Changes in Cervical Lordosis and Cervicovertebral Morphology in Different Ages with the Possibility of Estimating Skeletal Maturity

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SUMMARY

Introduction During growth, proportions of craniofacial and cervical structures are changed. Craniofacial and cervicovertebral structures are morphologically and functionally connected, but their each other's influence is still unknown.

Objective The aim of this study was to determine the changes in cervical lordosis and cervicovertebral morphology in different age periods and the possibility of estimating skeletal maturity, based on the percentage of anterior cervical vertebrae body height sum in the total anterior C2–C5 height.

Methods The study included lateral radiographs of 120 patients of both sexes, divided into three different age groups: eight, 12–13 and 17–18 years of age. Five craniofacial and 15 cervical parameters were measured and analyzed.

Results The results showed significant correlation between cervical lordosis angle and age, gender, anterior and posterior body height of C3, C4, C5, anterior C4–C5 and posterior C2–C3, C3–C4, C4–C5 intervertebral space, anterior body height of C2–C5. Overall values of all cervical body heights were more present in the total height of the spine in females, while all intervertebral spaces were more present in males. The percentage of anterior and posterior C2, C3, C4, C5 body height sum compared to total C2–C5 height increases with age.

Conclusion The cervical lordosis becomes more curved and vertebral bodies occupy more space in females, while intervertebral spaces occupy more in males. Skeletal maturity could be estimated following vertebral percentage distribution in the total anterior C2–C5 part.

Keywords: spinal curvatures; lordosis; growth; maturity

INTRODUCTION

During prenatal and postnatal period proportions of cervical structures change [1, 2]. Cervicovertebral morphology is influenced by factors such as age [3], gender [3-7], ethnic origin [5, 8] and craniofacial morphology [6, 7, 9].

The change in cervicovertebral morphology is a process lasting from birth to full maturity, passing through all stages of skeletal development [1]. Every stage can be seen on lateral cephalogram which was used to assess skeletal maturity using the cervical vertebral maturation (CVM) method [10, 11, 12]. However, validity, reliability and reproducibility of the CVM method were analyzed in several studies. It was suggested that this method was subjective and that it should be used with some other parameters that estimate skeletal maturity [13-18].

Cervical curve begins to form during fetal development, but it does not assume its natural form until after birth. It changes when it begins to bear the weight of the head. Also, lordotic curve results partly from difference in the anterior and posterior intervertebral space heights [19].

OBJECTIVE

Our aim was to determine the changes in cervical lordosis in different age groups, to compare the differences in cervicovertebral morphology between genders, and to determine the possibility of estimating skeletal maturity based on the percentage of anterior cervical vertebrae C2–C5 body height sum in comparison to the total anterior height of that part of the cervical spine.

METHODS

The study included lateral cephalograms of 120 (71 female, 49 male) patients treated at the Clinic of Orthodontics, School of Dental Medicine, University of Belgrade. The Ethical Committee of the School of Dental Medicine, University of Belgrade, approved this research (No. 36/14 – 2013).

The inclusion criteria were white subjects of Serbian population of both sexes with the visibility of the C1–C5 cervical vertebrae. Total sample was divided into three different age groups: I (eight-year-olds – pre-puberty), II (12- and 13-year-olds – accelerated period of growth) and III (17- and 18-year-olds – final phase of growth); each group consisted of 40 subjects. None of the subjects had a history of previous orthodontic treatment, craniofacial and cervical vertebra anomalies, trauma, or systemic muscle or temporomandibular joint disorders.

Lateral cephalograms were made using a standardized technique on a ProMax® device

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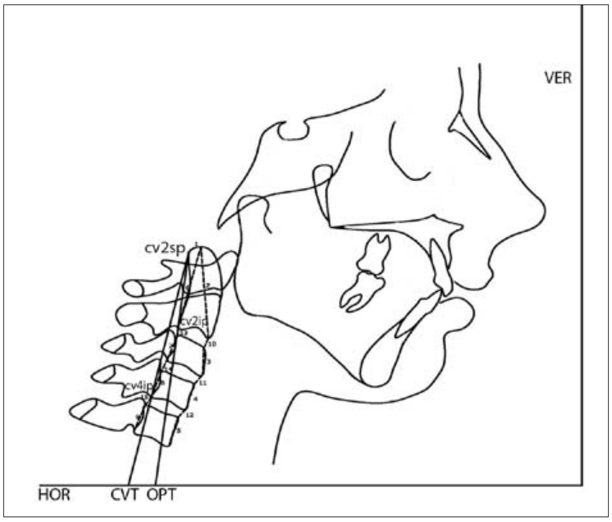

Figure 1. Cephalometric points, angular and linear measurements used for lateral cephalogram analysis

Ver – true vertical line projected on the film; Hor – true horizontal line drawn by constructing a line perpendicular to the true vertical line; cv2sp – postero-superior points of C2 vertebral bodies; cv2ip – postero-inferior points of C2 vertebral bodies; OPT – tangent of odontogenic processus through cv2sp and cv2ip; CVT – tangent through cv2sp and cv4ip

(enlargement factor 10%), Planmeca, Helsinki, Finland. The patients were in standing position, with the head in the natural head position, and with the teeth in occlusion [20]. All radiographs were traced manually, using acetate paper, and all measurements were taken by single observer (E.L.). On each radiograph cervical parameters (Figure 1, Table 1) were measured and used to assess cervicovertebral morphology in different age groups and genders.

