Acta odont scand 1971 *29:* 591—607

Keywords:
Posture
Head
Cervical vertebrae
Cephalometry
Adult

From:
The Institute of Orthodontics
The Royal Dental College
Copenhagen, Denmark

NATURAL HEAD POSITION IN STANDING SUBJECTS

BENI SOLOW
ANTJE TALLGREN

The natural head position in standing subjects was studied on cephalometric profile radiographs of 120 Danish male students aged 22—30 years. Two head positions were recorded, one determined by the subjects own feeling of a natural head balance (the self balance position) and the other by the subject looking straight into a mirror (the mirror position). The reproducibility of the two head positions was assessed. The reference points were recorded by the D-Mac Pencilfollower on punched cards, and a computerized technique was developed for transfer of reference points between the two series of films. It was found that in the mirror position the head was kept higher than in the self balance position. The variability in inclination of the craniofacial and cervical reference lines to the true vertical and to each other in the two head positions was reported. Analysis of the pattern of associations within the craniocervical complex was suggested to clarify the relationship between head balance and facial morphology.

The natural head position has been the subject of considerable interest in anthropological as well as in orthodontic literature. Widespread search has been made for a craniofacial reference plane which in the natural head position would exhibit a relatively constant relationship to the true horizontal or vertical plane. In the anthropological field the interest seems to have been motivated by a requirement for comparisons of cranial morphology in different population groups (*von Baer & Wagner,* 1861; *Broca,* 1862; *von Ihering,* 1872; *Schmidt,* 1876; *Lüthy,* 1912). In the orthodontic area the search may primarily have been due to a need for assessment of facial esthetics in orthodontic analysis and treatment planning (*Downs,* 1956; *Bjerin,* 1957; *Moorrees & Kean,* 1958; *Schönherr,* 1967; *Mills,* 1968).

This study was supported by the Danish Medical Research Council and by USPHS resecarh grant DE-02858 from NIDR, National Institutes of Health, Bethesda, Md., U.S.A.
Received for publication, May 28, 1971.

The natural head position has also been used for orientation of the head in studies of the mandibular rest position (*Tallgren,* 1957, 1966) and of the oro-pharyngeal structures (*Carlsöö & Leijon,* 1960; *Bench,* 1963; *Cleall,* 1965; *Cleall et al.*, 1966; *Fromm & Lundberg,* 1970).

The methods used for definition of the natural head position vary among the different authors. In particular it may be noted that in some of the studies mentioned, the position of the head was defined by means of a mirror (*Bjerin,* 1957; *Moorrees & Kean,* 1958), or a light source (*Cleall,* 1965; *Cleall et al.*, 1966), while in others no external reference was used. The registration of the head position has mainly been performed in the sitting position.

In previous studies of the natural head position the interest has been directed mainly towards the relationship of the head to the surroundings. No systematic analysis seems to have been made of the relationship of the head to the cervical column, and only minor attention has been devoted to the position of the cervical column in relation to the true vertical. In order to elucidate these relationships a roentgen cephalometric investigation of the natural head position in the erect posture was undertaken in a group of young Danish adults.

The purpose of the present paper is to report the methods of investigation and the reliability of these methods. The study further aims to present descriptive data on the relationship of the head and cervical column to the true vertical and to each other.

MATERIAL AND METHODS

Material. The sample consisted of male students from the Royal Dental College in Copenhagen. Subjects in the age range 20—30 years were chosen randomly from the two final classes during the years 1968 and 1969. No selection was made with regard to dental conditions. Three subjects displaying coalescence of cervical vertebrae on the cephalometric films, one subject with bilateral hypoplasia of the mandibular condyles and one with marked facial asymmetry were excluded. The final size of the sample was 120 subjects. The mean age was 24.9 years with a range from 22 to 30 years.

Roentgenographic technique. For the cephalometric profile recordings in the standing position a cephalometric unit designed by *Björk* was used in which the headholder, coupled to the x-ray source, is vertically adjustable and operated by a foot switch (*Björk,* 1968). An 0.5 mm lead wire suspending a weight was mounted in front of the cassette in order to indicate the true vertical on the film (Fig. 1). The transverse adjustment of the head in the

