Associations between thoracic kyphosis, head posture, and craniofacial morphology in young adults

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The aim of the present study was to investigate associations between thoracic hyper- and hypokyphosis, head posture, and craniofacial morphology in young adults. Using forward bending test and spinal pantographic measurements, 31 subjects, 16 with thoracic hyper- and 15 with hypokyphosis, were selected from a population-based cohort of 430 young adults. Lateral roentgen-cephalograms were taken in natural head posture and craniofacial and postural angular measurements were calculated. Any statistically significant differences between the groups—thoracic hyperkyphosis and thoracic hypokyphosis—were analysed using Student's *t* test. Subjects with thoracic hyperkyphosis had a larger atlantocervical angle (At/CVT, $P < 0.01$) than subjects with thoracic hypokyphosis. However, head position (NSL/VER) was similar in both groups, probably owing to the visual perception control of craniovertical relation. There was no statistically significant difference in craniofacial morphology between the groups. □ *atlanto-cervical angle; craniofacial morphology; head posture; spinal posture*

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In lateral projection, the human spine has three major curvatures; the lordotic curvatures of the cervical and lumbar regions and the kyphotic curvature at the thoracic region. The influence of the cervical lordosis on craniofacial morphology was mentioned by Bench (1), who suggested that individuals with a pronounced cervical lordosis have squared faces, while Schwarz, already in 1928 (2), put forward the hypothesis that poor posture, characterized by hyperkyphosis, contributed to the development of a postnormal dental occlusion with a retruded mandible. Gresham and Smithells (3), too, observed that pupils with poor sitting position had an elevation of their head and an increase in the prevalence of postnormal occlusion compared with their classmates with proper sitting position.

Since Solow & Tallgren (4) introduced a practical method for making natural head position roentgencephalograms, and described suitable landmarks for identification of head posture, a number of studies dealing with head posture and craniofacial morphology have become available (5–9). Solow & Tallgren (5) found that in adult males extension of the head was related to a steep mandibular inclination and facial retrognathism and forward inclination of the cervical column. These findings were later confirmed in a group of Finnish women (6). Huggare (7) and Cooke & Wei (8) discovered the existense of gender differences in cervical posture in that girls present with a more forward-inclined cervical spine than do boys.

However, there is only one study (9) providing information about postural relations between the body, the cervical spine, and the head. Hellsing et al. (9) studied a sample of 125 children 8, 11, and 15 years old, with no apparent deviation of the spinal column, and found that increased cervical lordosis was associated with a reduced anterior face height and increased thoracic kyphosis was associated with increased facial prognathism, while lumbar lordosis did not correlate with any of the craniofacial variables studied.

Studies dealing with associations between abnormal thoracic curvatures and craniofacial morphology and head posture have not been published, so far. Our aim was to investigate the spinal curvatures in healthy young adults and to compare head and spinal postures and craniofacial morphology between subjects with an excessive, pathologic thoracic curvature (hyperkyphosis) and subjects with very small curvatures (hypokyphosis).

Subjects and methods

Thirty-one subjects with thoracal hyper-or hypokyphosis were selected from an adult population-based spinal screening cohort of 430 young Finnish adults (208 females,

