Cervical vertebral dimensions in 8-, 11-, and 15-year-old children

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In a sample of 107 boys and girls registered at 8, 11, and 15 years of age and 22 adults the statural height and the height and length of the cervical vertebrae, measured from lateral skull radiographs, were studied. The height and length of the vertebrae increased with age among the children and were non-significantly higher for the girls in each age group. The 15-year-old girls matured earlier, reaching adult values at this age. The 15-year-old boys still showed significantly smaller values for vertebral height and length compared with the adult men. Statural height was significantly correlated with the variables for vertebral growth at 8 and 11 years, whereas there was no correlation at 15 years of age among the children who had passed the pubertal peak height. The development of the vertebrae showed similarities with earlier reported skeletal maturity indicators found in the hand–wrist area and could as such offer an alternative method of assessing maturity without the need for hand roentgenograms. □ *Cervical vertebrae; growth; statural height*

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Several orthodontic studies have described the correlation between the maturity of different skeletal variables and accelerated body growth. The main question has been to estimate the expected age for the prepubertal growth spurt, to establish the most effective time for a treatment period among children. The most commonly used indicators, advocated by many investigators, have been ossification stages in the hand–wrist area, statural height, and maturity of the reproductive organs (1–6). Mandibular growth has been correlated to statural height (1, 7) and to maturation of the cervical vertebrae (8, 9). Hunter (1) found that 57% of the maximum facial increments occurred at the same time as the maximum growth in statural height. Mandibular length was shown to have the most consistent relationship with growth in statural height throughout adolescence. Lamparski (8) found the cervical vertebrae as reliable and as valid as the hand–wrist area for assessing skeletal age, and O'Reilly & Yanniello (9) showed significant increases in mandibular growth associated with specific maturation stages in the cervical vertebrae. Hägg & Pancherz (7) found velocity growth curves of statural height to be the most useful aid for estimation of the growth capacity of the mandible. However, Houston (10) was more critical as to the role of ossification events used as predictors of the mandibular growth spurt. He found that predictions made more than 2 years in advance of the average age of peak height velocity (PHV) were of little clinical value.

The growth of cervical vertebrae has been studied longitudinally from 2 to 19 years of age by Bench (11), who found that by the age of 2 years the morphology of the cervical vertebrae was already established. Bench's general observations of the anteroposterior measurements agreed with those of King (12), according to whom the gradual enlargement of the vertebral bodies stayed in a central axis and, owing to increase in size, helped maintain a constant dimension of the oral and laryngeal pharynx. The longitudinal growth of the vertebral body takes place by means of true epiphysial cartilage plates, similar to the longitudinal growth of long bones (13). Knutsson (14) found that the position of the posterior surface of the vertebra was established at birth. The vertical growth of the vertebrae changed the relationship between the disks and the bodies within the spine. In adults the disks are one-quarter of the height of the spinal column, whereas in children with smaller vertebral size this relationship is different (15). Hellsing et al. (16) in a study of 8-, 11-, and 15-year-old children measured cervical lordosis between the second and sixth vertebra and found that the spine straightened with increasing age.

The relationship between the degree of enlargement of the cervical vertebrae related to statural height has not been reported previously. The aims of the present investigation were to measure the height and length of the cervical vertebrae in 8-, 11-, and 15-year-old children and compare this with adult values, and to examine whether the dimensions of the cervical vertebrae could be correlated to statural height at different ages.

Subjects and methods

The subjects were 107 children divided into three age groups 8, 11, and 15 years of age, respectively, and 22 adults. They had not received any orthodontic treatment and were of normal health and free from signs or symptoms of back disorders. Lateral skull radiographs were taken with an enlargement of 13%. The radiographs were exposed with the subjects standing in an orthoposition, looking into a mirror (17). This definition of natural head posture was achieved without ear rods as described by Hellsing et al. (16). Statural height was registered to the nearest millimeter by an orthopedic surgeon using the stretching-up technique (18).