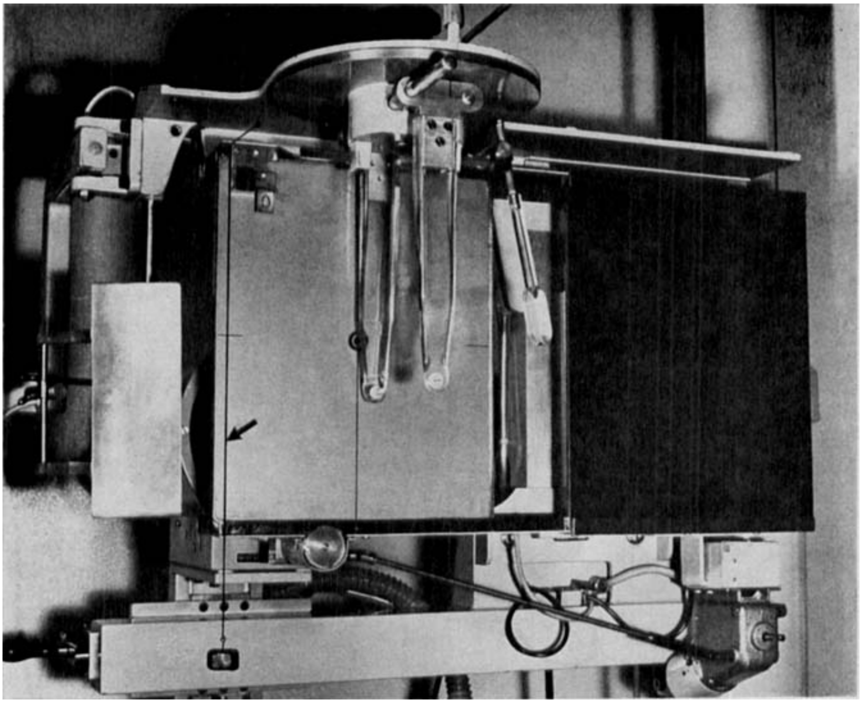

Fig. 1. Close-up of headholder of cephalometric unit (Björk 1968). An 0.5 mm lead wire suspending a weight was mounted in front of the cassette for indication of the true vertical on the film (arrow).

cephalostat was facilitated by a light source projecting a horizontal line through the plane of the ear rods and a vertical line through the median plane of the headholder. A closed-circuit television system connected to an image intensifier permitted a final check of the head position before exposure.

The focus-film distance was 190 cm and the distance from the median plane to the film was 10 cm. No corrections were made for the enlargement of 5.6 %. A movable grid and a wedgeshaped aluminium filter in front of the cassette were used to enhance image quality.

Head positions investigated. The natural head position was determined in two ways for each subject, one defined by the subjects own feeling of a natural head balance (position 1, the self balance position) and one by the subject looking straight into a mirror (position 2, the mirror position). The standing position used in the recordings was the orthoposition, defined by *Mølhave* (1958) as the intention position from standing to walking. Both recordings were made with the teeth in occlusion.

Before the positioning of the subject in the cephalostat the desired body posture, the orthoposition, was obtained by letting the subject walk slightly on the spot. The attainment of the self balance head position was facilitated by letting the subject tilt his head forwards and backwards with decreasing amplitude until he felt that a natural head balance was reached. The subject was then asked to assume the rehearsed body and head position below the raised headholder of the cephalometer so that both external auditory meatus corresponded to the vertical plane of the ear rods. The body posture and head position were controlled and, if necessary, the »walking on the spot» and »head bending» routines were repeated. The headholder was then lowered until the ear rods reached ear level, whereafter the rods were carefully inserted. Slight occipital support was also used (Fig. 2).

After this first recording the ear rods and the occipital support were released and a cloth covering a 20×100 cm mirror on the wall, 137 cm in front of the plane of the ear rods, was removed. The body posture was controlled and the subject was asked to assume a convenient head position while looking straight into his eyes in the mirror. After readjustment of the cephalometer and reinsertion of the ear rods, the second recording was made.

Film series. The first series of records of the two head positions was denoted series A.

In order to assess the reproducibility of the two head positions as well as the method errors due to the cephalometric technique, a second set of records of the two head positions was obtained from 21 subjects after an interval of two months (series B). In addition, 2 film copies were made by a copying machine of each of the 21 films taken in the self balance position. The designations used to distinguish the different series of films are given in Table I.

Measurements. The cephalometric reference points and lines used in the present study are defined in Table II and are shown in Fig. 3. For the craniofacial reference points and lines the definitions of *Björk* (1960) and *Solow* (1966) were used.

The variables studied are listed in Table III. The variables 1—6 describe craniofacial morphology, Nos. 7—10 the inclination of the craniofacial reference lines to the true vertical, and Nos. 11 and 12 the inclination of the two cervical lines to the true horizontal. The inclinations of the craniofacial components to the cervical column are expressed by variables 13—20, and the inclination of the two cervical reference lines to each other by variable 21.

Recording procedure. For recording of the reference points a semi-automatic equipment, the D-Mac Pencilfollower*, was used. The X- and Y-coordinates

* Illuminated modification of Pencilfollower type PF 10,000, Mark 1; D-Mac Ltd., Glasgow SW2, Scotland.

Table I

Survey of film series

Film series	Designation	Sample size
First series, head position 1	A 1	120
First series, head position 2	A 2	120
Second series, head position 1	B 1	21
Second series, head position 2	B 2	21
First copy of series B1	B 1^{c1}	21
Second copy of series B1	B 1^{c2}	21

