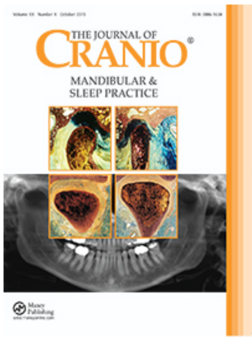

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Evaluation of Cervical Posture of Children in Skeletal Class I, II, and III

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ABSTRACT: Previous studies on the relationship between morphological structure of the face and cervical posture have predominantly focused on vertical dimensions of the face. The aim of this study was to investigate whether there are significant differences in cervical posture in subjects with a different sagittal morphology of the face, i.e., a different skeletal class. One hundred twenty (120) children (60 males and 60 females, average age 9.5 yrs., SD±0.5) were admitted for orthodontic treatment. Selection criteria was: European ethnic origin, date of birth, considerable skeletal growth potential remaining and an absence of temporomandibular joint dysfunction (TMD). Lateral skull radiographs were taken in mirror position. Subjects were divided into three groups based on their skeletal class. The cephalometric tracings included postural variables. The most interesting findings were: 1. children in skeletal class III showed a significantly lower cervical lordosis angle ($p<0.001$) than the children in skeletal class I and skeletal class II; 2. children in skeletal class II showed a significantly higher extension of the head upon the spinal column compared to children in skeletal class I and skeletal class III ($p<0.001$ and $p<0.01$, respectively). This is probably because the lower part of their spinal column was straighter than those of subjects in skeletal class I and II ($p<0.01$ and $p<0.001$, respectively). Significant differences among the three groups were also observed in the inclination of maxillary and mandibular bases to the spinal column. The posture of the neck seems to be strongly associated with the sagittal as well as the vertical structure of the face.

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Cervical posture is related to differing factors of the body (ethnic origin,[1-3] gender,[1,4-20] age,[17] and stature[21]), craniofacial morphology[12,21-25] (mostly mandibular divergence,[17] mandibular size,[22] and facial shape,[23,24]) functional factors (nasorespiratory function,[1,14,21,23,26-28] temporomandibular dysfunction[29]) and orthodontic therapy (use of removable orthodontic appliances or splints to increase vertical dimension[30]), or the use of anterior repositioning devices for skeletal class II children.[31]

It is not unreasonable to expect that spinal posture might be correlated with skeletal class. Studies on the relationship between spinal posture and the morphological aspects of the face have usually focused on the relationship between the spinal posture and vertical dimensions of the face and, consequently, the divergence and inclination of the mandibular and maxillary bases, not on the skeletal class of the subject. The findings of these previous investigations were clearly in agreement.

In fact, Gresham and Smithells[25] found a longer face and an increased prevalence of angle class II malocclusion in a group of individuals with "poor neck posture."

Subsequently, Bench[23] observed that patients with dolicocephalic faces often had a tendency for the spinal column to be straight and long, whereas brachycephalic subjects appeared to have a curved spinal column.

In other studies, a large craniocervical angulation was seen in connection with a vertical facial development, i.e., large anterior and posterior facial dimensions and small anteroposterior dimensions (dolicocephalic face) and a large inclination of the mandibular and palatal planes.[12,13] Descriptive studies underlined that a more forward head posture of the cervical spine was related to a reverse curvature, a more upright posture (i.e., extension of the head) and a lordotic curvature of the spine.[32]

Hellsing[16,17] confirmed in children ages eight, 11, and 15 years that the total facial height was negatively correlated to the angle of cervical lordosis and that the inclination of the upper segment of the spinal column (C2-C4) was negatively correlated to lower anterior facial height. In that same study, the inclination of the middle segment of the spinal column (C2-C4) was found to be correlated to maxillary and mandibular prognathism. The r^2 value for groups of regressors in relation to the variable expressing cervical lordosis angle showed that the inclination of the mandibular base, gender, and age of the subjects were all of notable importance.

In earlier studies done by the authors of the current study, significant correlations between cervical lordosis angle and mandibular length[24] were found, both in subjects with and without temporomandibular joint disorders (TMD).[29] Those studies also confirmed a relationship between mandibular inclination and cervical lordosis angle in subjects with and without TMD,[29] but they were always concerned with subjects in skeletal class II.

These studies indicated a relationship between maxillary and mandibular morphology and cervical posture; however, no studies were performed to compare the cervical posture of subjects to their skeletal jaw class.

The aim of the current study was to compare subjects in the three skeletal classes and to investigate whether there are significant differences in their cervical posture. The importance of investigating this point involves two different aspects. From a research point of view, it could clarify the relationships between cervical posture and the morphological aspects of the face, not only on the sagittal plane, but also on the vertical. The current study contributes to the knowledge of the complex system of interrelationships between cervical posture and facial morphology. It is also important since clinicians tend to classify their patients based on their skeletal class, rather than on vertical dimensions of the face. In this study, most of the therapeutic standard procedures are based and classified upon the sagittal interrelationships between mandibular and maxillary bases. If significant differences were found among the three groups in this study, a clinician might better understand the relationship between the postural and morphological variables of their patients.