The reference points recorded on the radiographs (Fig. 1), describing the height and length of the cervical vertebrae, are defined in Table 1. The height of the second vertebra (2vert) was defined as the distance

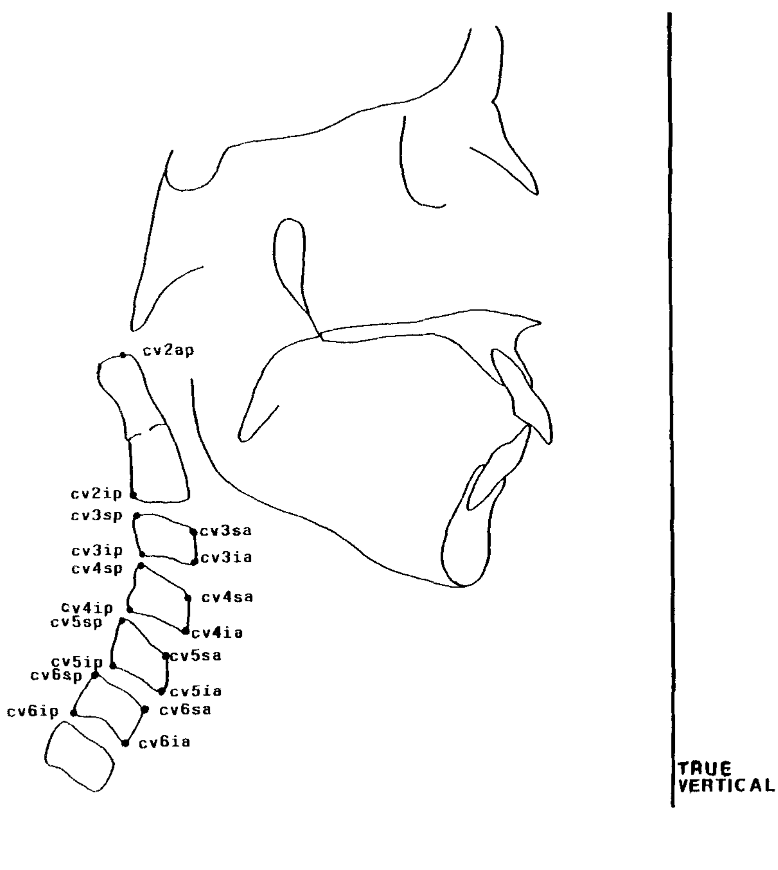

Fig. 1. Reference points measured on lateral skull radiographs and defined in Table 1.

Table 1. Reference points measured on lateral skull radiographs and variables used in the cephalometric analysis

Reference points for lateral skull radiographs	
cv2ap	the apex of the odontoid process of the second cervical vertebra
cv2ip	the most inferoposterior point on the body of the second cervical vertebra
cv3sp cv4sp cv5sp cv6sp	the most superoposterior point on the body of the third, fourth, fifth, and sixth cervical vertebra, respectively
cv3ip cv4ip cv5ip cv6ip	the most inferoposterior point on the body of the third, fourth, fifth, and sixth cervical vertebra, respectively
cv3sa cv4sa cv5sa cv6sa	the most superoanterior point on the body of the third, fourth, fifth, and sixth cervical vertebra, respectively
cv3ia cv4ia cv5ia cv6ia	the most inferoanterior point on the body of the third, fourth, fifth, and sixth cervical vertebra, respectively
Variables in the cephalometric analysis	
2vert	the distance between cv2ap and cv2ip (in mm)
3pvert	the distance between cv3sp and cv3ip (in mm)
4pvert	the distance between cv4sp and cv4ip (in mm)
5pvert	the distance between cv5sp and cv5ip (in mm)
6pvert	the distance between cv6sp and cv6ip (in mm)
3avert	the distance between cv3sa and cv3ia (in mm)
4avert	the distance between cv4sa and cv4ia (in mm)
5avert	the distance between cv5sa and cv5ia (in mm)
6avert	the distance between cv6sa and cv6ia (in mm)
3length	the distance between cv3ip and cv3ia (in mm)
4length	the distance between cv4ip and cv4ia (in mm)
5length	the distance between cv5ip and cv5ia (in mm)
6length	the distance between cv6ip and cv6ia (in mm)

between cv2ap and cv2ip. The posterior height of the third (3pvert) to sixth (6pvert) vertebra was measured between the points cv sp and cv ip for each vertebra. The anterior height of the vertebrae 3avert to 6avert was measured between points cv sa and cv ia. The lengths of the vertebrae were also calculated, 3length to 6length using the distance cv ip to cv ia.

