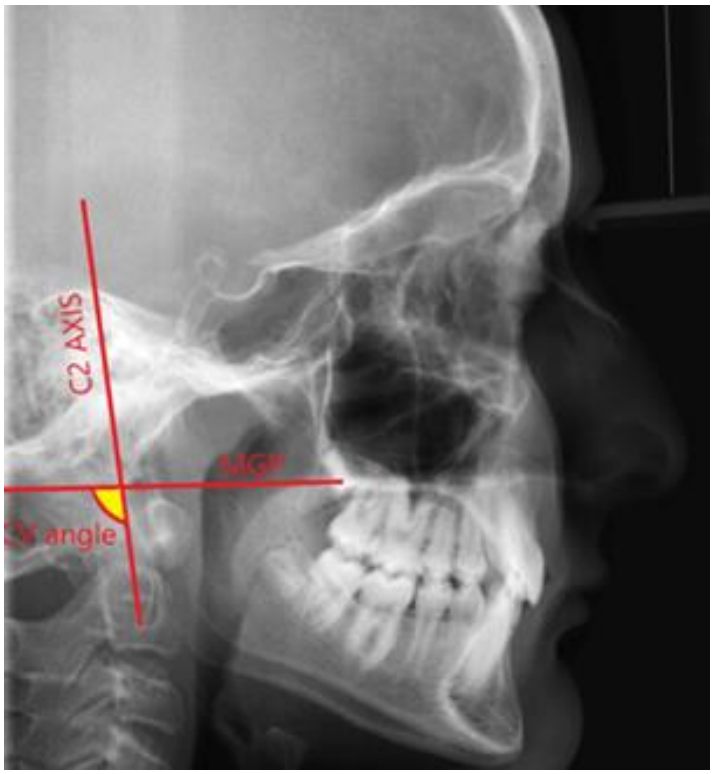


Figure 2: Measurement of the craniovertebral angle. McGregor's plane was drawn from the posterior nasal spine to the most caudal point of the occipital curve. The C2 axis was constructed by connecting the apex of the odontoid process with the most inferior anterior point of the C2 vertebral body. The posterior angle formed between McGregor's plane and the C2 axis was recorded as the craniovertebral angle.