Table II

Reference points and lines on the cephalometric films

Reference points	
s	Sella. The centre of the sella turcica. The upper limit of the sella turcica is defined as the line joining the tuberculum and dorsum sellae.
n	Nasion. The most anterior point of the frontonasal suture.
sp	Spinal point. The apex of the anterior nasal spine.
pm	Pterygomaxillare. The intersection between the nasal floor and the posterior contour of the maxilla.
gn	Gnathion. The most inferior point on the mandibular symphysis.
	Posterior tangent point ML.
	Lower tangent point RL.
	Upper tangent point RL.
cv 2^{tg}	Tangent point of OPT on the odontoid process of the second cervical vertebra.
cv 2^{ip}	The most inferior posterior point on the corpus of the second cervical vertebra.
cv 4^{ip}	The most inferior posterior point on the corpus of the fourth cervical vertebra.
	Lower point on vertical line.
	Upper point on vertical line.
Reference lines	
NSL	Nasion-sella line. The line through *n* and *s*.
NL	Nasal line. The line through *sp* and *pm*.
ML	Mandibular line. The tangent to the lower border of the mandible through *gn*.
RL	Ramus line. The tangent to the posterior border of the mandible.
OPT	Odontoid process tangent. The posterior tangent to the odontoid process through $cv2^{ip}$.
CVT	Cervical vertebrae tangent. The posterior tangent to the odontoid process through $cv4^{ip}$.
VER	True vertical line. The vertical line projected on the film.
HOR	True horizontal line. The line perpendicular to VER.

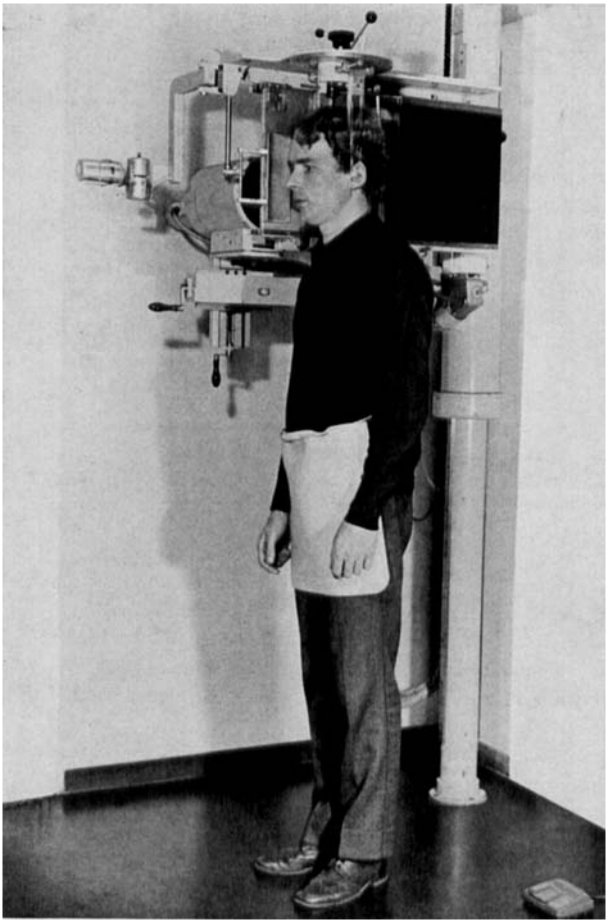

Fig. 2. Roentgen cephalometric recording of natural head position (self balance position) in a standing subject.

for each reference point were recorded in relation to a fixed point on the measuring table and were automatically punched on cards. The coordinates were not analysed directly but were used for calculation of the desired variables.

On the 120 films of the self balance position (series A1), all reference points were marked with a sharp soft pencil and thereafter recorded by the Pencil-follower.

For the 120 records of the mirror position (series A2) a different procedure was used. The reference points were transferred from series A1 to series A2 in two steps.