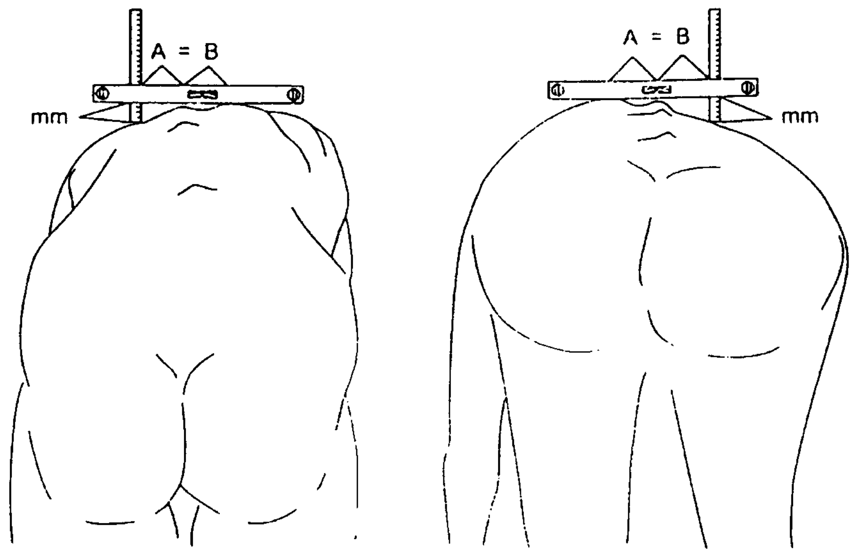

Fig. 1. Measurement of trunk asymmetry in the forward bending test (from Nissinen, 1996) (34).

222 males) in the age range between 21 and 23 years. The investigation was part of a cohort study focusing on the growth of the spine and a long-term evaluation of trunk asymmetry, comprising initially 1060 children 11 years of age (10, 11).

Trunk asymmetry and sagittal spinal posture was measured by a physiatrist. Trunk asymmetry was measured during a forward-bending test. In the forward-bending position, measurements were made of the hump (rib or lumbar), according to Vercauteren et al. (12) and Nissinen et al. (10), as the vertical distance between the horizontal on a spirit level and the trunk on the concavity (Fig. 1). Trunk asymmetry was considered when the hump exceeded 10 mm. The spinal sagittal profiles were measured using a spinal pantograph according to Nissinen et al. (10) and Willner (13), and the angles of thoracic kyphosis and lumbar lordosis were recorded (Fig. 2). Kyphoses exceeding 50 degrees were classified as thoracic hyperkyphosis and those less than 20 degrees as thoracic hypokyphosis. The reliability of the forward-bending test and spinal pantography is described in the literature (10, 14). Repeatability of the pantograph drawn at half-hour intervals for 56 children was good (intraclass correlation coefficient, $r = 0.80$ for thoracic kyphosis; $r = 0.70$ for lumbar lordosis). There was a systematic shift for lumbar lordosis (mean difference, 1.6 degrees) but not for thoracic kyphosis (0.7 degrees). Repeatability of the reading of the same pantographs was excellent ($r = 0.92$ for thoracic kyphosis; $r = 0.86$ for lumbar lordosis) (14).

Frontal and lateral cephalometric radiographic examination of the head and cervical spine was done in 91 subjects who were found to have either trunk asymmetry ($n = 75$) or thoracic hyper- or hypokyphosis ($n = 16$ and 15, respectively). Fifteen of the hyper- and hypokyphosis subjects also had trunk asymmetry. This study deals with the lateral cephalometric examination.

Lateral cephalograms were taken with the head in a natural head position according to the fluid level method (15–17) with a film-focus distance of 154 cm (140 cm from the focus to median sagittal plane). The habitual sagittal head orientation, indicated by the fluid level device and attached to the left temple, was repeated when the subject was positioned in the cephalostat. During the exposure, the teeth were in occlusion and, in cases of occlusal shift, a

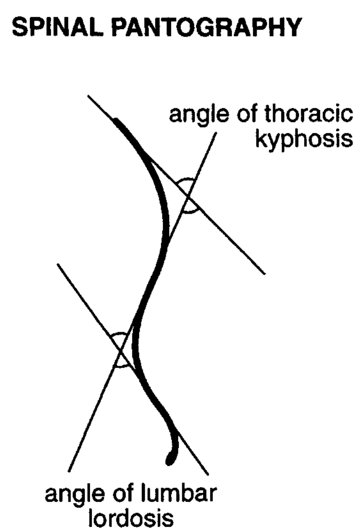

Fig. 2. Spinal pantography and the determination of the angles of thoracic kyphosis and lumbar lordosis (from Nissinen 1996) (34).