Statistical analysis

All statistical analyses were performed in IBM SPSS Statistics for Windows Software (Version 20.0, Armonk, NY, USA). The results were presented as frequency, percent and mean ± SD. The analysis of variance and Kruskal–Wallis test were used to compare three groups while t-test and Mann–Whitney U-test were used to compare two groups of patients. Bonferroni correction was used for multiple comparisons. Pearson correlation was performed to assess associations of OPT/CVT angle and other variables. All p-values less than 0.05 were considered significant.

RESULTS

Total sample consisted of 71 female and 49 male patients divided into three different age groups. This age distribution was made in order to see the cervicovertebral morphology in different age periods.

The results showed the trend of OPT/CVT angle increase from group I to group III and statistically higher value in female patients. A comparison between age groups showed statistically significant increase in older groups compared to younger ones (Table 2).

The parameters with statistically significant correlation with OPT/CVT angle are presented in Table 3. Correlation coefficients are presented in an interval from the smallest to the largest and showed weak to moderate correlation.

Tables 4 and 5 show values and comparisons between age group I compared to age group II, and age group II com-

Table 1. Description of cervical parameters

(1) OPT/CVT (°)	Angle of cervical curvature – lordosis; down open angle between OPT: tangent of odontogenic processus through cv2sp and cv2ip and CVT: tangent through cv2sp and cv4ip
(2–5) ABH C2–C5 (mm)	Anterior height of the cervical vertebra bodies – the distance between antero-superior and antero-inferior points of C2–C5 vertebral bodies
(6–9) PBH C2–C5 (mm)	Posterior height of the cervical vertebra bodies – the distance between postero-superior and postero-inferior points of C2–C5 vertebral bodies
(10–12) AIS C2–C5 (mm)	Anterior intervertebral space of the cervical vertebrae – the anterior distance between C2–C5 bodies
(13–15) PIS C2–C5 (mm)	Posterior intervertebral space of the cervical vertebrae – the posterior distance between C2–C5 bodies
%ABHC/AH C2–C5	Percentage of anterior body heights of C2, C3, C4 and C5 in total anterior height of the C2–C5 part
%PBHC/PH C2–C5	Percentage of posterior body heights of C2, C3, C4 and C5 in total posterior height of the C2–C5 part
%AIS C2–C3/AH C2–C5	Percentage of anterior intervertebral space height C2–C3, C3–C4, C4–C5 in total anterior height of the C2–C5 part
%PIS C2–C3/PH C2–C5	Percentage of posterior intervertebral space height C2–C3, C3–C4, C4–C5 in total posterior height of the C2–C5 part
%∑ABH C/AH C2–C5	Percentage of anterior C2, C3, C4, C5 body heights sum in total anterior height of the C2–C5 part
%∑PBH C/PH C2–C5	Percentage of posterior C2, C3, C4, C5 body heights sum in total posterior height of the C2–C5 part
%∑AIS/AH C2–C5	Percentage of anterior intervertebral space height sum in total anterior height of the C2–C5 part
%∑PIS/PH C2–C5	Percentage of posterior intervertebral space height sum in total posterior height of the C2–C5 part

Table 2. Changes of cervical lordosis angle according to age and gender

Variable OPT/CVT (°)	Age groups[a]						
	Overall	I	I vs II	II	II vs III	III	I vs III
Total (n=120)	4.03±3.07	2.51±3.14	*	4.63±2.06		4.95±3.33	**
Male (n=49)[b]	3.02±3.31	1.40±3.52		3.83±2.36		3.63±3.65	
Female (n=71)[b]	4.73±2.70*	3.18±2.74	*	5.27±1.55*		5.83±2.84*	**

[a] ANOVA; [b] Student's t-test;
* p<0.05; ** p<0.01
For a description of the variables, refer to Table 1.
n – number of patients

Table 3. Correlation of cervical lordosis angle (OPT/CVT) with different parameters

Variable	R
Gender	0.274**
Age	0.326**
ABH C3, C4, C5	0.269**–0.278**
PBH C3, C4, C5	0.246**–0.255**
AIS C4–C5	-0.189*
PIS C2–C3, C3–C4, C4–C5	-0.217**–-0.328**
ABH C2–C5	0.255**
%∑AH C/C2–C5	0.225*
%∑PH C/C2–C5	0.339**
%∑AIS/C2–C5	-0.225*
%∑PIS/C2–C5	-0.339**