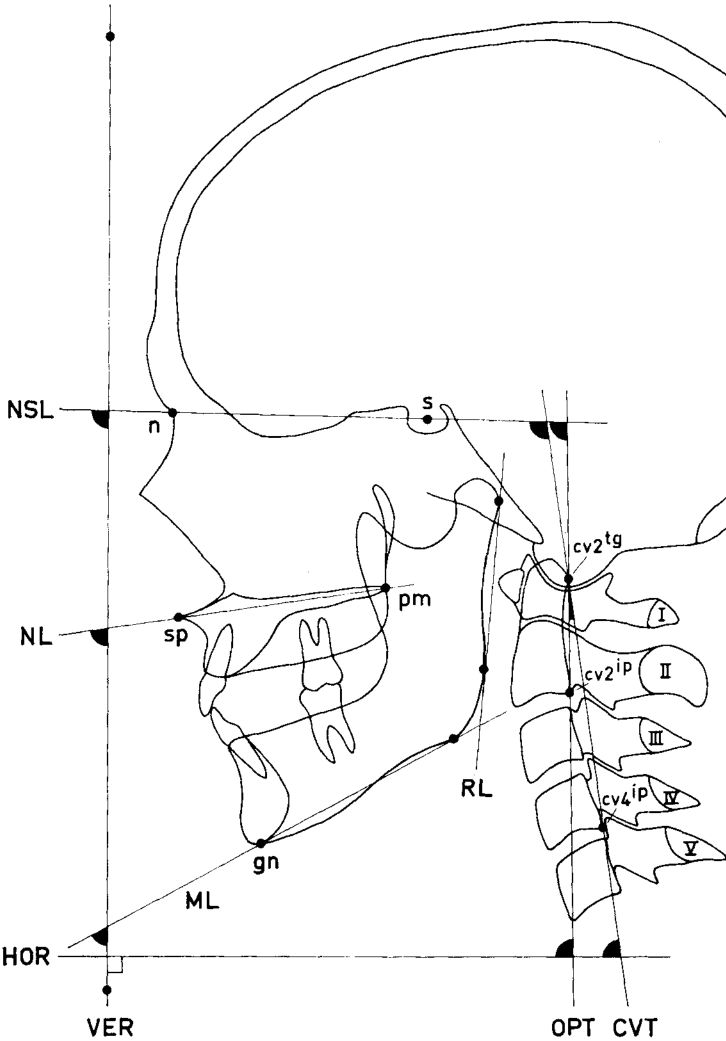

Fig. 3. Reference points and lines on the cephalometric films. The definitions of the principal angles are indicated in the figure. For all variables expressing the inclination of the craniofacial reference lines to the true vertical (VER) and to the cervical reference lines (OPT and CVT), the lower anterior angle was used. With the inclinations shown in the figure all variables are positive.

The first step consisted in transfer of points *s* and *n* and the cervical reference points from series A1 to series A2 by superimposition of the films. For transfer of points *s* and *n* the bony structures of the skull and the maxilla were used, for points $cv2^{tg}$ and $cv2^{ip}$ the second cervical vertebra,

Table III
List of variables

No.	Variable	No.	Variable	No.	Variable
1	NSL/NL	7	NSL/VER	13	NSL/OPT
2	NSL/ML	8	NL/VER	14	NL/OPT
3	NSL/RL	9	ML/VER	15	ML/OPT
4	NL/ML	10	RL/VER	16	RL/OPT
5	NL/RL	11	OPT/HOR	17	NSL/CVT
6	ML/RL	12	CVT/HOR	18	NL/CVT
				19	ML/CVT
				20	RL/CVT
				21	OPT/CVT

and for point $cv4^{ip}$ the fourth cervical vertebra. The reference points on the true vertical line were marked separately. The coordinates of these 7 reference points were then recorded by the Pencilfollower.

The second step consisted in transfer of the remaining craniofacial reference points from series A1 to A2 by computer. First the above-mentioned 7 points were translated and rotated by a mathematical transformation of their coordinates, corresponding to a superimposition of the nasion-sella lines with the sella point as point of registration. Thereafter, the coordinates of the remaining craniofacial reference points were transferred from series A1 to the vacant positions in series A2, thereby creating a complete set of coordinates for series A2. This computerized method for transfer of points was developed for the transfer of a larger set of craniofacial reference points to be used in the current head balance project.

The values of each variable for each subject were determined from the recorded coordinates by a modified version of program COORD (*Barrett, Brown & McNulty*, 1968). The statistical description of the variables was calculated according to *Solow* (1966, p. 36). All calculations were carried out at the NEUCC, the Northern Europe University Computing Centre in Copenhagen.

Method errors. For the craniofacial variables (Nos. 1—6), the total method error due to the roentgenographic procedure and the locating and recording of the reference points was assessed. For this purpose the craniofacial reference points were marked independently on the 21 B films of head position 1 (series B1). The method error $s(i)$ for the craniofacial variables was determined from the differences B1—A1 between the calculated values of the variables in the second and first series. No systematic errors were found. The $s(i)$ values ranged from 0.36° to 0.72° (Table V).

Table IV
Method errors and reproducibilities, s(i)

Variable	Method error		Reproducibility	
	Locating	Transfer	Position 1	Position 2
NSL/VER	.273	.208	2.479	1.427
NSL/OPT	.629	.492	1.762	1.428
NSL/CVT	.290	.273	1.813	1.407
OPT/CVT	.500	.343	.493	.590
OPT/HOR	.563	.438	2.705	1.947
CVT/HOR	.198	.182	2.469	1.763

$s(i) = \sqrt{\Sigma d^2/2n}$, where *d* represents the difference between double determinations of the same subject, and *n* the sample size ($n = 21$).

In order to assess the method error due to the locating of the cervical reference points introduced in the present study, points *s* and *n* and the cervical points were marked independently on the two series of films copied from series B1. No systematic errors in the locating of the reference points were observed. The *s(i)* values for 6 representative variables ranged from 0.20° to 0.63° (Table IV).

The method error due to the transfer of reference points was also assessed. For this purpose points *s* and *n* and the cervical points were transferred from the films of series A1 to series $B1^{c1}$ and $B1^{c2}$ after removal of the previous markings. No systematic errors in the transfer of the reference points were observed. The *s(i)* values for the 6 variables ranged from 0.18° to 0.49° (Table IV).

Reproducibility of head position

For assessment of the reproducibility of the two head positions points *s* and *n* and the cervical points were transferred from series A1 to series B1 and B2 after removal of the previous markings on series B1. The reproducibilities were determined from the differences B1−A1 (position 1) and B2−A2 (position 2) between the calculated values of the 6 representative variables (Table IV).

The results showed that both head positions could be reproduced without systematic error. For NSL/VER the reproducibility, *s(i)*, was 2.48° in the self balance position and 1.43° in the mirror position. These values include the method error due to the transfer of the reference points which, as described above, was found to be low.