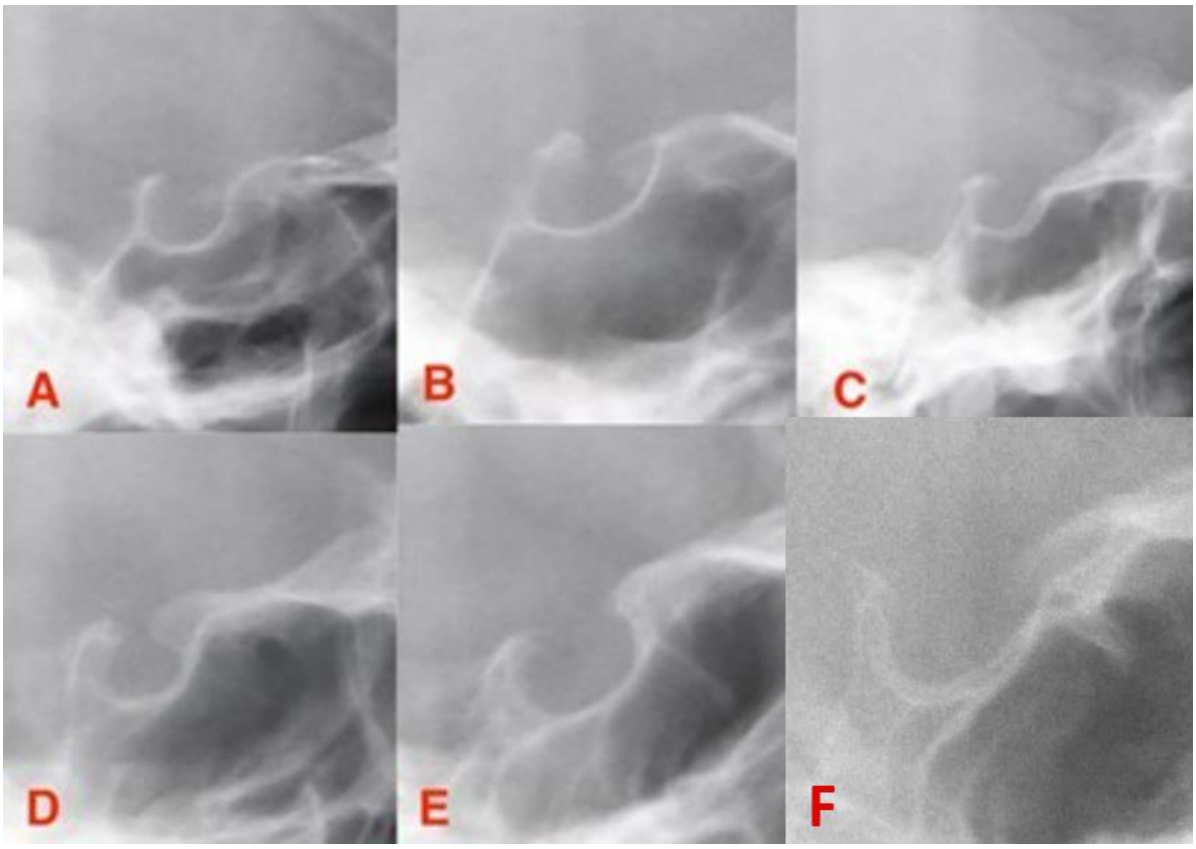


Figure 3: Sella turcica morphological categories according to Axelsson et al. (20): (A) normal sella turcica, (B) oblique anterior wall, (C) double contour of the floor, (D) sella turcica bridging, (E) irregularity (notching) in the posterior part of the dorsum sellae, and (F) pyramidal shape of the dorsum sellae.

Measurement of the Jarabak Ratio

The Jarabak ratio was calculated by dividing the posterior facial height (S–Go) by the anterior facial height (N–Me) and multiplying the result by 100. All linear measurements were obtained using ImageJ software (National Institutes of Health, Bethesda, MD, USA). Based on the Jarabak ratio, participants were classified as hyperdivergent (<62%), normodivergent (62–65%), or hypodivergent (>65%) (21). The Jarabak ratio was expressed as a percentage and used to characterize the vertical skeletal growth pattern (Figure 4). Because the Jarabak ratio is a dimensionless proportional measure, posterior and anterior facial heights were measured using the same image scale, and their ratio was calculated without reporting the individual linear measurements as absolute millimetric values.

Statistical Analysis

Only complete radiographic records containing all required anatomical landmarks and clearly visible cervical vertebrae were included in the final screening pool; consequently, there were no missing data in the final analyzed dataset of 594 participants.

All statistical analyses were performed using SPSS 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as mean, standard deviation, minimum, and maximum for continuous variables and as frequency and percentage for categorical variables. The distribution of CVA values within the comparison groups was assessed using the Kolmogorov–Smirnov test. CVA values did not deviate significantly from normality in any group except one sella turcica morphology subgroup. Considering the limited magnitude of this deviation, the adequate subgroup sample sizes, and the robustness of parametric tests to minor departures from normality, parametric methods were retained.