R – coefficient of correlation
* p<0.05, ** p<0.01

pared to age group III. Comparison between group I and group III was not described because of large age difference and expected statistical significance. Statistically significant increase of anterior and posterior C2, C3, C4 and C5 body heights between age groups is shown in Table 4. All anterior intervertebral spaces were statistically smaller in group III compared to group II, while posterior intervertebral spaces were statistically smaller in group II compared to group I. Therefore, there was general trend of cervical vertebrae body growth from group I to group III and decrease of the intervertebral space. There was a significant increase of total C2–C5 anterior and posterior height. According to sex, overall linear values were greater in males, except the values of the anterior body heights of the vertebrae C3, C4 and C5. Statistically significant difference between sexes was found in anterior and posterior body height of the vertebrae C2 and posterior intervertebral space C3–C4.

The results showed that the biggest part of the cervical spine C2–C5 was vertebra C2, average 44.12±2.09% of the anterior height and 42.35±2.35% of the posterior height of the part C2–C5. The rest was equally distributed with vertebrae C3, C4, C5 at around 12.7% of the anterior height, and around 15.3% of posterior height of the part C2–C5. The trend of increasing anterior and posterior C3, C4 and C5 body distribution was observed from group I to group III, while percentages of anterior and posterior C2 body height, as well as anterior and posterior height of all the intervertebral spaces, were lower (Table 5). Overall values of anterior and posterior body height were more presented in the total height of the spine in females, but statistical significances were found in anterior C4 and C5 body height. The values of all anterior and posterior intervertebral spaces were more present in the total height of the spine in males, but statistical significances were found in anterior C2–C3 and C4–C5 intervertebral spaces.

The percentage of anterior and posterior C2, C3, C4 and C5 body height sum compared to total C2–C5 height showed the trend of increasing from group I to group III and the percentage was greater in females from all groups. Statistical significance was found in most parameters of anterior part of the spine (Table 6).

In order to lower the margin of error, repeated measurements were taken during one week, by a single observer (E.L.), on 20 randomly selected radiograms. Inter-observer reliability was measured with inter-class correlation coefficient. The coefficient was high (ICC=0.986; p<0.001), which suggested high precision of measurements and low error.

DISCUSSION

Incompletely clarified link between craniofacial and cervical structures and common questions about the reliability of skeletal maturity estimations using cervical morphology changes makes the cervical region still a current field of research. Considering the visibility of C1–C5 vertebrae in lateral cephalograms, this study described the morphology of the stated cervical segment and cervical lordosis (OPT/CVT). Some previous studies analyzed the upper and middle (OPT, CVT) segment [4, 7, 21], and lower (EVT) segment of the cervical column and it was found that morphology changes in upper and middle segments were affected by facial development [6].

Age and sex play important roles in cervical lordosis change during growth as studies conducted by Hellsing et al. [3] and Nik and Aciyabar [7] have shown, so our study included three age groups of patients in different stages of development in order to notice the differences in values of OPT/CVT angle. Our results indicated a trend of increased angle in females with age, while the angle decreased after 12 and 13 years of age in male patients. Lower angle was found in males, which indicates straighter spine.

The positive correlation was found between cervical lordosis, and age and sex (Table 3).These results are in agreement with previous studies of differences in spinal curvature between sexes [3, 6, 7], not confirmed by Tecco and Festa [22]. Dos Santos et al. [1] included Brazilian six- to 16-year-old patients and analyzed angular inclination of cervical vertebrae (C1–C5) along the sagittal plane. They found opposite angular tendency of vertebrae C2, C3 and C4 during growth. The spine has a tendency for flexion in females, but extension in males. These findings match with the results of our study, but as a consequence of differences in age groups it was not possible to determine the magnitude of variations between them.

Dimensions of cervical vertebrae and intervertebral spaces change during growth [1, 2, 12, 23, 24]. Generally, in our study, the values of the vertebrae body heights got higher with age, while the spaces between them became smaller (Table 4). Anterior and posterior C2 body height, posterior C3, C4 and C5 body heights, anterior and posterior C2–C3, C3–C4 and C4–C5 intervertebral space heights were greater in males, while the values of the anterior C3, C4 and C5 body heights were greater in females. At the age of eight, the values of C2, C3, C4 and C5 anterior and posterior body heights and posterior intervertebral space C2–C3 were greater in females that entered puberty earlier. At the ages of 12 and 13, the values of anterior and posterior C3 and C4 body heights, anterior C5 body height, and posterior intervertebral space C3–C4 and C4–C5 were greater in females, while at the ages of 17 and 18, all linear parameters became greater in males (they reached females). The values of anterior and posterior C3, C4, and C5 body heights showed a positive correlation between cervical lordosis, while the values of anterior C4–C5 and posterior C2–C3, C3–C4, C4–C5 intervertebral spaces showed negative correlation (Table 3). The tendency of greater cervical dimensions in males and the fact that males have a longer spine than females was noted in several studies [5, 8]. On the other hand, Baydas et al. [23] study included 13- to 15-year-old patients and found similar results in most parameters for both sexes. Dos Santos et al. [1] study showed that anterior body height of the vertebra C2, anterior and posterior body