The difference between the reproducibility of NSL/VER in the two head positions was significant at the 1 % level. For the remaining variables expressing the relationship of the craniocervical components to each other and to the true horizontal, the differences between the reproducibilities in the two head positions were not significant.

RESULTS

The variables studied are described statistically in Tables V—VII.

Analysis of the distribution form showed that departures from normality were more pronounced for the variables describing the position of the head and cervical column than for the variables describing the craniofacial morphology. However, the magnitude of the observed departures from normal distribution form was generally moderate.

The inclination to the true vertical was studied for each of the craniofacial reference lines. In the self balance position the mean inclination of the nasion-sella line to the true vertical (NSL/VER) was 89.6°, and in the mirror position 92.6°. Thus, on the average, the head was kept more upward in the mirror position, the mean difference of 3° being significant at the 1 % level.

Regarding the inclination of the cervical column to the true horizontal, the mean inclination of the odontoid process tangent (OPT/HOR) changed from 88.2° in the self balance position to 90.4° in the mirror position. The corresponding change for the inclination of the cervical vertebrae tangent (CVT/HOR) was from 83.1° to 84.9°.

Table V

Statistical description and method errors of the craniofacial variables (Nos. 1—6)

Variable		min.	max.	$\bar{x}$	$s(\bar{x})$	s	s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Method error s(i)
1	NSL/NL	1.2	15.6	8.04	.28	3.08	9.49	.150	2.84	.475
2	NSL/ML	6.7	41.7	27.56	.57	6.20	38.47	—.231	3.01	.361
3	NSL/RL	77.5	98.6	86.74	.44	4.82	23.24	.031	2.24*	.677
4	NL/ML	4.7	30.9	19.52	.52	5.71	32.59	—.105	2.28*	.457
5	NL/RL	66.9	92.5	78.70	.42	4.63	21.47	.196	2.89	.719
6	ML/RL	107.1	137.0	120.82	.62	6.79	46.12	.153	2.65	.619

Sample size for statistical description = 120. Sample size for method error = 21. All variables are given in degrees.
$^*P \leq 0.05$, $^{**}P \leq 0.01$.

Table VI

Statistical description of variables 7—21: Self balance position (Head position 1)

Variable		min.	max.	$\bar{x}$	$s(\bar{x})$	s	s^2	Skewness $\sqrt{b1}$	Kurtosis b2
7	NSL/VER	73.5	111.6	89.57	.48	5.23	27.36	.190	5.35**
8	NL/VER	68.0	99.3	81.53	.46	5.02	25.20	.031	3.60
9	ML/VER	43.0	77.7	62.01	.64	7.00	48.99	—.218	3.11
10	RL/VER	—9.9	16.1	2.83	.53	5.80	33.66	.074	2.74
11	OPT/HOR	72.7	103.3	88.16	.56	6.14	37.74	.212	2.60
12	CVT/HOR	73.8	96.2	83.09	.49	5.39	29.04	.271	2.07**
13	NSL/OPT	74.4	105.9	91.41	.55	5.97	35.68	—.259	2.84
14	NL/OPT	66.9	95.9	83.37	.53	5.77	33.34	—.256	2.59
15	ML/OPT	50.3	85.8	63.84	.59	6.43	41.30	.621**	3.64
16	RL/OPT	—9.7	18.8	4.66	.54	5.89	34.70	—.249	2.53
17	NSL/CVT	82.7	111.9	96.48	.52	5.74	32.96	—.077	2.71
18	NL/CVT	75.2	101.2	88.44	.51	5.56	30.93	.051	2.34*
19	ML/CVT	52.4	90.5	68.92	.63	6.93	48.09	.546**	3.55
20	RL/CVT	—3.8	23.1	9.74	.52	5.67	32.11	—.092	2.52
21	OPT/CVT	—2.9	12.7	5.08	.24	2.63	6.94	—.273	3.37

Sample size = 120. All variables are given in degrees.
$^*P \leq 0.05$, $^{**}P \leq 0.01$

Table VII

Statistical description of variables 7—21: Mirror position (Head position 2)

Variable		min.	max.	$\bar{x}$	$s(\bar{x})$	s	s^2	Skewness $\sqrt{b1}$	Kurtosis b2
7	NSL/VER	78.7	111.9	92.59	.43	4.73	22.42	.199	4.79**
8	NL/VER	73.5	99.5	84.55	.43	4.69	22.01	.103	2.85
9	ML/VER	47.8	79.2	65.02	.60	6.60	43.55	—.333	2.63
10	RL/VER	—6.7	18.8	5.85	.50	5.49	30.13	.006	2.59
11	OPT/HOR	77.0	105.0	90.41	.54	5.89	34.68	.135	2.54
12	CVT/HOR	75.2	97.7	84.87	.47	5.19	26.90	.167	2.33*
13	NSL/OPT	73.1	104.7	92.18	.55	6.00	35.98	—.354	3.07
14	NL/OPT	65.6	95.9	84.14	.53	5.81	33.79	—.332	2.68
15	ML/OPT	52.2	86.4	64.61	.57	6.25	39.02	.562**	3.41
16	RL/OPT	—7.2	18.9	5.43	.54	5.89	34.73	—.259	2.28*
17	NSL/CVT	82.5	110.8	97.72	.52	5.65	31.94	—.262	2.84
18	NL/CVT	75.0	101.8	89.67	.51	5.54	30.64	—.046	2.23**
19	ML/CVT	56.1	91.6	70.15	.61	6.65	44.26	.532**	3.42
20	RL/CVT	—0.7	23.6	10.97	.51	5.63	31.70	—.037	2.32*
21	OPT/CVT	—2.6	11.9	5.54	.23	2.57	6.60	—.330	3.29