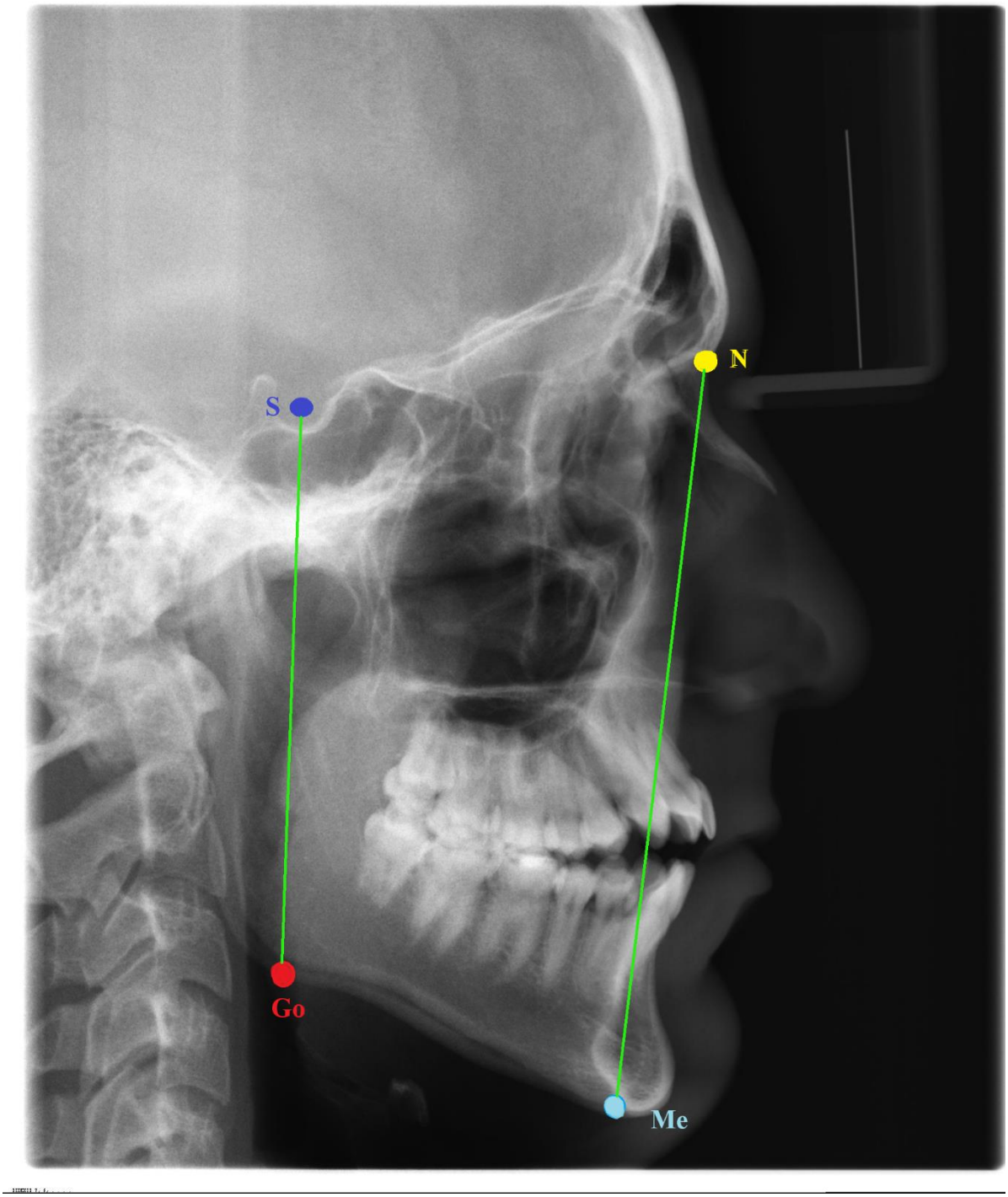


Figure 4: Lateral cephalometric image illustrating posterior facial height (S–Go) and anterior facial height (N–Me) used in the calculation of the Jarabak ratio. S: Sella, Go: Gonion, N: Nasion, Me: Menton

One-way ANOVA was used to compare CVA values between the ANB-based sagittal skeletal classes, vertical growth patterns based on the Jarabak ratio, and sella turcica morphology types. Homogeneity of variances was assessed using Levene's test. When a statistically significant overall

difference was detected by one-way ANOVA, pairwise comparisons were planned using Tukey's honestly significant difference test for homogeneous variances or Tamhane's T2 test when the homogeneity assumption was not met. An independent-samples t-test was used to assess sex-based differences in CVA and Jarabak ratio values. Associations between categorical variables were evaluated using Pearson's chi-squared test. Expected cell frequencies were examined to assess the suitability of the chi-squared approximation. Linear-by-linear association was additionally used to evaluate trends involving ordinal vertical growth pattern categories. Effect sizes were reported as eta squared (η^2) for one-way ANOVA and Cohen's d for independent-samples comparisons. All statistical tests were two-sided, and statistical significance was set at $P<0.05$. The reported P-values were not adjusted for multiple comparisons. Inter-observer reliability for the continuous cephalometric measurement assessed for reproducibility was evaluated using the intraclass correlation coefficient (ICC). Furthermore, to determine intra-observer reliability, 20 randomly selected radiographs were re-measured by the primary investigator under identical conditions after a two-week interval, yielding an intraclass correlation coefficient (ICC) of 0.945. P-value<0.05 was considered as significant.

Results

The study included 594 individuals: 219 males (36.9%) and 375 females (63.1%). Participants ranged in age from 15 to 25 years, with a mean age of 17.05±3.56 years. The Jarabak ratio ranged from 52.6% to 100.0%, with a mean of 69.6±5.8% (Table 1).

