

## REFERENCE VALUES OF FACIAL FEATURES IN SCANDINAVIAN CHILDREN MEASURED WITH A RANGE-CAMERA TECHNIQUE

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**Abstract.** Reference values of facial features in white Scandinavian children were ascertained using a newly developed range-camera technique with a three-dimensional measuring program specifically designed for anthropometric measurements. Seven facial features in 613 healthy subjects (322 girls, 291 boys), aged 1 month to 18 years, and nine subjects with the fetal alcohol syndrome, aged 7 to 18 years, were studied. Data were analysed by multivariate multiple regression and measurements of each facial feature plotted against age and presented as curves, with 95% and 99% univariate prediction limits. All children with fetal alcohol syndrome had shorter palpebral fissures, and in six of them the outer canthal distance was shorter than that in the reference group. The reference values presented may be useful in clinical practice - for example, in the evaluation of children with syndromes that result in dysmorphism of the face and in the planning of plastic and reconstructive surgery.

**Key words:** reference values, facial features, range-camera technique, white Scandinavian children.

When dealing with congenital anomalies of the face it is necessary to distinguish abnormal morphological features from normal ones. Craniofacial anthropometry is a useful tool and allows the dysmorphologist to identify syndromes and the surgeon to plan reconstructive surgery. Different races and population groups, however, need their own reference values for evaluation of detailed facial structures. The present study was initiated to create reference values of multiple facial features in healthy white Scandinavian children of various ages. A new range-camera technique with a program that allows three-dimensional measurements, was used (16). To compare the facial features of the

reference group with those of children with a dysmorphic syndrome, the fetal alcohol syndrome was chosen.

### PATIENTS AND METHODS

#### *Patients*

A total of 613 healthy volunteers, 322 girls and 291 boys, age range 1 month to 18 years, and with parents of white Scandinavian origin only, were included in the study (Fig. 1). To establish a reference series representative of the target population of white Scandinavians the subjects were recruited from different sources in Göteborg, Sweden, such as day-care centres, schools, junior soccer teams, and outpatient clinics at the Children's Hospital. Children whose birth weight was less than 2500 g, those who were premature (born before 37 weeks' gestation), and those with minor or major malformations or with disorders possibly associated with children's growth, were excluded.

Nine white Scandinavian children with the fetal alcohol syndrome, six girls and three boys aged 7–18 years, were compared with the reference group.

Written informed consent was obtained from the parents. The study was approved by the Committee for Ethics at the Medical Faculty, Göteborg University.

#### *Methods*

A range-camera technique, with a three-dimensional measuring program specifically designed for the quantitative analysis of various facial features, was used. A thorough description of the method, with assessment of the accuracy of the device and of the quality of the measurements, has been published (16). The range camera consists of a video-camera, a light projector, and a personal computer (Fig. 2). The video-camera captures a number of images of the face while it is being illuminated by different light patterns. From these, a three-dimensional "range image" is computed. Anatomical landmarks seen on

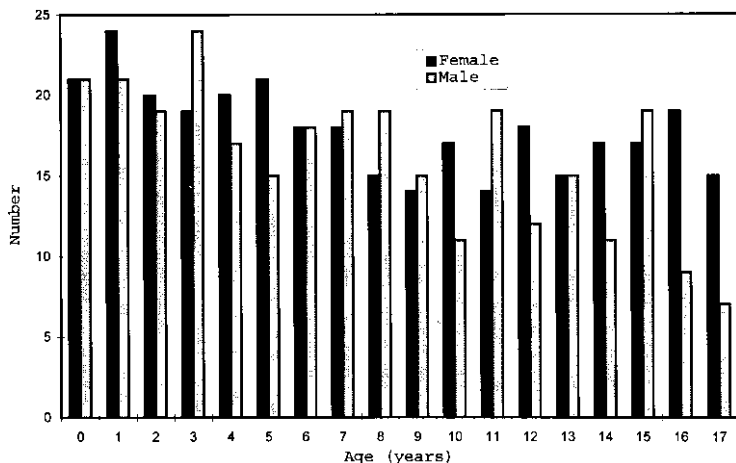


Fig. 1. Distribution by age of the 613 healthy white Scandinavian children studied.

the fully illuminated intensity image of the face are defined manually, and three-dimensional measurements are automatically obtained from the range image.