Sample size = 120. All variables are given in degrees.
$^*P \leq 0.05$, $^{**}P \leq 0.01$.

Table VIII
Survey of variances from Tables V—VII

	NSL	NL	RL	ML	Self balance position (Head position 1) VER (HOR)	CVT	OPT	Mirror position (Head position 2) VER (HOR)	CVT	OPT
NSL	—	9.5	23.2	38.5	27.4	33.0	35.7	22.4	31.9	36.0
NL	9.5	—	21.5	32.6	25.2	30.9	33.3	22.0	30.6	33.8
RL	23.2	21.5	—	46.1	33.7	32.1	34.7	30.1	31.7	34.7
ML	38.5	32.6	46.1	—	49.0	48.1	41.3	43.6	44.3	39.0
CVT					29.0	—	6.9	26.9	—	6.6
OPT					37.7	6.9	—	34.7	6.6	—

The table presents the variances of the angles formed by combination of the various reference lines.

The relationship of the head to the cervical column, as expressed by the mean inclination of the nasion-sella line to the odontoid process tangent (NSL/OPT) was 91.4° in the self balance position and 92.2° in the mirror position. The corresponding mean inclinations of the nasion-sella line to the cervical vertebrae tangent (NSL/CVT) were 96.5° and 97.7°. A detailed analysis of these changes in the positional relationship of the cranio-cervical components between the two head positions has been reported by *Solow & Tallgren* (1971).

A survey of the variances is given in Table VIII. Differences between the variances were tested by the F-test.

The variability of the craniofacial and cervical reference lines in relation to the true vertical and to each other showed the same general pattern in both head positions. The inclinations to the true vertical showed smaller variability in the mirror position than in the self balance position, but the differences were not significant.

The maxillary and mandibular reference lines (NL, ML and RL) were found to be more variable to the true vertical (VER) than to the anterior cranial base (NSL). The differences were significant at the 1 % level for the maxilla, but were less marked for the mandible.

The mandibular line displayed larger variances than the three other craniofacial reference lines both in relation to the true vertical and to the cervical reference lines (CVT and OPT). The differences were significant at the 1 % or 5 % levels in relation to VER and CVT.

It was further observed that the variability of the mandibular line to the true vertical was of the same magnitude as to the cervical reference lines.

This was also the case for the ramus line. The nasion-sella line and the nasal line, on the other hand, showed a smaller variability to the true vertical than to the cervical reference lines. The differences were in most instances significant at the 1 % or 5 % levels.

Of the two cervical reference lines, the odontoid process tangent showed larger variability to the true horizontal than the cervical vertebrae tangent, but the difference did not reach the 5 % level of significance. The variability in inclination of the two cervical reference lines to each other (OPT/CVT) was very small, and significantly smaller than the variability of these reference lines in relation to the true horizontal.

DISCUSSION

In the study of the natural head position the definition of the head position is a problem since there are no obvious criteria to decide whether a particular position is natural or not. The method most commonly used has been to let the subject orient his head by looking straight into a mirror. This method is based on the concept advanced by *von Baer & Wagner* (1861) and *Broca* (1862) that when a subject is standing with his visual axis horizontal his head is in its natural position. Determination of the head position by means of an external reference such as a mirror has the disadvantage, however, that the position obtained may not be the one habitaully used by the subject outside the experimental situation. In the present study it was considered of interest, therefore, to define a natural head position also without the use of an external reference.

As the position of the head is part of the total posture of the body it was essential first to define a reproducible and fysiologically meaningfull body posture. Among the standing positions considered and rejected were the »attention» position, which was not regarded as representative of habitual postural behaviour, and the relaxed position, which has been shown to be characterized by gradual alterations in the orientation of the weight-bearing body segments (*Mølhave*, 1958). The position selected, the orthoposition, was chosen because it is a habitual symmetrical standing position and has been found to be reproducible in postural investigations (*Mølhave*, 1958).

For definition of the head position without external reference, the subjects own feeling of his natural head balance was utilized (the self balance position). As representative of the head position defined by means of an external reference the mirror position was employed.