Measurements on the lateral skull radiographs were recorded by means of a digitizer with a resolution of ± 0.1 mm. The data were subsequently analyzed using conventional statistical methods. Student's *t* test was used to evaluate the differences between non-paired observations. To estimate the method error, duplicate measurements were made. The intra-observer method error s_i was calculated with the formula $s_i^2 = \Sigma d^2/2N$, where d is the difference between the first and second measurement, and N the number of double determinations. The values varied between 0.2 and 1.2. Errors of the radiographic method and the reproducibility of the head position have been reported previously (16). Corrections were made for the radiographic enlargement before statistical evaluation.

Table 2. The height and length of the vertebrae in the various age groups

	Age group, 8 years				Age group, 11 years				Age group, 15 years				Age group, adults			
	Boys, $n = 20$		Girls, $n = 18$		Boys, $n = 15$		Girls, $n = 23$		Boys, $n = 16$		Girls, $n = 15$		Men, $n = 10$		Women, $n = 12$	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Age (years)	8.0	0.3	7.8	0.2	10.9	0.2	10.8	0.3	15.8	0.5	15.2	0.3	27.8	4.7	30.8	6.7
Height (cm)	130.0	5.1	130.0	5.7	144.5	5.9	146.8	8.6	174.0	6.5	171.8	6.2	181.7	6.2	170.6	4.3
2vert(mm)	26.5	1.3	27.4	3.1	28.9	2.0	29.0	2.2	34.2	2.4	33.5	1.9	38.1	2.6	32.4	1.9
3pvert (mm)	6.8	0.5	7.6	1.2	8.2	0.6	8.4	1.1	11.7	1.2	12.4	0.8	14.8	0.6	12.5	1.3
4pvert (mm)	7.0	0.5	7.4	0.8	8.1	0.6	8.6	1.3	11.2	1.2	12.8	0.5	14.5	0.8	12.3	1.2
5pvert (mm)	6.9	0.5	7.3	0.8	8.0	0.7	8.6	1.3	11.0	1.3	12.8	0.7	14.2	1.1	12.1	1.3
6pvert (mm)	7.1	0.5	7.6	0.9	8.2	0.7	8.8	1.4	11.7	1.5	12.9	0.7	14.0	1.1	12.6	1.1
3avert (mm)	5.6	0.8	6.1	1.1	6.5	0.8	7.3	1.3	10.3	1.4	13.4	1.8	14.4	0.9	12.5	1.0
4avert (mm)	5.6	0.8	5.9	0.7	6.7	0.8	7.2	1.3	9.7	1.5	11.9	1.1	13.8	1.4	11.6	1.0
5avert (mm)	5.6	0.7	6.0	0.6	6.6	0.5	7.2	1.3	9.2	1.1	11.6	1.0	12.6	0.9	11.1	1.0
6avert (mm)	6.0	0.8	6.1	0.6	7.0	0.9	7.4	1.5	9.9	1.5	12.1	0.9	13.2	1.2	11.2	1.4
3length (mm)	11.5	0.8	11.0	0.9	12.6	0.8	12.5	1.3	14.3	1.1	13.6	1.4	15.1	0.7	13.8	0.8
4length (mm)	11.3	0.9	10.8	0.9	12.2	1.0	12.1	0.9	14.4	1.7	13.7	1.5	15.9	1.3	13.9	0.9
5length (mm)	11.4	0.9	11.2	0.8	12.7	0.8	12.4	1.2	14.0	1.5	13.9	1.2	16.0	0.9	14.5	0.8
6length (mm)	12.1	0.9	11.9	0.9	13.6	0.7	13.2	1.3	14.6	1.6	14.6	1.4	16.0	1.0	14.8	0.9

Results

There were no significant differences in body height between the boys and girls among the 8-, 11-, and 15-year-old children, whereas the adult men were significantly taller than the adult women (Table 2). The mean height of the second vertebra (2vert) increased from 26.5 mm to 34.2 mm for the boys and from 27.4 mm to 33.5 mm for the girls with increasing age. The mean posterior height of the third to sixth vertebra (3pvert, 4pvert, 5pvert, 6pvert) increased approximately from 6 mm to 12 mm with increasing age and with non-significantly higher values for the girls in each age group. The mean anterior height of the third to sixth vertebra (3avert, 4avert, 5avert, 6avert) increased from approximately 5 mm to 13 mm with increasing age for boys and girls and with non-significantly higher values for the girls in each age group. The mean length of the third to sixth vertebra (3length, 4length, 5length, 6length) was also measured. The values increased with increasing age from 11 mm to 14 mm for both boys and girls, with the highest value for the 15-year-old boys. When the adults were compared with the 15-year-old children, the values for the heights and lengths of the vertebrae were significantly higher for the adult men compared with the 15-year-old boys ($p < 0.05$–$p < 0.001$), whereas there were no significant differences between the 15-year-old girls and the adult women.