In the present study the dimensions of seven facial features were measured: the inner canthal distance (ICD), the outer canthal distance (OCD), the length of the right and left palpebral fissures (PFR, PFL), the length of the nose (LN) defined as the distance from the midpoint between the two inner canthi to the tip of the nose, the length of the upper lip (UL), and the length of the mouth (LM) (Fig. 3). In addition, the head circumference was measured with a tape.

The variables ICD, OCD, PFR, and PFL are inter-related. These variables were measured in a particular sequence (PFR, ICD, PFL, and OCD) to minimise the measurement error.

*Statistical methods*

Multivariate multiple regression was used to analyse the data. This makes it possible to predict the

dimension of each facial feature from a knowledge of the child's age and sex. The 95% and 99% univariate prediction intervals were calculated for the seven facial features and for head circumference. These eight variables were fitted to the function

$$y = a(x + x_0)^b$$

where *y* denotes any of the eight variables, *x* represents the age of the child, and *x*<sub>0</sub> is an age lag included in the model because growth begins before birth. One pair of variables (*a* and *b*), for each of the eight measurements and for each sex, is estimated in the regression.

To check the Gaussian assumption, a simultaneous *p* value was calculated for each child and the ordered values were plotted. This *p* value is a measure of how unusual the dimensions of the facial structures are

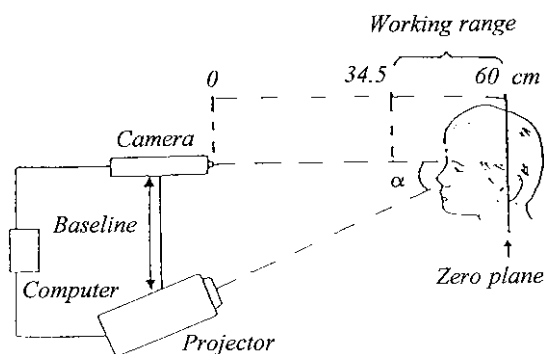


Fig. 2. Arrangement of the range-camera device. (From Strömmland K, et al. Assessment of facial features with a range camera. Scand J Plast Reconstr Surg Hand Surg 1998; 32: 91-96 (16).)

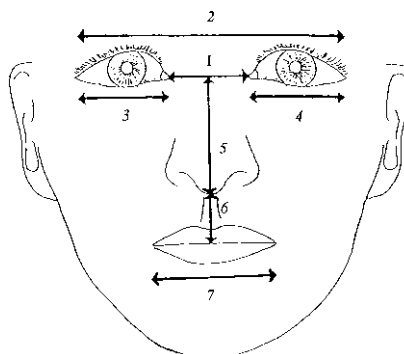


Fig. 3. Facial landmarks used for the measurements: 1 = inner canthal distance, 2 = outer canthal distance, 3 = right palpebral fissure, 4 = left palpebral fissure, 5 = length of the nose, 6 = length of the upper lip, and 7 = length of the mouth. (From Strömmland K, et al. Assessment of facial features with a range camera. Scand J Plast Reconstr Surg Hand Surg 1998; 32: 91-96 (16).)

Table I. Estimation of the variables (*a* and *b*) for each facial feature and head circumference in girls and boys. ICD = inner canthal distance, OCD = outer canthal distance, PFR = right palpebral fissure, PFL = left palpebral fissure, LN = length of nose, UL = length of upper lip, and LM = length of mouth

	Girls		Boys	
	a	b	a	b
ICD	24.6383	0.078779	24.5039	0.089241
OCD	62.1745	0.123354	63.5157	0.122933
PFR	19.1232	0.141503	19.4105	0.144262
PFL	18.9846	0.144514	19.4429	0.142713
LN	20.8067	0.241754	21.3676	0.236625
UL	13.9984	0.123480	14.2163	0.152749
LM	29.4835	0.184181	30.0656	0.179660
Head circumference	43.8769	0.084449	44.3630	0.090727

compared with those of a normal face. The result was sufficiently close to a straight line to indicate that the assumption of a Gaussian distribution was correct. Moreover, plots of the residuals compared with age were made. They showed no systematic pattern that would suggest that the usual regression assumptions are not fulfilled.

A statistical hypothesis test was used to check the symmetry assumption that PFR = PFL.