Material and Methods

The sample used in this study included 120 children (60 males and 60 females, average age 9.5 yrs., SD ±0.5) consecutively admitted to the Department of Orthodontics and Gnathology, University of Chieti, for orthodontic treatment. The criteria for selection were: European ethnic origin, date of birth, and considerable skeletal growth potential remaining as evaluated by height and weight. None of the children had yet received any orthodontic treatment. The children were examined for current problems associated with nasal obstructions, active symptoms of head, neck, or facial pain and none were found to be affected. Subjects were screened for normal, pain free, cervical range of motion. All the subjects were asymptomatic for TMJ or cervical spine disorders. To evaluate the relationship between the skeletal class and cervical posture, the subjects were divided into three groups: skeletal class I (group I, 20 males and 20 females); skeletal class II (group II, 20 males and 20 females; and skeletal class III (group III, 20 males and 20 females). The study was approved by the Ethics Committee of the University of Dentistry, Chieti. Informed consent was obtained from all subjects' parents.

Teleradiographs were made before beginning the study. Lateral skull radiographs were taken using Orthoceph 10E (Siemens AG, Germany). The machine's vertical adjustability allows for the recording of standing subjects. The x-ray source had a focus of 0.6 mm, exposure data were 80-86 kV and 32 mA. The equipment had a fixed film to focus plane distance of 190 cm and a fixed film to midsagittal plane distance of ten cm with a final enlargement of 10%. For all subjects, 18x24 cm films were used. A wire was mounted in front of the cassette to indicate true vertical on the film, since postural variables include many angles between craniofacial lines and true vertical. A 20x100 cm mirror was placed on the wall, 150 cm in front of ear rods, to allow recording of natural head posture and mirror position.[11,12] The recordings were taken between the hours of 8:00 am and 2:00 pm.

Sixteen reference points, reported in **Table 1** and **Figure 1**, were marked directly on each film with a soft sharp pencil: twelve points were in the craniofacial area and four points in the cervical column area. In order to determine these points, the whole neck area was drawn (**Figure 1**). Eleven lines, described in **Table 2**, were considered. The 20 variables studied are listed in **Table 3** and

Table 1
Reference Points on the Cephalograms (with Selected References)

Cephalometric reference points	Description	Characterization of reference points	Selected reference no.
Cranium			
S	Sella turcica	The midpoint of sella turcica, determined by observation	34
N	Nasion	The intersection of the internasal suture with the nasofrontal suture in the midsagittal plane	34
Po	Ponion	The midpoint on the upper edge of the porus acusticus externus (Björk)	34
Or	Orbitale	The lowest point on the lower margin of the bony orbit, midpoint between right and left images	34, 39
Mandibular base			
B	Supramentale	The most posterior point in the concavity between infradentale and pogonion (Downs)	34, 39
Gn	Gnathion	The most inferior point in the contour of the chin	34, 39
Go	Gonion	The point on which the jaw angle is the most inferiorly, posteriorly, and outwardly directed	34, 39
Ar	Articulare	The point of intersection of the dorsal contours of process articularis mandibulare and of temporale (Björk)	34
Gtp	Posterior tangent point at the angle of the mandible	The point of contact of the tangent to the angle of the mandible that passes through articulare	34
Maxillary base			
A	Subspinale	The deepest midline point on the premaxilla between the anterior nasal spine and prosthion (Downs)	34, 39
Ans	Anterior nasal spine	Tip of the anterior nasal spine seen on the x-ray from normal lateralis	34, 39
Pns	Posterior nasal spine	Tip of the posterior spine of the palatine bone in the hard palate	34, 39
Cervical Region			
Cv2tg		Tangent point of OPT line on the odontoid process of the second cervical vertebrae	12, 17
Cv2ip		The most inferior point on the corpus of the second cervical vertebrae	12, 17
Cv4ip		The most inferior posterior point on the corpus of the fourth cervical vertebrae	12, 17
Cv6ip		The most infero-posterior point on the body of the sixth cervical vertebrae	12, 17

shown in **Figure 2**. The skeletal class was assessed according to Downs.[33] The 16 postural variables were traced according to Solow and Tallgren[11,34]; the cervical lordosis angle (CVT/EVT) was traced according to Hellsing, et al.[16,17] Selected references are given in **Tables 1**, **2**, and **3**.

To evaluate error due to landmark identification, duplicate measurements were made for ten radiographs in the manner described by Hellsing, et al.[17] and shown in **Figure 2**, **Tables 2** and **3**. Variables were compared for each registration and the error variance calculated by using Dahlberg's formula.[35]

$$\delta = \sqrt{(\Sigma d^2/2N)}$$

where "d" is the difference between the first and the second measurement and "N" is the number of double registrations. Results are given in **Table 4**.