Table 1: Descriptive Statistics of Continuous Variables

Variable	N	Range (Min–Max)	Mean ± SD
Age (years)	594	15–25	17.05 ± 3.56
Jarabak Ratio (S-Go/N-Me) (%)	594	52.6–100.0	69.6 ± 5.8

N: Values are presented as mean ± standard deviation and minimum–maximum. No inferential statistical tests were performed for this table.

Inter-observer reliability was excellent, with an intraclass correlation coefficient (ICC) of 0.920. According to the ANB-based sagittal skeletal classification, participants were equally distributed among Class I, Class II, and Class III groups, with 198 individuals (33.3%) in each group. Sella turcica morphology was classified into six categories according to Axelsson et al. (2004): Type 1, normal sella turcica (23.6%); Type 2, oblique anterior wall (13.1%); Type 3, double contour of the floor (13.5%); Type 4, pyramidal shape of the dorsum sellae (14.0%); Type 5, irregularity of the posterior part of the sella turcica (20.9%); and Type 6, sella turcica bridging (15.0%). Based on the Jarabak ratio, 41 participants (6.9%) were classified as hyperdivergent, 101 (17.0%) as normodivergent, and 452 (76.1%) as hypodivergent (Table 2).

CVA values did not deviate significantly from a normal distribution within the sagittal skeletal, sex, vertical growth pattern, or sella turcica morphology groups ($P>0.05$), except for the double contour of the floor group (Type 3), in which a slight deviation was observed $P=0.04$). Given the adequate subgroup sample sizes and the robustness of the selected parametric tests, this minor deviation did not preclude parametric analysis.

One-way analysis of variance revealed no statistically significant differences in CVA between the ANB-based sagittal skeletal classes, $F(2, 591) = 2.345$, $P = 0.097$, $\eta^2 = 0.008$; sella turcica morphology types, $F(5, 588) = 0.769$, $P = 0.572$, $\eta^2 = 0.007$; vertical growth patterns, $F(2, 591) = 2.426$, $P = 0.089$, $\eta^2 = 0.008$; and sex, $t(592) = -1.010$, $P = 0.313$, Cohen's $d = 0.09$ (Table 3).

No significant association was observed between sex and sella turcica morphology ($P=0.08$). In contrast, females had a significantly higher Jarabak ratio than males ($P<0.001$). Vertical growth

patterns also differed significantly by sex (P=0.01) and showed a significant linear trend across the ordered categories (P<0.01).

Figure 5 presents group-specific CVA means and standard deviations.

Table 2: Distribution of categorical variables

Variable	Category	n (%)
Sex	Male	219 (36.9%)
	Female	375 (63.1%)
Skeletal Classification	Class I	198 (33.3%)
	Class II	198 (33.3%)
	Class III	198 (33.3%)
Sella Morphology	Type 1 (Normal)	140 (23.6%)
	Type 2 (Oblique anterior wall)	78 (13.1%)
	Type 3 (Double contour of floor)	80 (13.5%)
	Type 4 (Pyramidal shape)	83 (14%)
	Type 5 (Irregular dorsum sellae)	124 (20.9%)
	Type 6 (Bridge formation)	89 (15%)
Jarabak Pattern	Hyperdivergent (<62%)	41 (6.9%)
	Normodivergent (62–65%)	101 (17%)
	Hypodivergent (>65%)	452 (76.1%)

N: Values are presented as frequencies and percentages. No inferential statistical tests were performed for this table.

Table 3: Comparison of CVA among demographic and morphological groups

Group	Subgroup	CVA (Mean ± SD)	P-value
Sagittal skeletal classification	Class I	88.05 ± 8.44	0.097
	Class II	86.26 ± 8.77	
	Class III	86.56 ± 9.23	
Sex	Male	86.48 ± 8.18	0.313
	Female	87.24 ± 9.20	
Sella Morphology	Type 1	86.44 ± 8.55	0.572
	Type 2	87.40 ± 8.69	
	Type 3	86.87 ± 8.53	
	Type 4	85.66 ± 8.88	
	Type 5	87.72 ± 9.19	
	Type 6	87.60 ± 9.21	
Jarabak Pattern	Hyperdivergent	85.04 ± 8.25	0.089
	Normodivergent	85.78 ± 8.58	
	Hypodivergent	87.39 ± 8.92	

CVA: craniovertebral angle; SD: standard deviation. One-way ANOVA was used for comparisons among sagittal skeletal classes, sella turcica morphology types, and vertical growth patterns. An independent-samples t-test was used for the comparison between sexes.