Facial measurements of the nine children with fetal alcohol syndrome were compared with measurements from the reference group. Combined *p* values (partly simultaneous) were calculated for each of the two sets of variables (ICD, PFR, PFL, and head circumference) and (LN, UL, and head circumference), and also for all variables taken together.

## RESULTS

Measurements of the facial features and head circumference of the reference group are plotted against age and presented as curves, with prediction values and 95% and 99% univariate prediction limits.

The age lag  $x_0$  was estimated to 0.93, as this value gave the best overall fit. Table I lists the estimates of *a* and *b* for each facial feature and for head circumference in girls and boys. Fig. 4 shows the prediction values for all facial features of both sexes. Fig. 5a–g shows the 95% and 99% univariate prediction limits as well as the

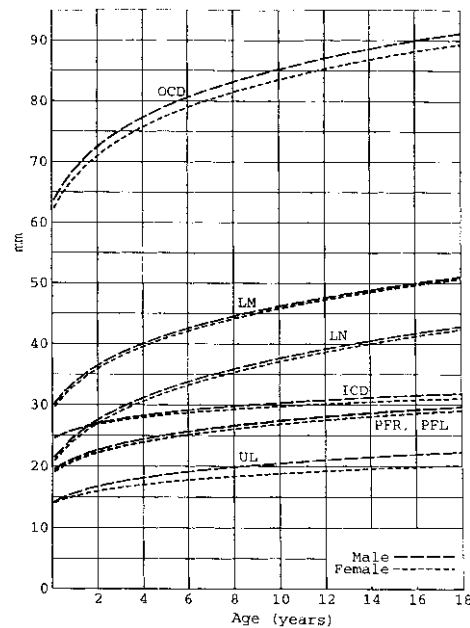


Fig. 4. Plots of prediction values for the measurements of seven facial features in 613 children. ICD = inner canthal distance, OCD = outer canthal distance, PFR = right palpebral fissure, PFL = left palpebral fissure, LN = length of nose, UL = length of upper lip, and LM = length of mouth.

prediction values for the seven facial variables; Fig. 5h gives the same curves for head circumference.

At all ages, all facial features of boys except the ICD were larger than those of girls. From birth to 1 year of age, the ICD of girls was larger than that of boys; thereafter that of boys was larger. Growth was fastest for OCD and slowest for ICD.

The *p* value for rejecting the symmetry hypothesis PFR = PFL was 0.22.

Measurements of all seven facial features and head circumference and univariate *p* values for children with fetal alcohol syndrome are shown in Table II. All children in this group had significantly shorter PFR and PFL than the reference group. Six of them also had a significantly shorter OCD, and four had a significantly smaller head circumference, compared with the reference group. No significant differences were found for ICD, LN, UL, and LM. Table II also shows the prediction values for

Table II. Measurements, predictive values, and univariate *p* values for seven facial features and head circumference of children with fetal alcohol syndrome, and combined *p* values for the two sets of variables (ICD, PFR, PFL, and head circumference) and (LN, UL, and head circumference) and *p* values for all variables assembled. ICD = inner canthal distance, OCD = outer canthal distance, PFR = right palpebral fissure, PFL = left palpebral fissure, LN = length of nose, UL = length of upper lip, and LM = length of mouth. Distances were measured in mm. (mv = measured value, tv = typical (predicted) value, pv = univariate *p* value)