Data were statistically analyzed by using SPSS 9.0 for Windows (Statistical Software, Chicago, IL) procedure for nonparametric test and expressed as mean, median, 25th and 75th percentiles, range, minimum, and maximum. Differences between groups were analyzed by using nonparametric methods (Kruskal Wallis test) for

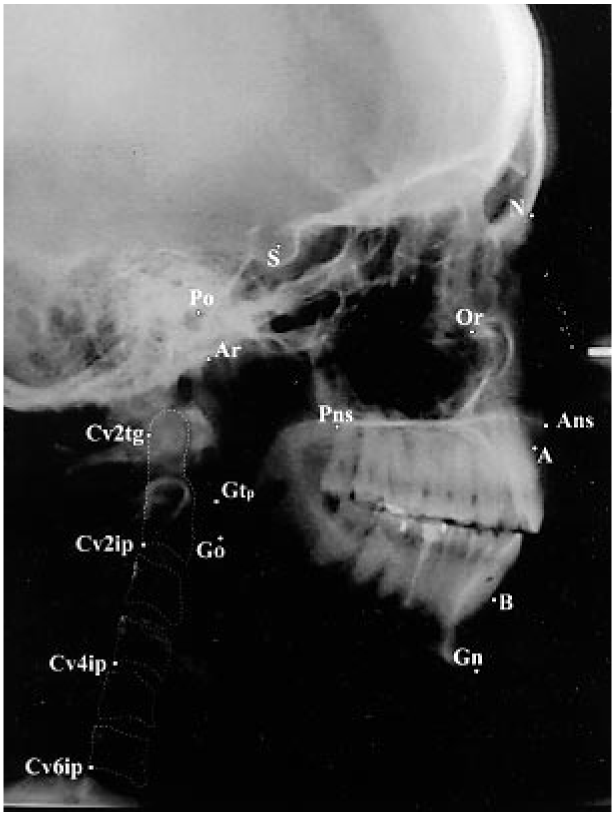

Figure 1
Reference points used in the study.

three independent groups. The 2-tailed Dunnett T3 test was used to individuate between groups. Levels of p<0.05 were considered statistically significant.

Results

When error in landmark localization was evaluated, the difference in the means revealed that the error was less than five percent of the biological variance of the whole sample (**Table 4**).

Cervical lordosis angle (CVT/EVT angle): Children in skeletal class III showed a significantly lower CVT/EVT angle than children in skeletal classes I and II (<0.001) (**Table 5**). The difference between the mean CVT/EVT angles was about five degrees. The range of values did not include negative values in any of the children in skeletal class I or II, while negative values were observed in some of the children in skeletal class III (**Table 5**). As 25th p.le in Group III was 0.00 (**Table 5**), it is concluded that 25% of subjects in skeletal class III showed a reversed cervical lordosis curvature.

Cervical posture (OPT/Ver, CVT/Ver, EVT/Ver angles): No significant differences were observed among the three groups in the values of the inclination of upper (OPT) and middle (CVT) segments of the spinal column, while significant differences were observed in the inclination of the lower segment (EVT) of the spinal column.

Subjects in skeletal class III showed a significantly straighter spinal column in the area between the fourth and sixth vertebra, since the EVT/Ver angle was smaller (as absolute value) than in subjects in skeletal class I and II (p<0.01 and p<0.001, respectively), (**Table 5**). This seems to be related to a previous finding in the CVT/EVT angle suggesting that subjects in skeletal class III showed a straighter spinal column in the lower segment (C4-C6) and a smaller CVT/EVT angle than subjects in skeletal classes I and II.

Cranial posture (SN/Ver, pns-ans/Ver, GoGn/Ver, RL/Ver angles): No significant differences in cranial posture were observed among the three groups in cranial posture (**Table 5**).

Craniocervical posture (SN/OPT, SN/CVT, pns-ans/OPT, pns-ans/CVT, GoGn/OPT, GoGn/CVT, Rasc/OPT, Rasc/CVT angles): Cranio-cervical angulation is the extension of the head upon the spinal column. In the current study, no significant differences were observed among the three groups in the angle between the horizontal lines of the head (respectively, from the forehead to the chin: SN, pns-ans, and GoGn) and the upper section of the spinal column (OPT, the line between the first and second vertebra) (**Table 5**). The angle created between the head the midsection of the spinal column (CVT) showed significant differences among the three groups. Subjects in skeletal class II showed a significantly more extended head upon the spinal column (SN/CVT) than subjects in skeletal classes I and III (respectively, p<0.001 and p<0.01.

Also, a significant difference among the three groups was observed in the angle between the maxillary base and the midsection of the spinal column (pns-ans/CVT) (**Table 5**). A further finding regarding the mandible is that significant differences were observed in the angle between the mandibular line and the midsection of the spinal column (GoGn/CVT), as subjects in skeletal class II showed a significantly lower angulation than subjects in skeletal class III (p<0.05). Additionally, subjects in skeletal class III showed a significantly lower angle between the ramus and the midsection of the spinal column (RL/CVT) than subjects in skeletal class I (p<0.01) and skeletal class II (p<0.05).