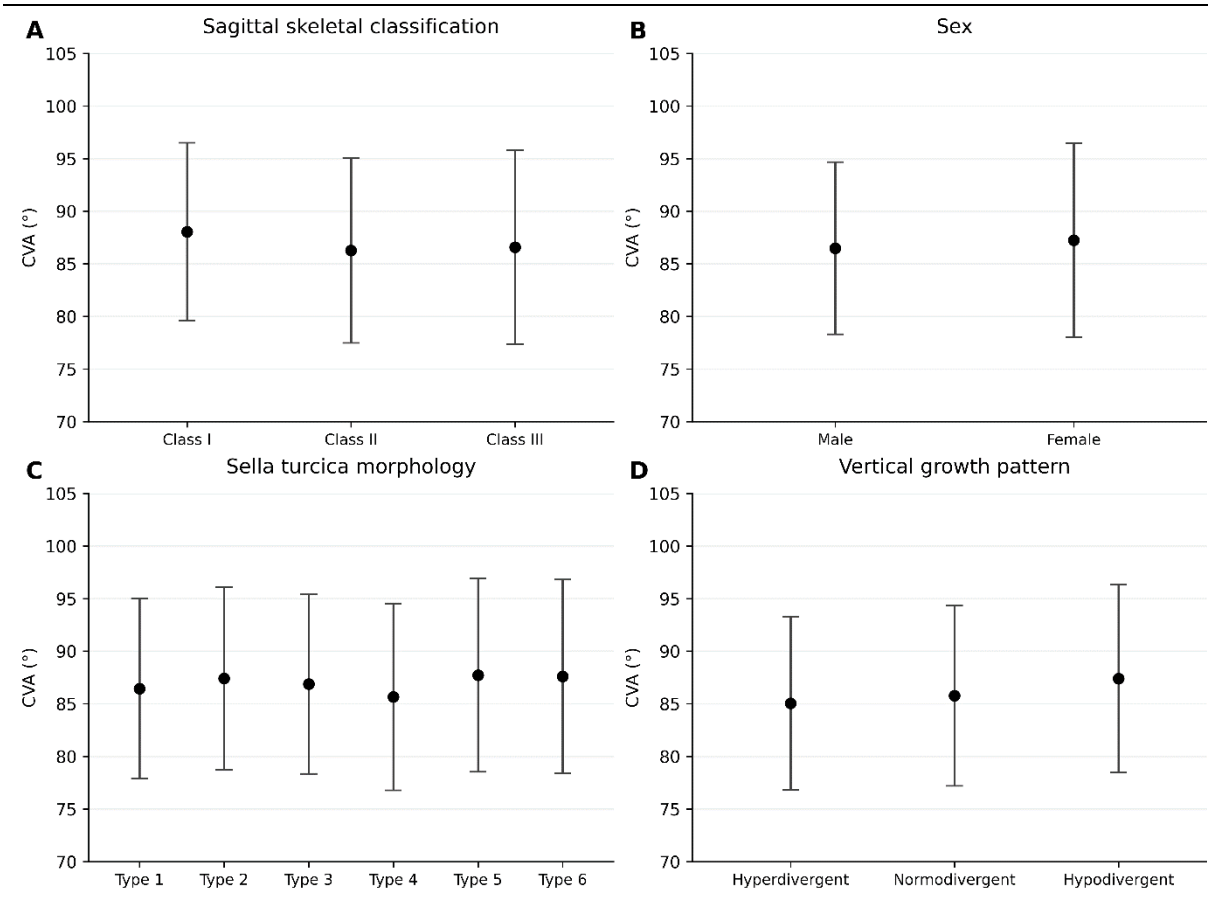


Figure 5: Mean radiographic craniovertebral angle (CVA) according to (A) sagittal skeletal classification, (B) sex, (C) sella turcica morphology, and (D) vertical growth pattern. Dots represent group means, and error bars indicate ±1 standard deviation.