Table 4. Changes of cervical linear parameters according to age and gender

Variable (mm)		Gender[b]	Age groups[a]					
			Overall	I	vs	II	vs	III
C2	ABH	Total	31.94±3.97	28.31±2.58	***	31.97±2.57	***	35.56±2.79
		Male	32.44±4.76	27.28±2.28	***	32.38± 2.75	***	37.36 ±2.57
		Female	31.60±3.31†	28.92±2.60†	**	31.63±2.42	***	34.36±2.26†
	PBH	Total	28.76±3.37	25.92±2.35	***	28.79±2.23	***	31.58±2.78
		Male	29.31±4.14	25.13±2.39	***	29.07±2.60	***	33.49±2.40
		Female	28.39±2.68†	26.40±2.23	**	28.55±1.90	**	30.30±2.26†
C3	ABH	Total	9.57±3.04	6.45±0.90	***	9.18±1.63	***	13.07±1.40
		Male	9.56±3.27	6.20±0.77	***	8.68±1.16	***	13.71±1.21
		Female	9.57±2.89	6.60±0.94	***	9.58±1.87	***	12.65±1.38†
	PBH	Total	10.63±2.51	8.03±0.86	***	10.47±1.47	***	13.39±1.30
		Male	10.86±2.81	7.87±0.65	***	10.41±1.32	***	14.17±1.40
		Female	10.48±2.31	8.13±0.97	***	10.53±1.62	***	12.87±0.95†
C4	ABH	Total	9.26±2.79	6.46±0.78	***	8.76±1.50	***	12.55±1.24
		Male	9.11±2.91	6.17±0.36	***	8.22±1.00	***	12.90±0.99
		Female	9.35±2.72	6.64±0.91	***	9.21±1.71†	***	12.31±1.35
	PBH	Total	10.55±2.59	7.87±0.94	***	10.32±1.33	***	13.46±1.30
		Male	10.82±2.91	7.60±0.74	***	10.46±1.42	***	14.24±1.18
		Female	10.36±2.35	8.02±1.03	***	10.20±1.28	***	12.95±1.14†
C5	ABH	Total	9.27±2.73	6.76±0.83	***	8.63±1.42	***	12.54±1.22
		Male	9.17±2.91	6.20±0.41	***	8.33±1.08	***	12.89±1.05
		Female	9.35±2.62	6.76±0.74†	***	9.07±1.56	***	12.31±1.29
	PBH	Total	10.49±2.58	7.84±0.89	***	10.19±1.23	***	13.44±1.32
		Male	10.71±2.94	7.53±0.86	***	10.23±1.28	***	14.24±1.18
		Female	10.34±2.31	8.03±0.87	***	10.15±1.22	***	12.91±1.15†
C2–C3	AIS	Total	4.18±1.39	4.95±1.05		4.58±1.22	***	3.03±1.09
		Male	4.64±1.30	5.16±1.12		5.16±0.88	***	3.58±1.24
		Female	3.87±1.37	4.82±1.01		4.10±1.27†	***	2.67±0.81†
	PIS	Total	2.84±0.96	3.33±0.86	* *	2.80±0.95		2.40±0.86
		Male	2.94±0.96	3.19±0.74		2.93±1.17		2.71±0.89
		Female	2.77±0.96	3.41±0.92	**	2.68±0.74		2.19±0.79
C3–C4	AIS	Total	4.29± 1.42	5.18±1.06		4.69±1.16	***	3.01±1.03
		Male	4.70±1.35	5.49±0.67		5.11±1.19	***	3.51±1.21
		Female	4.00±1.41	4.98±1.21		4.35±1.05†	***	2.68±0.74†
	PIS	Total	2.48± 0.96	3.06±0.85	**	2.26±0.87		2.12±0.91
		Male	2.67±1.10	3.43±0.79	**	2.26±1.06		2.42±1.07
		Female	2.35±0.85†	2.83±0.84†	*	2.27±0.71		1.93±0.74
C4–C5	AIS	Total	3.88 ±1.23	4.48±0.96		4.27±1.04	***	2.90±1.04
		Male	4.40±1.11	4.89±0.90		4.87±0.67	***	3.48±1.16
		Female	3.51±1.18	4.24±0.92†		3.78±1.05†	***	2.51±0.74†
	PIS	Total	2.44± 0.92	3.03±0.78	***	2.20±0.83		2.09±0.87
		Male	2.51±1.02	3.23±0.93	**	2.16±0.81		2.24±1.03
		Female	2.39±0.85	2.92±0.67	**	2.23±0.86		1.99±0.75
C2–C5	AH	Total	72.44±9.80	62.58±4.63	***	72.07±5.27	***	82.66±6.08
		Male	74.08±11.34	61.60±4.62	***	72.63±5.11	***	87.42±3.68
		Female	71.30±8.49	63.17±4.64	***	71.62±5.47	***	79.48±5.24†
	PH	Total	68.19±9.51	59.08±3.81	***	67.01±4.84	***	78.48±6.55
		Male	69.81±11.27	57.97±3.35	***	67.51±4.87	***	83.50±4.78
		Female	67.07±7.97	59.74±3.98	***	66.60±4.89	***	75.13±5.36†