In the correlation analyses between statural height and the height and length variables for the cervical vertebrae, the boys and girls in each age group were pooled (Table 3). The statural height for the 8- and 11-year-old children was significantly correlated to the height of the second vertebra and the posteroanterior height and length of the vertebrae ($p < 0.05$–$p < 0.001$). There were no correlations between the statural height and the dimensions of the vertebrae among the 15-year-old children.

Discussion

The relation between the thickness of the intervertebral disks and the vertebral bodies changes with increasing age, resulting in proportional enlargement of the vertebral bodies. This changed relationship within the cervical spine may be associated with the previously established changes towards a straighter spine (16, 19). Factors influencing the curvature of the cervical spine have been found by Hellsing et al. (20). A negative correlation between lordosis and the incli-

Table 3. Correlation analyses between variables describing the height and length of the cervical vertebrae and statural height. Number of subjects (n) and correlation coefficients (r) for boys and girls pooled in age groups

	Statural height of age group 8, $n = 38$, r	Statural height of age group 11, $n = 38$, r	Statural height of age group 15, $n = 31$, r
2vert	0.55***	0.73***	NS
3pvert	0.48**	0.78***	NS
4pvert	0.36*	0.72***	NS
5pvert	0.36*	0.74***	NS
6pvert	0.45**	0.76***	NS
3avert	0.54***	0.65***	NS
4avert	0.43**	0.65***	NS
5avert	0.46**	0.65***	NS
6avert	0.42**	0.69***	NS
3length	0.54***	0.41**	NS
4length	0.48**	0.36*	NS
5length	0.40**	0.40**	NS
6length	0.57***	0.41**	NS

NS = non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

nation of the mandible and anterior facial height was found among 8-, 11-, and 15-year-old children.

Kylämarkula & Huggare (21) measured head posture as the inclination between the anterior skull base and the second cervical vertebra. The results showed a negative correlation with the vertical height of the dorsal arch of the atlas. Tulsi (22) found that the overall growth of the vertebral bodies between early childhood and maturity was least in the cervical and most in the lumbar region and that, in contrast to the spinal canal, the bodies mature late. This was associated with the need to withstand greater stresses and strain.

It could be seen from the results presented here that the height of the vertebral bodies was greater among the girls than the boys at each age. The 15-year-old girls reached adult values for the size of the vertebral bodies. It is generally asserted that stature becomes constant once epiphysial union is complete and remains so for several decades of life. Stature then declines after about the 6th decade owing to compression of the intervertebral disks. In adult studies, however, the body of the third cervical vertebra has shown a continuing enlargement in women through to adulthood (23, 24).The 15-year-old boys had not completed their vertebral growth, as they displayed smaller values for vertebral height than the adult men. This sexual divergence in growth pattern is in agreement with other studies concerning skeletal and pubertal developmental indicators for establishing physiologic age, such as those by Björk (3), Fishman (4), and Hägg (5).

Because the values for statural height did not differ significantly within the age groups the boys and girls were pooled in each age group before the correlation analyses. Furthermore, the growth curve for statural height and age has been shown to be approximately linear, whereas the velocity growth curve follows the pubertal development (25). Among the 8- and 11-year-old children the height and length of the vertebral bodies showed significant correlations with statural height. This may illustrate that the increment of the cervical vertebral bodies follows statural height in growing individuals. However, among the 15-year-old children no correlation was found between vertebral size and body height. This may be due to the decreasing velocity of growth after the pubertal peak.

The results of this cross-sectional study suggest the possible use of cervical vertebral height and length as growth predictors. An advantage in using cervical vertebral dimensions is that it avoids additional radiographic exposure, since the vertebrae are already recorded on the lateral cephalometric radiograph.

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