Discussion

Previous studies have used both photographic and radiographic methods to evaluate craniovertebral posture. Derwich et al. (2022) reported significant changes in cervical curvature following combined physiotherapy and occlusal splint therapy in patients with TMDs, whereas the craniovertebral angle did not change significantly (19). However, differences in study population, intervention, and measurement technique limit direct comparison with the present findings. Surface-based photographic measurements may not fully correspond to radiographic measures of sagittal cervical alignment (22,23). In the present study, lateral cephalometric radiographs were used because they allowed the cranial and cervical anatomical landmarks required for the selected radiographic CVA measurement to be identified on the same image. Nevertheless, findings from different CVA definitions and imaging methods should be interpreted cautiously.

The present study found no statistically significant differences in radiographic CVA according to sagittal skeletal classification, vertical growth pattern, sella turcica morphology, or sex. Previous studies have examined the relationship between dentofacial morphology and posture (24) and changes in head posture following rapid maxillary expansion (25). In the present study, the effect sizes were small, suggesting that inter-group differences in CVA were limited within the study sample. Nevertheless, the absence of statistically significant differences should not be interpreted as evidence of equivalence or the complete absence of a relationship. Functional, developmental, and dynamic postural factors were not evaluated in this retrospective study.

McGuinness and McDonald (2006) reported no significant immediate changes in craniofacial angles following rapid maxillary expansion (26). Lippold et

al. (2006) found significant correlations between selected craniofacial measurements and fleche cervicale, but not for trunk inclination or fleche lombaire (27). Qadir and Mushtaq (2017) found no significant differences in linear cervical lordotic curvature among sagittal skeletal classes. However, the modified cervical angle differed significantly between Class I and Classes II and III (28). Differences in study populations, designs, and postural measures limit direct comparison of these findings with the present results.

In contrast, Hedayati et al. (2013), Arntsen and Sonnesen (2011), and Tauheed et al. (2019) reported differences or associations between sagittal skeletal relationships and cervical or head posture (18,29,30). Variability between these findings and those of the present study may reflect differences in sample characteristics, anatomical reference lines, and postural measurement methods. Peng et al. (2024) also evaluated craniocervical posture across different growth periods, emphasizing the potential importance of developmental stage when interpreting the relationship between skeletal malocclusion and cervical posture (13). Because skeletal maturation was not directly assessed in the present study, differences between studies cannot be attributed solely to growth stage. More specifically, Peng et al. stratified participants by cervical vertebral maturation and found that associations varied across growth periods and postural variables (13). The present analysis pooled individuals aged 15–25 years without maturation-based stratification and evaluated a single McGregor–C2 angle. Thus, a difference reported for another angular measure or maturation subgroup would not necessarily be reproduced by the present comparison.

Alexa et al. (2022) reported differences in craniocervical posture between skeletal malocclusion groups using cephalometric angular measurements (4). Conversely, Efendiyeva et al. (2014) evaluated long-term changes in head posture following bimaxillary orthognathic surgery in individuals with Class III malocclusion (31). Differences in study design, clinical population, and angular definitions limit direct comparison with the present cross-sectional findings.

Recent findings also illustrate why categorical comparisons and posture–morphology correlations should be distinguished. Ertem Arslan et al. reported no inter-group differences in photographic posture measures but identified sagittal head angle correlations within the Class II Division 2 subgroup (16). Their photographic tragus–C7 angle is different from the McGregor–C2 angle assessed here. Conversely, Salazar-Lara et al. used a McGregor–odontoid plane measure and found lower angles in Class II children (15). Although this is a closer anatomical comparison, their participants were 6–12 years of age. Differences in age range, sampling, and acquisition procedures may explain the contrasting results; their contribution cannot be determined from the present data.

Sella turcica morphology shows considerable anatomical variation, and Axelsson et al.'s classification provides a structured method for categorizing these patterns (20). In the present study, radiographic CVA did not differ significantly between the six sella turcica morphology types. Previous research has investigated sella turcica morphology in relation to dental anomalies and skeletal malocclusions using different populations and imaging methods (32). These methodological and population differences should be considered when comparing their findings with the present results. The current findings indicate that, in this study sample, the evaluated sella turcica morphology types were not associated with detectable differences in radiographic CVA. This distinction is important because the sella classification describes local osseous shape, whereas CVA describes the orientation of the cranium relative to C2. An association between sella morphology and skeletal malocclusion would not, by itself, establish an association with craniocervical orientation. The present analysis also compared categorical sella types rather than continuous sella dimensions and therefore does not address whether sella size is related to CVA.