The reproducibility, $s(i)$, of the two head positions, as determined from

Table IX

Survey of means and variabilities obtained for the natural head position in studies of young adults

Study	Body position	Head reference	Sex	Age range	Sample size	NSL/VER* $\bar{x}$	NSL/VER* s	Method error n	Method error s(i)
Bjerin (1957)	Sitting	Mirror	M+F	22–36	35	96.2	4.4	35	1.62
	Standing	»	M+F	22–36	35	94.3	4.0	35	1.34
Moorrees & Kean	Sitting	Mirror	F	18–20				66	2.05
(1958)	»	»	F	18–20	61	94.7	3.9	61	1.54
	»	»	F	18–20	61	95.3	3.7		
Carlsöö & Leijon	Sitting	No ref.	M	20–29	9	93.0	7.6	17	4.6
(1960)	»	»	F	20–29	11	96.9	6.1		
Fromm & Lundberg	Sitting	No ref.	M	21–26	30	99.8	5.7		
(1970)	»	»	F	21–26	30	102.4	3.4		
Present study	Standing	No ref.	M	22–30	120	89.6	5.2	21	2.48
	»	Mirror	M	22–30	120	92.6	4.7	21	1.43

* The means reported by the various authors have been transformed in accordance with the definition of NSL/VER in the present study (cf. Fig. 3). The values are given in degrees.

recordings on two separate occations, was found to be 2.48° for the self balance position and 1.43° for the mirror position. These values compare favourably with *s(i)* values reported by previous authors (Table IX). Thus, *Carlsöö & Leijon* (1960) found an *s(i)* value of 4.6° for a head position defined without external reference, and *Bjerin* (1957) and *Moorrees & Kean* (1958) reported values for the mirror position ranging from 1.34° to 2.05°.

A comparison of the means for the two head positions revealed that in the mirror position the head was kept higher than in the self balance position, the mean difference of 3° being significant at the 1 % level. The analysis of this change in head position has been reported elsewhere (*Solow & Tallgren*, 1971).

Means and standard deviations reported in the literature for the natural head position (NSL/VER) in different samples in the same age range as the present one are compiled in Table IX. For a head position determined without external reference *Carlsöö & Leijon* (1960) and *Fromm & Lundberg* (1970) reported means ranging from 93.0° to 102.4°, while a value of 89.6° was found for the self balance position in the present sample. For the mirror position *Bjerin* (1957) and *Moorrees & Kean* (1958) reported means ranging folm 94.3° to 96.2°, as compared with the value of 92.6° found in the present sample.

Regarding the variability in head position a standard deviation of 5.2°

was found for the self balance position in the present sample. This value was within the range of standard deviations, 3.4°—7.6°, reported by *Carlsöö & Leijon* (1960) and *Fromm & Lundberg* (1970) for the head position determined without external reference. For the mirror position a standard deviation of 4.7° was found in the present sample, while *Bjerin* (1957) and *Moorrees & Kean* (1958) reported values ranging from 3.7° to 4.4°. The inclination of the nasion-sella line to the true vertical thus in both head positions showed somewhat smaller means in the present investigation than in previous studies. The standard deviations were of the same order of magnitude as reported by the previous authors.

In the search for a basic reference line for cephalometric analyses considerable attention has been devoted to the Frankfort line on the basis of its mean inclination to the true vertical being close to 90°. This plane has been widely used also for orientation of the head in cephalometric recordings.

In the present investigation the Frankfort line was not included, but it may be of interest to note that a mean inclination to the true vertical very close to 90° (89.6°) was found for the nasion-sella line in the self balance position. However, in view of the large inter-individual variability of the craniofacial reference lines in relation to the true vertical, the preference of a particular line on the basis of its mean inclination to the true vertical seems questionable in the analysis of the individual subject.

As pointed out by *Björk* (1955), the choice of reference line depends on the purpose of the analysis. For assessment of individual facial growth and development *Björk* emphasized that the basic reference line should be chosen so that it conforms to the growth zones of the skull. On the basis of phylogenetic and ontogenetic considerations he selected the nasion-sella line for this purpose. For cephalometric recordings, on the other hand, *Björk* (1953, 1954) orientated the head according to its natural balance and not according to any particular line, in order to avoid a strained head position.

Moorrees & Kean (1958) also recommended the natural head position for cephalometric recordings. These authors, however, suggested to use the true vertical as the basic reference line both in analysis of facial morphology and in assessment of facial development. This suggestion was based on their finding that in the natural head position (the mirror position) the reproducibility, $s(i)$, of the craniofacial reference lines in relation to the true vertical was smaller than the inter-individual variability, s, of these lines to the true vertical. The difference between the reproducibility in head position and the variability of craniofacial reference lines in relation to the true vertical is statistically confirmed by the findings of *Bjerin* (1957) and *Carlsöö & Leijon* (1960), as well as by the present study. However, as emphasized by

Cleall et al. (1966), this does not indicate that the craniofacial structures are less variable to the true vertical than to each other. The present study showed that in both head positions the maxillary and mandibular reference lines were more variable to the true vertical than to the cranial base. For the maxilla the difference was particularly marked, and significant at the 1 % level.

In the study of the relationship between facial morphology and head position it is important to take into account not only the relationship of the head to the true vertical but also its relationship to the supporting cervical column. Such an analysis was initiated in the present study. Examination of the craniofacial variability to the true vertical and to the cervical column revealed that of the craniofacial reference lines studied, the mandibular line showed the largest variability both to the true vertical and to the cervical reference lines. This is consistent with previous findings regarding the intracranial variability, that the mandibular line displays a higher relative variability than other craniofacial reference lines when the distance between the points defining each reference line is taken into account (*Solow*, 1966).