[a] ANOVA; [b] Student's t-test;
Significant gender difference † p<0.05; Significance level at * p<0.05, ** p<0.01, *** p<0.001
For a description of the variables, refer to Table 1.

Table 5. Percentage of anterior and posterior cervical vertebrae body height and intervertebral space compared to total anterior and posterior height of C2–C5 part

Variable (%)		Gender[b]	Age groups[a]					
			Overall	I	vs	II	vs	III
C2	ABH	Total	44.21± 2.09	45.21±1.95		44.37±1.88	**	43.04±1.88
		Male	43.88± 1.99	44.30±1.98		44.57±1.73	*	42.71±1.83
		Female	44.43±2.14	45.76±1.75†	*	44.20±2.01		43.27±1.92
	PBH	Total	42.35±2.35	43.84±1.92		42.97±1.72	***	40.26±1.73
		Male	42.15±2.27	43.28±2.18		43.03±1.58	***	40.10±1.55
		Female	42.50±2.41	44.17±1.71		42.92±1.87	***	40.37±1.87
C3	ABH	Total	12.94±2.67	10.32±1.28	***	12.69±1.79	***	15.81±1.17
		Male	12.58±2.55	10.07±1.01	***	11.93±1.11	***	15.68±1.18
		Female	13.19±2.75	10.47±1.42	***	13.32±2.01†	***	15.90±1.19
	PBH	Total	15.42±1.91	13.61±1.25	***	15.59±1.53	***	17.07±1.02
		Male	15.35±1.82	13.59±1.12	***	15.39±1.35	**	16.96 ±1.24
		Female	15.47±1.98	13.62±1.34	***	15.75±1.67	**	17.15±0.86
C4	ABH	Total	12.55±2.41	10.34±1.19	***	12.12±1.58	***	15.20±1.20
		Male	12.05± 2.21	10.04±0.59	**	11.30±0.97	***	14.78±1.25
		Female	12.90±2.49†	10.53±1.14	***	12.79±1.68†	***	15.47±1.11
	PBH	Total	15.28±1.98	13.30±1.25	***	15.37±1.40	***	17.16±0.88
		Male	15.27±2.04	13.13±1.27	***	15.47±1.51	**	17.06±1.07
		Female	15.28 ±1.95	13.41± 1.25	***	15.29±1.33	***	17.23±0.75
C5	ABH	Total	12.65±2.24	10.81±1.15	***	11.94±1.46	***	15.19±1.13
		Male	12.16±2.20	10.41±0.95		11.29±1.29	***	14.76±1.23
		Female	12.98±2.22†	11.05±1.21	***	12.47±1.40†	***	15.47±0.98
	PBH	Total	15.19±1.96	13.28±1.33	***	15.18±1.27	***	17.13±0.89
		Male	15.11±2.08	13.01±1.59	***	15.12±1.31	***	17.06±1.07
		Female	15.25±1.89	13.44± 1.15	***	15.22±1.26	***	17.18±0.77
C2–C3	AIS	Total	5.97±2.32	7.89±1.50	***	6.39±1.81	***	3.64±1.19
		Male	6.52 ±2.26	8.35±1.53		7.15±1.38	***	4.09±1.40
		Female	5.60±2.30†	7.61±1.44	***	5.77±1.90†	***	3.34±0.95
	PIS	Total	4.29±1.67	5.64±1.36	***	4.21±1.46	***	3.04±1.03
		Male	4.37±1.68	5.51±1.28		4.39±1.77		3.27±1.13
		Female	4.24±1.68	5.71±1.42	***	4.05±1.17	**	2.29±0.96
C3–C4	AIS	Total	6.14±2.39	8.26±1.54	***	6.54±1.62	***	3.63±1.13
		Male	6.62±2.34	8.91±0.72	***	7.04±1.52	***	4.01±1.33
		Female	5.81±2.39	7.87±1.77†	***	6.12±1.61	***	3.38±0.92
	PIS	Total	3.76±1.70	5.20±1.53	***	3.40±1.37		2.68±1.07
		Male	3.99±1.93	5.91±1.35	***	3.38±1.67		2.68±1.21
		Female	3.60±1.51	4.77±1.50	**	3.42±1.10		2.65±0.96
C4–C5	AIS	Total	5.54±2.06	7.17±1.49	***	5.96±1.51	***	3.48±1.12
		Male	6.19±2.00	7.92±1.34	*	6.73±0.93	***	3.97±1.25
		Female	5.08±1.99†	6.71±1.40†	**	5.34±1.61†	***	3.16±0.91†
	PIS	Total	3.69±1.60	5.14±1.30	***	3.28±1.26		2.66±1.06
		Male	3.76±1.80	5.56±1.57	***	3.21±1.22		2.68±1.21
		Female	3.65±1.46	4.88±1.07	***	3.34±1.31		2.65±0.96

[a] ANOVA; [b] Student's t-test;
Significant gender difference **†** p<0.05; Significance level at * p<0.05, ** p<0.01, *** p<0.001
For a description of the variables, refer to Table 1.