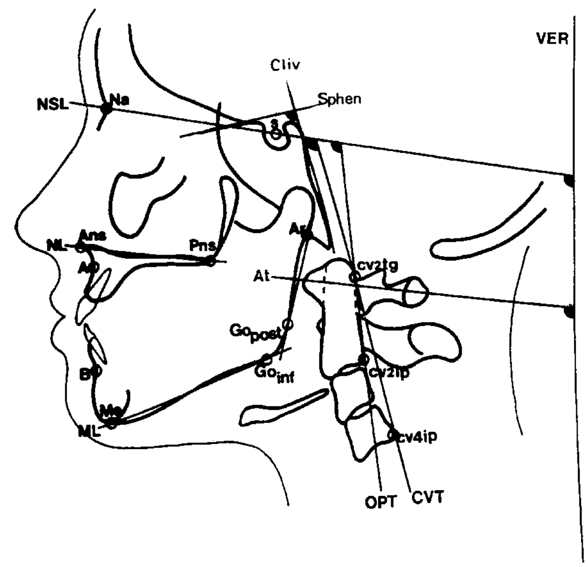

Fig. 3. Reference points and lines measured on lateral cephalograms. The true vertical was reproduced from the plumb line seen on cephalograms. With regard to angles related to this vertical, the angles opening downward in front of the vertical were taken as positive and behind as negative.

wax index was used with the teeth in the retruded contact position.

Twenty-three landmarks were identified from the lateral cephalograms and digitized using the X-Metrix software program (SmartSystems Oy, 1996). Radiographic enlargement (10%) was corrected. The landmarks we used have been defined and published earlier (4, 18, 19) and are shown in Fig. 3. The statistical significance of the differences in head posture and craniofacial morphology between the hyper- and hypokyphotic groups were analysed using Student's t test for unpaired samples. As we did 20 tests, without correction for the possibility of achieving a significant difference just by chance, we sat the level of significance to $P < 0.01$ (20).

Errors in landmark identification were detected by digitizing 10 cephalograms twice at a 2-month interval. The error variance for each measurement was calculated using the formula $S(i) = \sqrt{\Sigma d^2/2N}$, where d is the difference between the first and second digitization and N is the number of double digitizations (21). The range of error variance between two digitizations was 0.02–1.76 degrees. This was considered acceptable when compared with other cephalometric studies.

Results

The means and standard deviations for the variables studied are presented separately for males and females in Table 1. Men had higher mean values for thoracic kyphosis ($P < 0.001$) than women. Women had steeper mandibles (smaller ML/VER, larger NSL/ML, NL/ML, $P < 0.01$ and smaller ML/CVT, $P < 0.001$) and larger gonial angles ($P < 0.001$) than men.

Mean values and standard deviations of the variables for the hypokyphosis and the hyperkyphosis groups are presented in Table 2. There was a significant difference between the groups for the inclination of the atlas to the cervical spine (At/CVT; At/OPT); in the hyperkyphosis group, the At/CVT angle was 5.2 degrees ($P < 0.01$) wider than in the hypokyphosis group.

Discussion

In the sagittal plane the physiologic spinal posture comprises kyphosis at the thoracic level and lordosis at lumbar level. In the population-based cohort of 430 young adults, the mean thoracic kyphosis was 26 degrees (SD 9 degrees) in women and 34 degrees (SD 10 degrees) in men, measured using the spinal pantograph (Nissinen, pers. comm.), indicating a significantly more pronounced kyphotic curvature in men. This is in line with the findings of Hellsing et al. (22), who found that the thoracal spine in boys at age 15 years is more kyphotic than that of girls.

The 31 subjects in this study having thoracic hyper- or hypokyphosis were selected from the 91 subjects who had trunk asymmetry >10 mm or thoracic hyperkyphosis >50 degrees, which were the screening criteria of abnormal spinal posture in this population-based cohort study focusing on the growth of spine. The range of physiologic thoracic kyphosis is considered to be 25–40 degrees measured in the lateral standing radiograph (23). We observed some distinct gender differences in the craniofacial morphology, too, women having a steeper inclination of the mandible and a larger gonial angle than men. These differences have been found reported in studies of young adult Danes (24), Swedes (25), and Finns (26), although to a much lesser extent. However, the craniofacial morphology did not significantly differ between the thoracic hypo- and hyperkyphosis groups.