Discussion

Previous studies by the authors included all female subjects[24,29] because cervical spine inclination has been

Table 2
Reference Lines on the Cephalograms (With Selected References)

Cephalometric reference lines	Description	Characterization of reference lines	Selected reference no.
Cranium			
Ver	True vertical line	Vertical line projected on the film, perpendicular to the Frankfurt plane	12, 17
SN	Cranial base	Line extending between sella and nasion	34, 35
FH	Frankfurt horizontal plane	Horizontal plane running through ponion and orbitale	34, 35
NA		Line extending between nasion and point A	34, 35
NB		Line extending between nasion and point B	35
Mandibular base			
GoGn	Mandibular plane	Line extending between gonion and gnathion	34, 35
RL	Ramus line	Line extending between Ar and Gtp	17, 34, 35
Maxillary base			
pns-ans	Palatal plane	Line extending between Ans and Pns	34
Cervical region			
CVT	Cervical vetebra tangent	Posterior tangent to the odontoid process through Cv4ip (Solow)	12, 17
EVT		Line through Cv4ip and Cv6ip. Lower part of the cervical spine (Hellsing)	17
OPT	Odontoid process tangent	Posterior tangent to the odontoid process through Cv2ip (Solow)	12, 17

linked to gender, since men usually exhibit a straightened curve and women usually exhibit a partly reversed curvature.[4-20,36]

Some studies on cervical posture divided the sample based on age.[17] In the current study, no separate evaluation was made based on age or gender because of the small number of subjects. The authors had two reasons for not dividing the sample into age and gender. First, the standard deviation for age was very small (±0.5), meaning that all the subjects could be considered the same age. Second, each group included 50% males and 50% females, therefore, the mean value of each cephalometric variable could be considered the mean value of males and females in each group. The authors thought that the significant differences among the three groups observed in this study could be considered differences totally associated with the different skeletal classes and not with age and gender.

One of the most important findings of this study was that the cervical spine was significantly straighter in subjects in skeletal class III than in subjects in skeletal classes I and II, since the CVT/EVT angle results were significantly smaller ($p<0.001$) in group III.

Interestingly, this finding seems to be associated with the finding that the lower part of the spinal column was significantly straighter in subjects in skeletal class III than in subjects in skeletal class I ($p<0.01$) and skeletal class II ($p<0.001$). These two findings suggest that the smaller CVT/EVT angle observed in subjects in skeletal class III is probably associated with the significant straightening of the lower part of the spinal column (EVT/Ver) in subjects in skeletal class III and not to any difference in the inclination of the upper (OPT) or the middle (CVT) part of the cervical spine. No significant differences among the three groups were observed in the inclination of the middle segment (CVT/Ver), or in the upper segment (OPT/Ver) of the spinal column. Previous researchers[37] observed that, whereas the morphological development of the upper and the middle segments of the spine (represented in our cephalometric tracing by the OPT line and the CVT line, respectively) is closely linked to facial development, the lower segment of the spinal column (represented in our cephalometric tracing by the EVT line) is morphologically considered the final upper part of the column. Our findings agree with this observation, since the OPT and the CVT lines showed no difference in their inclination and consequently, were similar in pattern. The EVT line showed significantly different inclination in all three groups. This finding could be con-

Table 3
List of Variables (With Selected References)

Cephalometric variables	Description	Characterization of reference lines	Selected reference no.
Maxillary base			
SNA (degree)	Prognathism of the maxillary apical base to cranial base	Sella-nasion-point A angle	34, 39
Mandibular base			
SNB (degree)	Prognathism of the mandibular apical base to cranial base	Sella-nasion-point B angle	34, 39
Skeletal class			
ANB (degree)	Antero-posterior apical base relationship (skeletal pattern)	Point A-nasion-point B angle	34, 39
Cervical posture			
CVT/EVT (degree) cervical inclination	Cervical lordosis angle	Downward opening angle between CVT line and EVT line	12
OPT/Ver (degree)	Odontoid angle	Downward opening angle between OPT line and Ver line*	12, 17
CVT/Ver (degree)	Upper cervical column posture	Downward opening angle between CVT line and Ver line*	12, 17
EVT/Ver (degree)	Lower cervical column posture	Downward opening angle between EVT line and Ver line*	17
Craniofacial posture			
SN/Ver (degree)	Anterior cranial base inclination	Downward opening angle between SN line and Ver line*	12, 17
pns-ans/Ver (degree)	Palatal line inclination	Downward opening angle between pns-ans line and Ver line*	12, 17
ML/Ver (degree)	Mandibular line inclination	Downward opening angle between GoGn line and Ver line*	12, 17
RL/Ver (degree)	Ramus line inclination	Downward opening angle between GoGn line and Ver line*	17
Craniocervical angulation			
SN/OPT (degree)	Craniocervical posture	Downward opening angle between SN line and OPT line	12, 17
SN/CVT (degree)		Downward opening angle between SN line and CVT line*	12
pns-ans/OPT (degree)	Maxillary base inclination upon cervical column	Downward opening angle between pns-ans line and OPT line*	12, 17
pns-ans/CVT (degree)		Downward opening angle between pns-ans line and CVT line*	12, 17
ML/OPT (degree)	Mandibular base inclination upon cervical column	Downward opening angle between GoGn line and OPT line*	12, 17
ML/CVT (degree)		Downward opening angle between GoGn line and CVT line*	12, 17
RL/OPT (degree)	Mandibular ramus inclination upon cervical column	Downward opening angle between RL line and OPT line*	12, 17
RL/CVT (degree)		Downward opening angle between RL line and CVT line*	12, 17