Table 6. Percentage of anterior and posterior C2, C3, C4, C5 body heights sum compared to total anterior and posterior height of C2–C5 part

Variable		%ΣABH C/AH C2–C5					%ΣPBH C/PH C2–C5				
		Age groups[a]									
		I	vs	II	vs	III	I	vs	II	vs	III
Gender[b]	Total	76.68±3.55	**	81.11±4.31	**	89.24±3.13	84.03±3.20	**	89.11±3.33	**	91.62±2.46
	Male	74.82±2.40	**	79.08±2.62	**	87.93±3.68	83.02±3.48	**	89.01±3.82		91.16±3.25
	Female	77.81±3.68*	**	82.78±4.75*	**	90.12±2.41*	84.63±2.92	**	89.19±2.95	**	91.92±1.78

[a] ANOVA; [b] Student's t-test
* p<0.05; ** p<0.01
For a description of the variables, refer to Table 1.

height C3 and posterior height C5, anterior intervertebral space C3–C4 and posterior C4–C5 were greater in females, but without statistical significance, in the beginning of pubertal growth, while anterior body height C3 was greater in females with accelerated growth only. The results of the Altan et al. [2] longitudinal study, which included Turkish girls aged eight to 17 years, showed that the growth of the vertebrae had its peak at around 13.5 years of age, immediately before the s4 stage of cervical maturity. The slowing of the process started at around 15.5 years of age, but anterior vertebrae growth stopped at around the age of 16.5 (s6). Mito et al. [25] analyzed vertebrae growth in Japanese eight- to 14-year-old girls, and concluded that in girls, accelerated growth of the anterior and posterior body height existed between the ages of 10 and 13. In our study, greater linear growth was present mostly between the group of 12- and 13-year-olds and the group of 17- and 18-year-olds.

Due to possible differences in the patients' body constitution, as well as individual variations during growth, we wanted to show in our study the percentual presence of vertebrae and intervertebral spaces in addition to linear measures and how their relationship changed in different age periods. The study showed that body growth of the vertebra C2 is different than that of vertebrae C3, C4 and C5. It was determined that the biggest part of the cervical spine is the vertebra C2. The rest was equally distributed with vertebrae C3, C4 and C5 (Table 5). With age, percentage of anterior and posterior body height of the vertebra C2 was decreased in total length, while anterior and posterior body heights of the vertebrae C3, C4 and C5 was increased. The percentage of intervertebral spaces was decreased as well. Higher percentage of vertebra C2 was found in females, except at the ages of 12 and 13. Anterior and posterior C3, C4 and C5 body heights occupied more space in females, except for posterior body height of the vertebra C4 at the ages of 12 and 13. With age, their anterior and posterior side occupied greater percent and posterior side was greater than the anterior in all three age groups (Table 5). It was noted that anterior and posterior intervertebral space height decreased with greater values in males, except for the posterior intervertebral space C2–C3 height at the age of eight, and for the anterior intervertebral space C3–C4 and C4–C5 height at the ages of 12 and 13. This study demonstrated that the vertebra C2 was the biggest, but grew slowly, and that intervertebral spaces were reduced due to growth of vertebral bodies. Females showed a greater presence of anterior and posterior body height of all vertebrae in total length, while intervertebral spaces were smaller. This means that females had higher percentage of vertebral body presence, while males had more intervertebral spaces.

Percentage-wise, the total sum of anterior and posterior C2, C3, C4 and C5 body heights increased in growth and took up more space in C2–C5 height regardless of sex. At the age of eight, anterior height of all vertebrae (C2–C5) occupied about 75% in total length, while the posterior one occupied around 85%. At the ages of 12 and 13, the anterior height was about 80% and the posterior one was 90%. At the ages of 17 and 18, anterior height occupied about 90%, the same as posterior. Thus, the sum of all anterior body heights increased around 15%, while the sum of the posterior heights increased about 5% (Table 6). The percentage of anterior and posterior body height sum compared to total C2–C5 height showed positive correlation between cervical lordosis, while the percentage of anterior and posterior intervertebral spaces height sum compared to total C2–C5 height showed negative correlation (Table 3). Accordingly, these changes were monitored more easily if the sum of all anterior heights was taken into account. Larger changes of anterior vertebral dimensions indicate the possibility for easier growth curve detection (the puberty onset, growth spurt, maximum growth and decrease of the growth intensity).