Case No.	Sex	Age (years)		ICD	OCD	PFR	PFL	LN	UL	LM	Head circumference
1	F	7.6	mv	32	72	20	21	33	19	31	49
			tv	29.2	81	25.9	25.9	35	18.2	43.8	52.6
			pv	0.20	0.02	0	0	0.5	0.74	0	0.03
2	F	11.2	mv	34	82	23	24	42	21	41	52
			tv	30	84.5	27.2	27.2	38	19	46.7	54.2
			pv	0.08	0.56	0.001	0.02	0.24	0.43	0.13	0.20
3	F	12.9	mv	29	75	23	23	34	22	44	50.5
			tv	30.3	85.9	27.7	27.7	39.2	19.4	47.8	54.8
			pv	0.54	0.009	0	0.001	0.09	0.30	0.33	0.01
4	F	13.5	mv	27	70	21	21	35	20	44	53
			tv	30.4	86.4	27.9	27.9	39.7	19.5	48.2	55
			pv	0.1	0	0	0	0.14	0.83	0.28	0.25
5	F	15.4	mv	29	79	25	24	36	18	47	53
			tv	30.7	87.7	28.4	28.4	40.9	19.8	49.3	55.5
			pv	0.43	0.04	0.02	0.002	0.14	0.45	0.57	0.14
6	F	15.5	mv	34	83	25	25	38	22	45	53.5
			tv	30.7	87.8	28.4	28.4	40.9	19.8	49.4	55.6
			pv	0.16	0.28	0.02	0.02	0.39	0.39	0.28	0.24
7	M	7.0	mv	30	70	20	20	30	19	38	47.5
			tv	29.5	82	26.2	26.1	34.9	19.5	43.6	53.5
			pv	0.81	0.003	0	0	0.08	0.83	0.11	0
8	M	15.6	mv	32	82	24	25	40	19	48	54
			tv	31.5	89.7	29.1	29	41.5	21.8	49.8	57.2
			pv	0.82	0.09	0	0.006	0.67	0.26	0.67	0.07
9	M	18.0	mv	29	81	26	25	36	20	42	52.5
			tv	31.9	91.2	29.7	29.6	42.9	22.3	51	57.9
			pv	0.19	0.02	0.01	0.002	0.04	0.38	0.02	0.002

the children with fetal alcohol syndrome as well as the combined *p* values for the two sets of variables (ICD, PFR, PFL, and head circumference) and (LN, UL, and head circumference), and the *p* values for all eight variables assembled. All the children with fetal alcohol syndrome had a combined *p* value for the set (ICD, PFR, PFL, and head circumference) of less than 0.03 and three had a combined *p* value for (LN, UL, and head circumference) of less

than 0.05. Seven of the nine children had *p* values of less than 0.05 when all facial features and head circumference were considered together.

## DISCUSSION

In this study, the fastest period of growth for all facial features in both sexes occurred during the first two years of life, which is in agreement with

<i>p</i> Value for combined variables:		<i>p</i> Value for all facial features and head circumference
ICD, PFR, PFL, and head circumference	LN, UL, and head circumference	
0	0.16	0
0.001	0.15	0.001
0.002	0.04	0.01
0	0.41	0
0.02	0.22	0.18
0.02	0.48	0.08
0	0.002	0
0.001	0.23	0.02
0.003	0.006	0.02

current reports (6, 10). The rate of growth then slowed down between 3 to 6 years of age, and after 7 years of age the growth was even slower.

To minimise the measurement error the inter-related variables ICD, OCD, PFR, and PFL were measured in the following sequence, starting at the right outer canthus: PFR, ICD, PFL, and OCD. This procedure reduced the number of

changes of the mouse position and consequently the measurement error.

No significant difference was found in the measurements of the right and left palpebral fissures, which is in accordance with previous studies (9, 11–13, 15).

The values of ICD in the present study confirm the results of Pryor (14) and Feingold and Bossert (9), but are lower than those of Farkas et al. (8). Our OCD values are in agreement with the data of Feingold and Bossert (9), but are slightly higher in all age groups compared with the results of Pryor (14). In children aged 1–3 years, Farkas et al. (8) found higher values for OCD than we did, but similar values in children over 3 years old. The values for the palpebral fissures (PF) were lower in our study than those of Farkas et al. (7). PF was lower from birth to 8 years of age than that reported by Tomas et al. (17), but was higher thereafter.

When the nine children with fetal alcohol syndrome were compared with the reference group, it was found that they generally had a shorter PF, which is in agreement with other studies (1–5). A shorter OCD was found in six children, which might be caused by the shorter palpebral fissures.

We think that the reference material presented is valuable and unique from several points of view. We collected data on facial features of a large number of subjects of all ages from birth to 18 years of age, representative of different stages of normal development. The series also provides a valuable database for measurements of additional facial structures in white Scandinavian children. The reference values of facial features will be used to facilitate the identification of syndromes with dysmorphic facial features and in the planning and follow-up of plastic and reconstructive surgery.