*The standard used for angles related to true vertical line was that downward opening angles formed behind the the vertical were considered negative, whereas angles formed in front were considered positive.

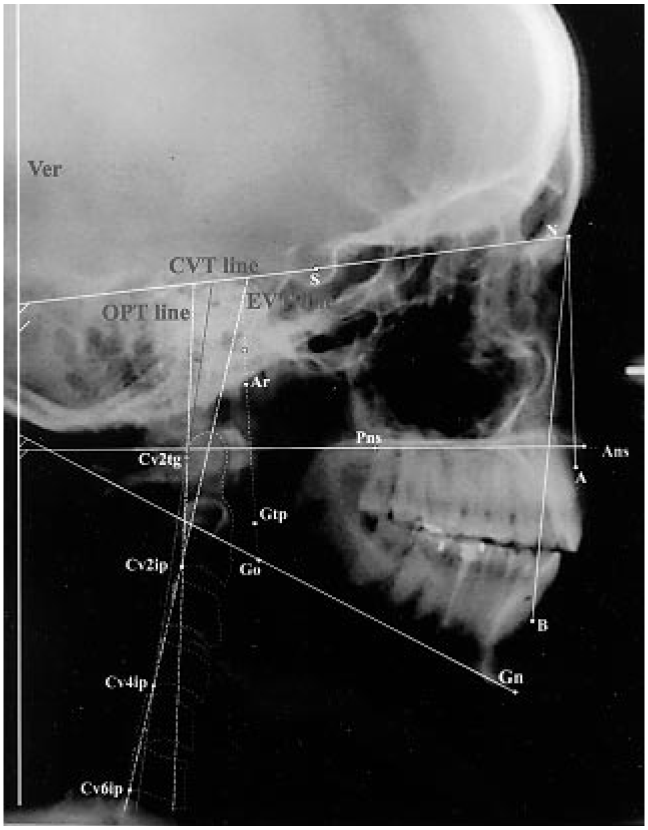

Figure 2
Cephalometric tracings and variables studied.

sidered as an effect of the difference in development of the upper and the middle sections compared to the lower section of the spinal column and seems to be in agreement with earlier research.[37] However, in the current study the different morphological aspects of the face (i.e., different skeletal classes) resulted in an association with different inclinations of the lower section of the spinal column and not to any changes in the upper section of the spinal column. This is, in part, a disagreement with previously cited research[37] and points out the complexity of the developmental behavior of the face and the spinal column.

In previous studies,[24,29] the authors found a significantly negative correlation between the CVT/EVT angle and mandible length in adult Caucasian females, skeletal class II, and TMD. Huggare and Raustia[19] found an increased cranio-cervical angulation and no statistically significant increase in cervical lordosis in patients with craniomandibular dysfunction. Later, those authors found a significantly smaller average CVT/EVT angle in subjects with TMD when compared to a control group.[29]

Another study by the same authors[31] found a mild to moderate increase in the CVT/EVT angle in children, although usually associated with increasing age, from eight years to ten years of age. This could have been partly due to functional therapy with FR-2 in skeletal class II female children. In the same studies, the results of the multiple linear regression demonstrated that a decrease in maxillary base length and improvement of mandibular protrusion (distance between Pog and McNamara line)

Table 4
Intra-Observer Method Error Variance in Ten Duplicate Radiographic Measurements Using the Formula $\delta^2 = (\Sigma d^2/2N)$, Where N is the Number of Double Determinations and d the Difference Between the Two Measurements, (S^2) the Variance for the Whole Sample of Children (pretreatment), (δ) and (δ^2) an Estimate of the Method Error and Its Variance

Variable	δ	δ^2	S^2 (N=40)	δ^2 as % of S^2
CVT/Ver (degree)	0.63	0.40	12.86	3.11
EVT/Ver (degree)	0.95	0.90	32.11	2.80
SN/Ver (degree)	1.69	2.85	139.14	2.05
pns-ans/Ver (degree)	1.48	2.20	102.73	2.14
Go-Gn/Ver (degree)	1.55	2.40	73.53	3.26
RL/Ver (degree)	0.50	0.25	10.94	2.29
SN/OPT (degree)	0.50	0.25	22.27	1.12
SN/CVT (degree)	0.50	0.25	21.07	1.19
pns-ans/OPT (degree)	0.50	0.25	17.74	1.41
pns-ans/CVT (degree)	0.67	0.45	18.50	2.43
Go-Gn/OPT (degree)	0.50	0.25	14.88	1.68
Go-Gn/CVT (degree)	0.50	0.25	14.18	1.76
RL/OPT (degree)	0.55	0.30	21.15	1.42
RL/CVT (degree)	0.55	0.30	20.47	1.47