Subjects with thoracic hyperkyphosis had larger atlantocervical angles (At/ CVT; At/OPT) than subjects with thoracic hypokyphosis. However, thoracal hyper-and hypokyphosis were not associated with any certain features of craniofacial morphology or head posture. The atlanto-cervical angle might be increased owing to either a superior displacement of the anterior part of the atlas or to a forward inclination of the upper cervical spine. It is likely that in our hyperkyphotic subjects this was due to a combined effect, since the spine was slightly more forward inclined (OPT/VER; CVT/VER) and the atlas was slightly more cranially inclined anteriorly (At/VER) in the hyperkyphosis group.

Head position is the individual habit of maintaining the head in space (craniovertical relation), while head posture is defined as the relationship of the cranium to the cervical spine (craniocervical relation). On a cephalometric-radiograph the craniovertical relation can be measured as the

Table 1. Mean values (in degrees) and standard deviations of the variables studied ($n = 91$) according to gender

	Males ($n = 50$)		Females ($n = 41$)	
	Mean	SD	Mean	SD
Spinal curvatures				
Cervical lordosis (OPT/CVT)	−5.78	2.71	−6.91	3.42
Thoracic kyphosis	38.06	11.83	27.63	11.20***
Lumbar lordosis	35.31	8.55	39.03	9.07
Positional				
NSL/VER	94.65	5.87	94.19	4.49
OPT/VER	−0.73	7.20	−2.32	7.33
CVT/VER	5.04	6.58	4.60	6.64
At/VER	102.12	6.82	102.11	6.47
ML/VER	68.48	7.13	64.02	6.47**
Craniocervical				
NSL/CVT	99.70	7.31	98.79	7.41
NSL/OPT	93.92	7.44	91.87	7.73
ML/CVT	73.51	6.96	68.62	6.56***
Cervical				
At/CVT	107.16	6.67	106.72	6.81
At/OPT	101.38	6.06	99.80	6.31
Craniofacial (Basal)				
Sphen/Clivus	110.71	7.91	111.25	8.79
N-S-Ar	123.91	5.99	123.14	5.50
Craniofacial (Vertical)				
NSL/NL	5.74	2.87	5.40	2.98
NSL/ML	26.18	6.28	30.15	6.25**
NL/ML	20.44	6.41	24.76	6.42**
Go angle	117.36	6.52	121.83	6.52***
Craniofacial (Sagittal)				
SNA	82.84	3.42	82.09	3.50
SNB	80.21	3.57	79.46	3.93
ANB	2.64	2.32	2.63	2.43

*** $P < 0.001$, **$P < 0.01$, by Student's t test.

angle between the nasion sella line and the gravity vertical (NSL/VER), while the craniocervical relation can be measured as the angle between the nasion-sella line and the tangent line to the uppermost part of the cervical spine (NSL/CVT or NSL/OPT) (Fig. 3). The craniocervical angle may thus be increased owing to either elevation of the head or forward inclination of the cervical spine, or to both of these conditions.

The head position (NSL/VER) was nearly the same in the hypokyphosis and hyperkyphosis groups. This might show the strong influence of visual perception in maintaining a stable craniovertical position. In studying head posture in blind people, Fjellvang & Solow (27) found that the craniovertical relations were more variable in blind subjects than in a control group of individuals with unimpaired vision. The craniovertical angulation (NSL/VER) was 4.3 degrees less and the neck 4.5 degrees more forwardly inclined in the blind group compared to the control subjects. Similar findings were reported by Dogan & Erturk (28), who stressed that the deviated head posture in blind subjects is produced by forward-downward tilting of the head and neck, while craniocervical angulation remains unchanged. Impaired nasal breathing influences head posture, too (29). In contrast, during this condition the craniocervical angulation is affected. In obstructive sleep apnea (OSA) patients, for instance, there is an extreme increase in the craniocervical angle (NSL/OPT), a phenomenon suggested to be a physiological adaptation for maintenance of adequate airway space. However, as in this condition the craniovertical angle remains unchanged, the increase in the craniocervical angle must be a result of a forward inclination of the cervical spine followed by a forward position of the head (30).