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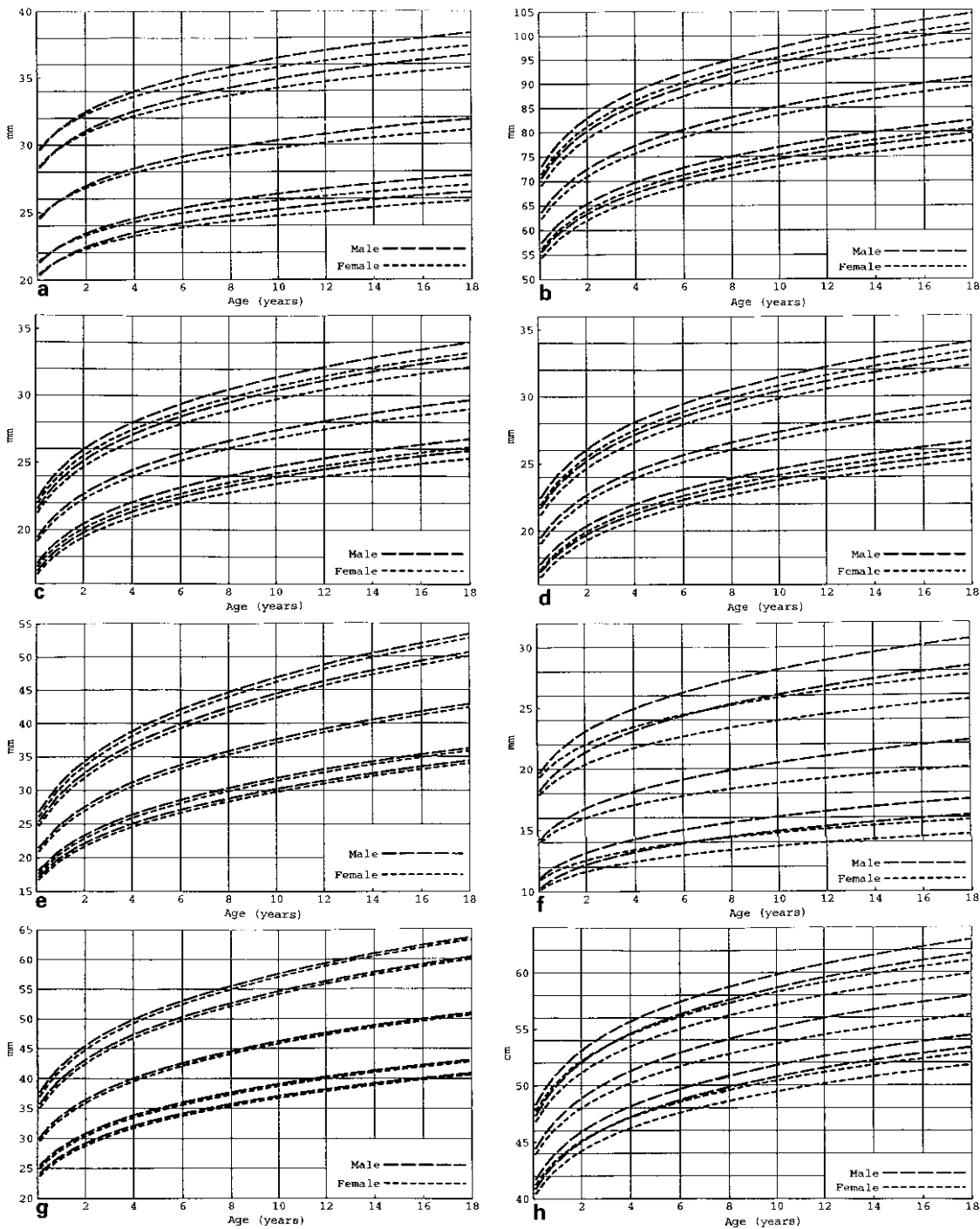


Fig. 5. Prediction values together with 95% and 99% univariate prediction limits, for the measurements of seven facial features and head circumference of 613 healthy children. A total of 5% of the study population have values outside the 95% limits, while 1% have values outside the 99% limits. These limits therefore coincide with 1.96 and 2.58 SD, respectively. The middle line indicates the prediction values. (a) ICD, (b) OCD, (c) PFR, (d) PFL, (e) LN, (f) UL, (g) LM, and (h) head circumference. ICD = inner canthal distance, OCD = outer canthal distance, PFR = right palpebral fissure, PFL = left palpebral fissure, LN = length of nose, UL = length of upper lip, and LM = length of mouth.

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