Table 5

Postural variables (25th p.le, Median, 75th p.le and Range) in the three groups. Between group differences were tested by using Kruskal Wallis test for three independent groups

	Group I (Subjects in skeletal class I) N = 40					Group II (Subjects in skeletal class II) N = 40					Group III (Subjects in skeletal class III) N = 40				
	25th p.le	Median	75th p.le	Range	Group I versus Group II	25th p.le	Median	75th p.le	Range	Group II versus Group III	25th p.le	Median	75th p.le	Range	Group I versus Group III
CVT/EVT	5.25	9	14.75	1.5/20	NS	5.5	9	14.7	1/21.5	***	0	3.5	10	-4/15	***
OPT/Ver	-0.75	2	3	-8/8	NS	0.2	2.5	4.0	-5/7	NS	-0.75	2	4	-8/9	NS
CVT/Ver	2	3	5	-4/8.5	NS	1	2.5	4.9	-8/11	NS	1	3	5	-6/12	NS
EVT/Ver	-9.75	-6	-3.1	-18/3	NS	-11.5	-8.5	-3.1	-18/3	***	-5	-1	2.75	-18/9	**
SN/Ver	80	96	100.7	70/110	NS	79.2	87	101	73/110	NS	85.2	99	106	70/112	NS
pns-ans/Ver	72	83.5	90	60/99	NS	71.5	84	90	62/99	NS	74.2	85.5	93	82/98	NS
GoGn/Ver	57	64	69	44/82	NS	58	63.5	67	45/90	NS	59	64	69	45/76	NS
RL/Ver	2.2	5	6	-3/9	NS	2	4	6	-5/8	NS	2.2	5	7	-5/10	NS
SN/OPT	78.2	83	85.7	70/95	NS	78.2	82	88	73/93	NS	81.2	84	87.5	73/94	NS
SN/CVT	78.2	81	84	68/93	***	85	86	91	78/98	**	80	83	87	74/96	NS
pns-ans/OPT	71.2	76.6	78	66/88	NS	72	75	78	68/84	NS	73	77	80.7	68/88	NS
Pns-ans/CVT	68.2	72	75	69/84	***	70	74	77	66/85	*	72	75	79.7	67/84	**
GoGn/OPT	52.2	55.5	57.7	44/65	NS	54	55.5	57.7	48/85	NS	55	58	60.7	48/66	NS
GoGn/CVT	64	66.5	80	49/88	NS	56.2	58	61	52/68	*	53	57	59.7	48/65	NS
RL/OPT	6.2	11	13	1/15	NS	6	9	10.7	-2/16	NS	5.5	10	12	-2/17	NS
RL/CVT	7.2	12	14.7	1/17	NS	8	11	13	1/18	**	4	5.5	11	3/17	*

* = p < 0.05; ** = p < 0.01; *** = p < 0.001; NS = non significant

were two major factors that correspond (R^2=0.272, p<0.05) to an increase in the CVT/EVT angle.

Together with our findings and those of other studies,[24,31] it is suggested that cervical lordosis decreases in subjects with long mandibles (mostly subjects in skeletal class III).[24,29] However, it seems to increase if the mandibular base is repositioned in a more anterior position by using, for example, a repositioning device like a FR-2.[31] Based on these observations, the most important conclusion is that it is possible that the size and position of the mandible are two factors that are strongly related to cervical posture. However, conclusions about the mechanism of influence or "which causes which" are not possible because of the cross-sectional structure of the investigations. We can only hypothesize about the relationship between mandibular length and/or shape and cervical lordosis and/or posture.

One hypothesis relative to the relationship between skeletal class and cervical posture concerns the displacement of the mandible influencing the degree of vertical and sagittal opening, the expansion of the pharyngeal airway space, the improvement in respiratory function and, consequently, the extension of the head upon the spinal column with an increase of the CVT/EVT angle.[11,17,34] Based on this hypothesis, recent descriptive studies underline the fact that a more forward head posture to form a lordotic curvature of the cervical spine is related to a partially reversed curvature and a more upright posture.[37] In the current study, a significant higher extension of the head upon the middle section of the spinal column (SN/CVT) and consequently, a more upright posture of the head, was found in subjects in skeletal class II compared with subjects in skeletal class I (p<0.001) and in skeletal class III (p<0.01) (**Table 5**). However, subjects in skeletal class III exhibited a significantly smaller CVT/EVT angle than subjects in skeletal class I and skeletal class II (p<0.001).