The cervical spine was more forward inclined in the hyperkyphosis group than in the hypokyphosis group, but the difference between groups was not statistically significant. Nevertheless, cervical lordosis (OPT/CVT) was virtually the same in both groups, which shows that the main adjustment to an increased thoracic curvature takes place by a forward inclination of the cervical spine rather than by a change in the spinal curvature. This is in accordance with the findings both in OSA patients (30) and in healthy youngsters in whom no correlation between the thoracic kyphosis and cervical lordosis has been observed (9).

There was a significant difference between the groups in the inclination of atlas to the cervical spine (At/CVT)—the mean angle in the hyperkyphosis group was 5.1 degrees wider than in the hypokyphosis group. This indicates the site of adaptation of the craniocervical

Table 2. Mean values (in degrees) and standard deviations for postural and morphological variables in the hypokyphosis ($n = 15$) and hyperkyphosis ($n = 16$) groups.

	Hypokyphosis <20°		Hyperkyphosis >50°	
	Mean	SD	Mean	SD
Spinal curvature				
Cervical lordosis (OPT/CVT)	−5.06	2.74	−5.91	2.72
Thoracic kyphosis	15.87	3.38	53.50	2.97***
Lumbar lordosis	36.73	6.91	40.25	13.05
Positional				
NSL/VER	93.42	5.34	94.89	6.91
OPT/VER	−1.83	7.58	0.01	9.21
CVT/VER	3.25	5.87	5.90	8.21
At/VER	100.16	5.76	102.64	7.84
ML/VER	63.78	5.23	67.51	10.04
Craniocervical				
NSL/CVT	96.67	7.87	100.82	8.65
Cervical				
At/CVT	103.43	5.78	108.55	4.69**
At/OPT	98.33	6.06	102.64	4.68
Craniofacial (Basal)				
Sphen/Clivus	110.75	7.77	109.22	7.01
N-S-Ar	123.92	4.35	124.27	4.97
Craniofacial (Vertical)				
NSL/NL	5.83	2.48	4.84	2.48
NSL/ML	29.65	7.40	27.38	7.22
NL/ML	23.81	6.50	22.53	7.55
Go angle	119.13	5.10	119.01	6.31
Craniofacial (Sagittal)				
SNA	81.29	3.89	82.74	4.61
SNB	78.81	4.17	80.54	4.63
ANB	2.48	2.89	2.20	2.99

*** $P < 0.001$, ** $P < 0.01$.

complex to the thoracic curvature. The main site of motions in flexion extension of the head is between the occipital condyles and the superior facets of the atlas, but this site is accompanied by a smaller motion between the inferior facets of the atlas and superior facets of the axis, the second vertebra (31).

The forward inclination of the spine seen in the hyperkyphotic group would potentially lead to a disturbed head balance, bringing the gravity of the head more forward from its physiological position. Forward head position has indeed been reported as a risk factor for development of temporomandibular and cervical spine dysfunction (32, 33) and it would therefore be of interest to study whether this could be detected also in our hyperkyphotic subjects. This will be dealt with in a separate article.

In conclusion, our results show that thoracal hyperkyphosis is associated with a large atlantocervical angle without affecting the craniofacial morphology. Subjects with thoracal hyperkyphosis seem to adapt to their abnormal sagittal spinal posture by increasing their atlantocervical angle and inclining their cervical spine forward while holding their head position (NSL/VER) stable, possibly due to visual perception control.