It was further observed that the upper face and the cranial base (NL and NSL) showed a consistently lower variability to the true vertical than to the cervical column (CVT and OPT). The variability in inclination of the mandible (RL and ML) to the true vertical, on the other hand, was found to be of the same magnitude as to the cervical column. These findings may reflect interrelationships between the facial morphology and the head balancing mechanism.

In order to further analyse the relationship between head balance and facial morphology a more comprehensive analysis of the pattern of associations within the cranio-cervical complex seems necessary.

REFERENCES

von Baer, K. E. & R. Wagner, 1861: Bericht über die Zusammenkunft einiger Anthropologen im September 1861 in Göttingen zum Zwecke gemeinsamer Besprechungen. Leopold Voss, Leipzig.

Barrett, M. J., T. Brown & E. C. McNulty, 1968: A computer-based system of dental and cranio-facial measurement and analysis. Aust. dent. J., *13:* 207—212.

Bench, R. W., 1963: Growth of the cervical vertebrae as related to tongue, face, and denture behavior. Amer. J. Orthodont., *49:* 183—214.

Bjerin, R., 1957: A comparison between the Frankfort horizontal and the sella turcica-nasion as reference planes in cephalometric analysis. Acta odont. scand., *15:* 1—12.

Björk, A., 1953: Variability and age changes in overjet and overbite. Amer. J. Orthodont., *39:* 779—801.

—»— 1954: Cephalometric x-ray investigations in dentistry. Int. dent. J., *4:* 718—744.

Björk, A., 1955: Cranial base development. Amer. J. Orthodont., *41:* 198—225.

—»— 1960: The relationship of the jaws to the cranium. *In* Lundström (ed.): Introduction to Orthodontics. McGraw-Hill, London, p. 104—140.

—»— 1968: The use of metallic implants in the study of facial growth in children: Method and application. Amer. J. phys. Anthrop., *29:* 243—254.

Broca, M., 1862: Sur les projections de la tête, et sur un nouveau procédé de céphalométrie. Bull. Soc. Anthrop. Paris, *3:* 514—544.

Carlsöö, S. & G. Leijon, 1960: A radiographic study of the position of the hyo-laryngeal complex in relation to the skull and the cervical column in man. Trans. roy. Sch. Dent. Stockholm and Umeå, *5:* 13—34.

Cleall, J. F., 1965: Deglutition: A study of form and function. Amer. J. Orthodont., *51:* 566—594.

Cleall, J. F., W. J. Alexander & H. M. McIntyre, 1966: Head posture and its relationship to deglutition. Angle Orthodont., *36:* 335—350.

Downs, W. B., 1956: Analysis of the dentofacial profile. Angle Orthodont., *26:* 191—212.

Fromm, B. & M. Lundberg, 1970: Postural behaviour of the hyoid bone in normal occlusion and before and after surgical correction of mandibular protrusion. Svensk tandläk.-T., *63:* 425—433.

von Ihering, H., 1872: Ueber das Wesen der Prognathie und ihr Verhältniss zur Schädelbasis. Arch. Anthrop., *5:* 359—407.

Lüthy, A., 1912: Die vertikale Gesichtsprofilierung und das Problem der Schädelhorizontalen. Arch. Anthrop. N.F., *11:* 1—87.

Mills, P. B., 1968: A grid and visual head positioning as adjuncts to cephalometric analysis. Amer. J. Orthodont., *54:* 521—531.

Moorrees, C. F. A. & M. R. Kean, 1958: Natural head position, a basic consideration in the interpretation of cephalometric radiographs. Amer. J. phys. Anthrop., *16:* 213—234.

Mølhave, A., 1958: En biostatisk undersøgelse. Menneskets stående stilling teoretisk og statometrisk belyst. With an English summary. [A biostatic investigation of the human erect posture.] Munksgård, Copenhagen.

Schmidt, E., 1876: Die Horizontalebene des menschlichen Schädels. Arch. Anthrop., *9:* 25—60.

Schönherr, E., 1967: Natürliche Kopfhaltung, individuelle Kauebene und ihr Wert für die kieferorthopädische Profil- und Modellanalyse. Fortschr. Kieferorthop., *28:* 297—312.

Solow, B., 1966: The pattern of craniofacial associations. A morphological and methodological correlation and factor analysis study on young male adults. Acta odont. scand., *24:* suppl. 46.

Solow, B. & A. Tallgren, 1971: Postural changes in craniocervical relationships. Tandlægebladet, *75:* 1247—1257.

Tallgren, A., 1957: Changes in adult face height due to ageing, wear and loss of teeth and prosthetic treatment. Acta odont. scand., *15:* suppl. 24.

—»— 1966: The reduction in face height of edentulous and partially edentulous subjects during long-term denture wear. Acta odont. scand., *24:* 195—239.

Address:
Royal Dental College,
Jagtvej 160,
2100 Copenhagen Ø, Denmark