The current study also revealed that a more lordotic curve of the spine is related to a greater extension of the head on the spinal column and, additionally, to a skeletal class II. A more straightened curve of the cervical spine seems to be related to a more forward head posture and to subjects in skeletal class III.

Regarding the physiopathological mechanism associated with significant differences in cervical posture in the three groups, a muscular-neural network could play an important role. Several researchers[38-39] have underscored that the existence of muscular-neural connections between oral functions and the neck area could be responsible for some of the common symptoms of disorders of the masticatory system and/or of the cervical spine.

Miralles, et al.[39] showed, in a group of 15 healthy subjects, a significant increase in basal tonic EMG activity of the neck muscles when varying the vertical dimension every few millimeters from vertical dimension of occlusion to 45 mm of jaw opening. His work confirmed that reflex connections exist between the morphological structure of the face and the fusimotor muscle spindle system of the dorsal neck muscles. Visscher, et al.[36] also supported those findings from a clinical point of view by showing that the prevalence of cervical spine pain, assessed using oral history and dynamic/static testing with a Visual Analog Scale (VAS), was higher in a group of craniomandibular pain patients than in a group of subjects without craniomandibular pain. Perhaps this was because of neurophysiological principles of convergence and sensation.

Also in the current study, the angle between the maxillary base (pns-ans) and the middle segment of the cervical spine (CVT) was significantly different in the three groups. Maxillary base was more distally inclined to the middle section of the cervical spine (pns-ans/CVT) in skeletal class III than in subjects in skeletal class I ($p<0.01$) and in skeletal class II ($p<0.05$). This finding was expected, since it seems to be connected to the fact that the subjects were selected according to skeletal class (according to the difference in the size and shape of the maxillary and mandibular bases.

The current study found that the mandibular inclination on the middle segment of the spinal column was significantly different among the three groups. The angle created by the mandibular line and the middle part of the spinal column (Go-Gn/CVT) showed a significant difference between subjects in skeletal class II and skeletal class III ($p<0.05$) and a higher mean value difference. Subjects in skeletal class III showed a significantly lower angle between the ramus line and the middle segment of the spinal column (RL/CVT) than subjects in skeletal class I ($p<0.01$) and in skeletal class II ($p<0.05$).

The results in the study relative to maxillary and mandibular posture seem to introduce another hypothesis to explain differences in cervical posture in subjects in differing skeletal classes. Differences in maxillary and mandibular posture (the inclination of these bases on the spinal column) could be considered the cause of the differences in cervical posture. There may exist a strong relationship between mandibular and maxillary shape and size and cervical posture.

Conclusion

Within the limits set by the sample examined, the findings of this study suggest:

1. The spinal columns of the children in skeletal class III were significantly straighter than the children in skeletal classes I and II, which was associated with the children in skeletal class III evidencing straightening of the lower segment of the spine (C4 to C6);
2. The study found more head extension in the middle segment of the spinal column in children in skeletal class II than the other two classes;
3. The study also found significant differences in the inclination of the maxillary base of the middle segment of the spinal column among skeletal classes I, II, and III. Children in skeletal class III had a significantly lower inclination of the mandibular base on the middle segment of the spinal column.