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References

1. Bench RW. Growth of the cervical vertebrae as related to tongue, face and denture behaviour. Am J Orthod 1963;49:183–214.
2. Schwarz AM. Positions of the head and malrelations of the jaw. Int J Orthod 1928;14:56–68.
3. Gresham H, Smithells PA. Cervical and mandibular posture. Dental Rec 1954;74:261–4.
4. Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand 1971;29:591–607.
5. Solow B, Tallgren A. Head posture and craniofacial morphology. Am J Phys Anthrop 1976;3:417–35.
6. Tallgren A, Solow B. Hyoid bone position, facial morphology and head posture in adults. Eur J Orthod 1987;9:1–8.
7. Huggare J. A cross-sectional study of head posture and craniofacial growth in children from the north of Finland. Proc Finn Dent Soc 1987;83:5–15.
8. 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.
9. 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; 9:254–64.
10. Nissinen M, Heliövaara M, Ylikoski M, Poussa M. Trunk asymmetry and screening for scoliosis: a longitudinal cohort study of pubertal schoolchildren. Acta Paediatr 1993;82:77–82.
11. Nissinen MJ, Heliövaara MM, Seitsamo JT, Könönen MT, Hurmerinta KA, Poussa MS. Development of trunk asymmetry in a cohort of children from the age of 11 to 22 years. Spine 2000;25:570–74.
12. Vercauteren M, van Beneden M, Verplaetse R, Croebe P, Uyttendale D, Verdonk R. Trunk asymmetries in a Belgian school population. Spine 1982;7:555–62.
13. Willner S. Spinal pantograph—a non-invasive technique for describing kyphosis and lordosis in the thoraco-lumbar spine. Acta Orthop Scand 1981;52:525–29.
14. Nissinen M, Heliövaara M, Seitsamo J, Poussa M. Trunk asymmetry, posture. Growth and risk of scoliosis. A three-year follow-up study of Finnish prepubertal school children. Spine 1993;18:8–13.
15. Showfety KJ, Vig PS, Matteson S. A simple method for taking natural-head-position cephalograms. Am J Orthod 1983;83:495–500.
16. Huggare J. The "fluid-level method" for recording natural head posture. Proc Finn Dent Soc 1985;8:199–203.
17. Huggare JA. A natural head position technique for radiographic cephalometry. Dentomaxillofac Radiol 1993;22:74–7.
18. Koski K. The Finnish female face in norma lateralis. Trans Eur Orthod Soc 1964. p. 463–9.
19. Kylämarkula S, Huggare J. Head posture and the morphology of the first cervical vertebra. Eur J Orthod 1985;7:151–6.
20. Harrison JE. Current products and practice section. Evidence-based orthodontics—How do I assess the evidence? J Orthod 2000;27:189–96.
21. Dahlberg G. Statistical methods for medical and biological students. London: George Allen and Unwin; 1940.
22. 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;9:129–38.
23. Bradford D, Moe J, Winter R. Kyphosis and postural round back deformity in children and adolescents. Minn Med 1973;56:114.
24. Ingerslev CH, Solow B. Sex differences in craniofacial morphology. Acta Odontol Scand 1975;33:85–94.
25. Sarnäs KV. Early adult changes in the skeletal and soft-tissue profile. Eur J Orthod 1980;2:1–12.
26. Huggare J. Head posture and craniofacial morphology in adults from northern Finland. Proc Finn Dent Soc 1986;82:199–208.
27. Fjellvang H, Solow B. Craniocervical postural relations and craniofacial morphology in 30 blind subjects. Am J Orthod 1986;90:327–34.
28. Dogan A, Erturk N. The effect of vision on craniocervical posture and its relation to craniofacial and dentoalveolar morphology. Quintessence Int 1990;21:401–6.
29. Solow B, Greve E. Craniocervical angulation and nasal respiratory resistance. In: McNamara JA, editor. Naso-respiratory function and craniofacial growth. Monograph 9, Craniofacial Growth Series. Centre for Human Growth and Development, University of Michigan, Ann Arbor 1979. p. 87–119.
30. Solow B, Ovesen J, Nielsen PW, Wildschiödtz G, Tallgren A. Head posture in obstructive sleep apnoea. Eur J Orthod 1993; 15:107–14.
31. Panjabi M, Dvorak J, Duranceau J, Yamamoto I, Gerber M, Rauschning W, et al. Three-dimensional movements of the upper cervical spine. Spine 1988;13:726–30.
32. Rocabado M, Johnston BE, Blakney MG. Physical therapy and dentistry. An overview. J Craniomand Pract 1983;1:47–9.
33. Shiau YY, Chai HM. Body posture and hand strength of patients with temporomandibular disorder. J Craniomand Pract 1990;8: 244–51.
34. Nissinen M. The growth of the adolescent back. Thesis Publications of the National Public Health Institute A 17, Helsinki; 1996.

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