The Jarabak ratio is a commonly used indicator of vertical skeletal pattern, with lower values corresponding to a hyperdivergent pattern and higher values corresponding to a hypodivergent pattern (21). In the present study, radiographic CVA did not differ significantly between the hyperdivergent, normodivergent, and hypodivergent groups. Because the continuous relationship between the Jarabak ratio and CVA was not evaluated using correlation or regression analysis, the present findings should be interpreted as group-based comparisons only. The predominance of hypodivergent individuals (76.1%), compared with 17.0% normodivergent and 6.9% hyperdivergent individuals, also produced unequal subgroup precision. Furthermore, grouping the Jarabak ratio by predefined thresholds does not evaluate variation within each category. These features may influence the ability to characterize subtle vertical pattern–posture relationships, but they do not establish why the overall comparison was non-significant.

Baruah et al. (2024) compared craniocervical angular measurements between individuals with different vertical growth patterns and reported differences in the angle between the nasion–sella line (NSL) and the odontoid process tangent (OPT) (33). However, the NSL/OPT angle used in that study and the radiographic CVA evaluated in the present study are based on different anatomical reference lines and should not be considered interchangeable. Differences in participant characteristics, vertical pattern classification, and measurement technique may therefore account for the differing results. These findings emphasize the importance of using consistent anatomical landmarks and standardized measurement protocols when comparing craniocervical posture across studies. In addition, Baruah et al. classified vertical patterns using the Frankfort–mandibular plane angle, whereas the present study used the posterior-to-anterior facial height ratio (33). Consequently, the studies differ in both the definition of the exposure and the postural outcome.

No significant sex-related difference was observed in radiographic CVA, but females had a higher mean Jarabak ratio, and the distribution of vertical growth pattern categories differed by sex. Because higher Jarabak ratios correspond to a more hypodivergent pattern, this finding should not be interpreted as evidence of a greater vertical growth tendency in females. Peng et al. (2022) noted that sex was insufficiently considered in the available studies; only one included study compared boys and girls and reported no significant difference (17). The present findings similarly suggest that sex-related differences in vertical facial proportions may not necessarily be accompanied by differences in radiographic CVA. However, because these were secondary analyses and no adjustment was applied for multiple comparisons, the results should be interpreted cautiously.

Age was not included as a covariate in the present analyses. Although the study was restricted to 15–25-year-old individuals to reduce age-related heterogeneity, residual confounding factors associated with developmental changes within this age range cannot be excluded. Future studies should account for age and skeletal maturation when examining the relationship between craniofacial morphology and craniovertebral posture.

Limitations

Several methodological considerations should be acknowledged when interpreting the findings. The balanced sampling strategy improved comparability and statistical efficiency across the sagittal skeletal groups; however, the resulting group proportions may not fully reflect the natural distribution of skeletal malocclusions in the source population. As the study was conducted at a single center, the findings should be generalized to other geographic and ethnic populations with appropriate consideration. Furthermore, due to the retrospective cross-sectional design, the results primarily reflect associations rather than temporal or causal relationships. Although standardized radiographic acquisition and measurement procedures were applied, two-dimensional lateral cephalometric assessment inherently involves potential effects of patient positioning, anatomical superimposition, and landmark identification. Differences in CVA definitions and reference lines across studies should also be considered when comparing findings in the literature. Finally, as adjustments for multiple comparisons were not applied, the secondary findings should be regarded as exploratory and interpreted alongside their effect sizes and the overall pattern of results. Despite these considerations, the relatively large sample and standardized assessment protocol strengthen the reliability of the present findings.

Conclusion

Within the limitations of this retrospective cross-sectional study, radiographic CVA did not differ significantly according to ANB-based sagittal skeletal classification, vertical growth pattern, sella turcica morphology, or sex among 15–25-year-old individuals. Although the Jarabak ratio differed by sex, this difference was not accompanied by a significant sex-related difference in CVA. These findings indicate that the evaluated static craniofacial characteristics were not associated with detectable differences in radiographic CVA within the study sample. Longitudinal studies accounting for age, skeletal maturation, and functional factors are needed to clarify these relationships.

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Conflict of Interests

No potential conflict of interest relevant to this article was reported.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Authors' Contributions

S.K. and A.K. contributed to the conceptualization and supervision of the study. S.K. was responsible for manuscript writing and data interpretation. F.K., S.B., G.K., and S.N.M. were involved in data collection and curation. A.K. performed the final critical review and approval of the manuscript. All authors have read and approved the final version of the manuscript.

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