Some of the studies consider that CVM method is subjective and should be used in combination with some other parameter that estimates skeletal maturity [1, 2, 13-16]. Our research offers the percentage of anterior body heights of vertebrae C2, C3, C4 and C5 sum compared to total anterior C2–C5 part of the spine, as possible skeletal maturity estimation.

Our study is designed as a cross-sectional study, which might have its limitations. To accurately determine the changes in cervical lordosis and cervicovertebral morphology at different age and the possibility of estimating skeletal maturity, it is necessary to perform longitudinal studies, or obtain the values for every year of patient's life. Further growth researches are necessary to determine the growth curve and exact percentage ratio of the cervical vertebral bodies to the total length of the measured spine. Limitations in inclusion criteria, necessity of repeated radiographic examinations and potential loss of subjects for follow-up make such studies difficult to perform.

CONCLUSION

Cervical lordosis alters during growth and is more curved in females. The connection was observed between cervical lordosis and the values of C3, C4, and C5 body heights and intervertebral spaces.

Anterior and posterior vertebrae body height increase, and intervertebral spaces decrease in older age groups, and they are larger in 17- to 18-year-old males compared to females of the same age.

Vertebral body height and spaces between them change their percentage ratio with growth. The percentual presence of vertebra C2 body height and intervertebral spaces decrease and the percentual presence of vertebrae C3, C4, and C5 increase in older age groups. Vertebral bodies occupy more space of the spine in females, while intervertebral spaces occupy more of this space in males.

It might be expected that skeletal maturity can be estimated by determining percentage distribution of anterior C2, C3, C4 and C5 body height sum compared to the total anterior C2–C5 spine part. This percentage ratio should be used with some other parameters in estimation of skeletal maturity.