References

1. Solow B, Barrett MJ, Brown T: Craniocervical morphology and posture in Australian Aboriginals. *Am J Phys Anthrop* 1982; 59:33-45.
2. Grave B, Brown T, Townsend G: Comparison of cervicovertebral dimensions in Australian Aborigines and Caucasians. *Eur J Orthod* 1999; 21:127-135.
3. Cooke MS, Wei SHY: Intersex differences in craniocervical morphology and posture in southern Chinese and British Caucasians. *Am J Phys Anthrop* 1988; 77:43-51.
4. Kylämarkula S, Huggare JÅV: Morphology of the first cervical vertebra in children with enlarged adenoids. *Eur J Orthod* 1985; 7:93-96.
5. Kylämarkula S, Huggare JÅV: Head posture and the morphology of the first cervical vertebra. *Eur J Orthod* 1985; 7:151-156.
6. Huggare JÅV: The first cervical vertebrae as an indicator of mandibular growth. *Eur J Orthod* 1989; 11:10-16.
7. Huggare JÅV: Association between morphology of the first cervical vertebra, head posture, and craniofacial structures. *Eur J Orthod* 1991; 13:435-440.
8. Huggare JÅV, Cooke MS: Head posture and cervicovertebral anatomy as mandibular growth predictors. *Eur J Orthod* 1994; 16:175-180.
9. Sandikçioglu M, Skov S, Solow B: Atlas morphology in relation to craniofacial morphology and head posture. *Eur J Orthod* 1994; 16:96-103.
10. Huggare JÅV, Houghton P: Association between atlantoaxial and craniomandibular anatomy. *Growth Dev Aging* 1996; 60:21-30.
11. Solow B, Tallgren A: Natural head position in standing subjects. *Acta Odontol Scand* 1971; 29:591-607.
12. Solow B, Tallgren A: Head posture and craniofacial morphology. *Am J Phys Anthrop* 1976; 44:417-436.
13. Marcotte MR: Head posture and dentofacial proportions. *Angle Orthod* 1981; 51:208-213.
14. Solow B, Siersbæk-Nielsen S, Greve E: Airway adequacy, head posture and craniofacial morphology. *Am J Orthod* 1984; 86:214-222.
15. Solow B, Siersbæk-Nielsen S: Growth changes in head posture related to craniofacial development. *Am J Orthod* 1986; 89:505-507.
16. Hellsing E, Reigo T, McWilliam J, Spangfort E: Cervical and lumbar lordosis and thoracic kyphosis in 8, 11, and 15-year-old children. *Eur J Orthod* 1987; 9:129-138.
17. Hellsing E, McWilliam J, Reigo T, Spangfort E: The relationship between craniofacial morphology, head posture, and spinal curvature in 8, 11, and 15-year-old children. *Eur J Orthod* 1987; 9:254-264.
18. Showfety KJ, Vig PS, Matteson S, Phllips C: Association between the postthodural orientation of sella-nasion and skeletodental morphology. *Angle Orthod* 1987; 57:99-112.
19. Huggare JÅV, Raustia A: Head posture and cervicovertebral and craniofacial morphology in patients with craniomandibular dysfunction. *J Craniomandib Pract* 1992; 10:173-177.
20. Solow B, Siersbæk-Nielsen S: Cervical and craniocervical posture as predictors of craniofacial growth. *Am J Orthod Dentofac Orthop* 1992; 101:449-458.
21. Huggare JÅV, Tellervo Laine-Alava M: Nasorespiratory function and head posture. *Am J Orthod Dentofac Orthop* 1997; 112:507-511.
22. Özbek MM, Köklü A: Natural cervical inclination and craniofacial structure. *Am J Orthod Dentofac Orthop* 1993; 104:584-591.
23. Bench RW: Growth of the cervical vertebrae as related to tongue, face, and denture behavior. *Am J Orthod* 1963; 49:183-214.
24. Festa F, et al.: Relation between cervical lordosis and facial morphology in Caucasian women with skeletal class II malocclusion: a cross-sectional

study. *J Craniomandib Pract* 2003; 21:121-129.
25. Gresham H, Smithells PA: Cervical and mandibular posture. *Dental Record* 1954; 74:261-264.
26. Linder-Aronson S: Adenoids: their effect on mode of breathing and nasal airflow and their relationship to characteristics of the facial skeleton and the dentition. *Acta Otolaryngol* (Stockholm) 1970; Suppl 265.
27. Linder-Aronson S: Effects of adenoidectomy on dentition and nasopharynx. *Am J Orthod* 1974; 65:1-15.
28. Carlsöö S, Leijon G: A radiographic study of the position of the hyo-laryngeal complex in relation to the skull and the cervical column in man. Stockholm and Umeå: *Transactions of the Royal Schools of Dentistry* 1960; 5:13-34.
29. D'Attilio M, Tecco S, Dolci M, Ciuffolo F, Epifania E, Filippi MR: Cervical lordosis angle measured on lateral cephalograms: findings in skeletal class II female subjects with and without TMD. A cross-sectional study. *J Craniomandib Pract* 2004; 22:27-44.
30. Miralles R, et al.: Increase of the vertical occlusal dimension by means of a removable orthodontic appliance and its effect on craniocervical relationships and position of the cervical spine in children. *J Craniomandib Pract* 1997; 15:221-228.
31. Tecco S, et al.: Evaluation of cervical spine posture after functional therapy with FR-2: a longitudinal study. *J Craniomandib Pract* 2005; 23:53-66.
32. Jacobson A: The "Wits" appraisal of jaw disharmony. *Am J Orthod* 1976; 70:179-189.
33. Downs W: Variation in facial relationships. Their significance in treatment and prognosis. *Am J Orthod* 1948; 10:812-840.
34. Solow B: The pattern of craniofacial associations. A morphological and methodological correlation and factor analysis study on young male adults. *Acta Odontol Scand* 1966; 24 (Suppl 46).
35. Dahlberg G: *Statistical methods for medical and biological students*. London: George Allen and Unwin, Ltd., 1940.
36. Visscher CM, de Boer W, Naeije M: The relationship between posture and curvature of the cervical spine. *J Manipulative Physiol Ther* 1998; 21:388-391.
37. Graber TM: Implementation of the roentgenographic cephalometric technique. *Am J Orthod* 1958; Dec:906-932.
38. Hellstro F, Thunberg J, Bergenheim M, Sjo-lander P, Djupsjo-backa M, Johansson J: Increased intra-articular concentration of bradykinin in the temporomandibular joint changes the sensitivity of muscle spindles in dorsal neck muscles in the cat. *Neurosci Res* 2002; 42:91-99.
39. Miralles R, et al.: Vertical dimension. Part 2: the changes in electrical activity of the cervical muscles upon varying the vertical dimension. *J Craniomandib Pract* 2002; 20:39-47.

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