REFERENCES

1. dos Santos MFH, de Lima RL, De-Ary-Pires B, Pires-Neto MA, de Ary-Pires R. Developmental steps of the human cervical spine: parameters for evaluation of skeletal maturation stages. Anat Sci Int. 2010; 85(2):105-14. [DOI: 10.1007/s12565-009-0065-7] [PMID: 19943131]
2. Altan M, Dalci ON, Iseri H. Growth of the cervical vertebrae in girls from 8 to 17 years. A longitudinal study. Eur J Orthod. 2012; 34(3):327-34. [DOI: 10.1093/ejo/cjr013] [PMID: 21511819]
3. 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(4):254-64. [DOI: 10.1093/ejo/9.4.254] [PMID: 3480226]
4. Solow B, Tallgren A. Head posture and craniofacial morphology. Am J Phys Anthropol. 1976; 44(3):417-35. [PMID: 937521]
5. Cooke MS, Wei SHY. Intersex differences in craniocervical morphology and posture in southern Chinese and British Caucasians. Am J Phys Anthropol. 1988; 77(1):43-51. [PMID: 3189522]
6. D'Attilio M, Caputi S, Epifania E, Festa F, Tecco S. Evaluation of cervical posture of children in skeletal class I, II, and III. Cranio. 2005; 23(3):219-28. [DOI: 10.1179/crn.2005.031] [PMID: 16128357]
7. Nik TH, Aciyabar PJ. The relationship between cervical column curvature and sagittal position of the jaws: using a new method for evaluating curvature. Iran J Radiol. 2011; 8(3):161-6. [DOI: 10.5812/kmp.iranjradiol.17351065.3379] [PMID: 23329934]
8. Grave B, Brown T, Townsend G. Comparison of cervicovertebral dimensions in Australian Aborigines and Caucasians. Eur J Orthod. 1999; 21(2):127-35. [PMID: 10327736]
9. Watanabe M, Yamaguchi T, Maki K. Cervical vertebra morphology in different skeletal classes: a three-dimensional computed tomography evaluation. Angle Orthod. 2010; 80(4):719-24. [DOI: 10.2319/100609-557.1] [PMID: 20482359]
10. Lamparski DG. Skeletal age assessment utilizing cervical vertebrae [thesis]. Pittsburgh: University of Pittsburgh; 1972.
11. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofac Orthop. 1995; 107(1):58-66. [PMID: 7817962]
12. Baccetti T, Franchi L, McNamara Jr JA. The Cervical Vertebral Maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Seminars in Orthodontics. 2005; 11(3):119-29.
13. Gabriel DB, Southard KA, Qian F, Marshall SD, Franciscus RG, Southard TE. Cervical vertebrae maturation method: poor reproducibility. Am J Orthod Dentofac Orthop. 2009; 136(4):478.e1–478.e7. [DOI: 10.1016/j.ajodo.2007.08.028] [PMID: 19815136]
14. Fudalej P, Bollen AM. Effectiveness of the cervical vertebral maturation method to predict postpeak circumpubertal growth of craniofacial structures. Am J Orthod Dentofac Orthop. 2010; 137(1):59-65. [DOI: 10.1016/j.ajodo.2008.01.018] [PMID: 20122432]
15. Nestman TS, Marshall SD, Qian F, Holton N, Franciscus RG, Southard TE. Cervical vertebrae maturation method morphologic criteria: poor reproducibility. Am J Orthod Dentofac Orthop. 2011; 140(2):182-8. [DOI: 10.1016/j.ajodo.2011.04.013] [PMID: 21803255]
16. Zhao XG, Lin JX, Jiang JH, Wang QZ, Ng SH. Validity and reliability of a method for assessment of cervical vertebral maturation. Angle Orthod. 2012; 82(2):229-34. [DOI: 10.2319/051511-333.1] [PMID: 21875315]
17. Baccetti T, Franchi L, McNamara JA. Reproducibility of the CVM method: a reply. Am J Orthod Dentofac Orthop. 2010; 137(4):446-7. [DOI: 10.1016/j.ajodo.2010.02.010] [PMID: 20362890]
18. Santiago RC, Costa LFD, Vitral RWF, Fraga MR, Bolognese AM, Maia LC. Cervical vertebral maturation as a biologic indicator of skeletal maturity – a systematic review. Angle Orthod. 2012; 82(6):1123-31. [DOI: 10.2319/103111-673.1] [PMID: 22417653]
19. Nguyen, Ngoc-Lam M, Baluch, Daniel A, Patel, Alpesh A. Cervical sagittal balance: a review. Contemporary Spine Surgery. 2014; 15(1):1-8.
20. Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand. 1971; 29:591-607. [PMID: 5290983]
21. Pachi F, Turla R, Checchi AP. Head posture and lower arch dental crowding. Angle Orthod. 2009; 79(5):873-9. [DOI: 10.2319/060708-595.1] [PMID: 19705927]
22. Tecco S, Festa F. Cervical spine curvature and craniofacial morphology in an adult Caucasian group: a multiple regression analysis. Eur J Orthod. 2007; 29(2):204-9. [DOI: 10.1093/ejo/cjl061] [PMID: 17218718]
23. Baydas B, Yavuz I, Durna N, Ceylan I. An investigation of cervicovertebral morphology in different sagittal skeletal growth patterns. Eur J Orthod. 2004; 26(1):43-9. [DOI: 10.1093/ejo/26.1.43] [PMID: 14994881]
24. Chen LL, Xu TM, Jiang JH, Zhang XZ, Lin JX. Quantitative cervical vertebral maturation assessment in adolescents with normal occlusion: a mixed longitudinal study. Am J Orthod Dentofac Orthop. 2008; 134(6):720.e1-720.e7. [DOI: 10.1016/j.ajodo.2008.03.014] [PMID: 19061795]
25. Mito T, Sato K, Mitani H. Cervical vertebral bone age in girls. Am J Orthod Dentofac Orthop. 2002; 122(4):380-5. [DOI: 10.1067/mod.2002.126896] [PMID: 12411883]

Промене кривине вратне кичме и морфологије цервикалних пршљенова у различитим узрастима и могућност процене скелетне зрелости

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КРАТАК САДРЖАЈ

Увод Током раста пропорције краниофацијалних и цервиковертебралних структура се мењају. Ове структуре су морфолошки и функционално повезане, али је њихов међусобни утицај и даље непознат.

Циљ рада Циљ ове студије је био да се уоче промене кривине вратне кичме и морфологије вратних пршљенова у различитим узрасним групама, као и могућност процене скелетне зрелости засноване на процентуалној заступљености збира предњих висина вратних пршљенова Ц2, Ц3, Ц4 и Ц5 у укупној дужини предње висине кичме од Ц2 до Ц5.

Методе рада Студија је обухватила 120 испитаника оба пола који су сврстани у три старосне групе: 8, 12–13 и 17–18 година. Пет кранијалних и 15 цервикалних параметара је мерено и анализирано.

Резултати Резултати су показали статистички значајну корелацију између закривљености вратне кичме и година, пола, предње и задње висине тела пршљена Ц2, Ц3, Ц4, предњег Ц4–Ц5 и задњег Ц2–Ц3, Ц3–Ц4, Ц4–Ц5 међупршљенског простора. Просечне вредности висине тела вратних пршљенова процентуално су биле чешће код испитаница, а сви међупршљенски простори код особа мушког пола. Проценат збира предње и задње висине пршљена Ц2, Ц3, Ц4 и Ц5 повећавао се са годинама.

Закључак Кривина вратне кичме постаје закривљенија и тела пршљенова заузимају више простора код жена, а међупршљенски простор више код мушкараца. Процена скелетне зрелости би могла да се прати на основу процентуалне заступљености висине тела пршљена у укупној дужини предњег дела кичме (Ц2–Ц5).

Кључне речи: кичмена кривина; лордоза; раст; сазревање

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