EVALUATION OF SHORT NECK: NEW NECK LENGTH PERCENTILES AND LINEAR CORRELATIONS WITH HEIGHT AND SITTING HEIGHT

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ABSTRACT

Qualitative impressions of neck length are often used as aids to dysmorphology in syndromes like Turner, Noonan, Klippel-Feil and in craniovertebral anomalies, some of which have serious neurological implications.

There are no national or international standards for neck length. The present study attempted to create standards and percentile charts for Indian children and compute age-independent correlations of neck length with linear measurements such as standing and sitting height. A total of 2724 children of both sexes between 3 and 15 years, whose heights and weights conformed to ICMR standards were inducted. Neck length was measured by a modified two-point discriminator between two fixed bony points-inion and spinous process of C7 with the head held in neutral position. Percentiles (5th-95th) were constructed for both sexes. Growth was rapid from 3 to 6 years. Neck length formed a mean of 12.7 ± 4.58% of height and 20.1 ± 6.73% of sitting height.

Age independent linear regression equations: Neck length = 10 + (0.035 x height) and Neck length = 9.65 + (0.07 x sitting height) were highly significant ($p<0.001$). Neck length relationships of 30 randomly selected normal children clustered around the regression lines and 16 with genetic syndromes fell below the regression lines.

Key words: *Short neck, Neck length.*

Accurate assessment of growth status is critical in health care of the child and adolescent. Access to information on limits of normal variation, both qualitative and quantitative are necessary. Objective measurements of morphologic features are more reliable than visual impressions. Standard curves depicting patterns of normal growth to be applied universally have been developed(l). Unusual measurements such as ear length or interpupillary distance are often required for dysmorphology diagnosis for which standards are available(2). Standards for Indian children have been attempted in **a** few recent studies(3-6) for different measurements.

Short neck is an important feature of conditions like craniovertebral anomalies which have neurological complications, and of dysmorphic syndromes like Turner, Noonan, Klippel-Feil and mucopolysaccharidoses. There are currently no national or international standards for neck length and its variation with age and sex or its relation to other linear measurements.

The present study was designed to create standards for neck length in the childhood years upto mid-adolescence for Indian children and attempts to standardize age-independent inter-relationships of neck length with other linear growth parameters.

Material and Methods

A cross-sectional study population com-

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prising 2724 children of ages 3 to 15 years was inducted. There were 1369 boys and 1355 girls. The children belonged to an English medium school in North Bombay. An average of 100 children of each sex were enrolled in each age group from 3 to 15 years. Routine measurements which included weights, standing heights and head circumference were taken using standard instruments and methods, excluding those whose heights and weights did not fall within two standard deviations for age using the Indian Council of Medical Research (ICMR) charts. Sitting height was measured with the child seated on a stool with feet hanging down, back in contact with an upright surface and head held so that the lower border of the orbital cavities were in the same horizontal plane as the external auditory meatus(7).

Neck length was measured as the linear distance between two easily recognizable and fixed bony points—the external occipital protuberance and the spinous process of C7 vertebra (vertebra prominens); with the child standing upright and neck held in neutral position *(Fig. 1)* so that a horizontal plane drawn from a line connecting the lower borders of the eyes remains parallel to the floor. This position was maintained until the measurement was completed to avoid errors. A modified two-point discriminator *(Fig. 1)* with atraumatic tips was used to record the measurements in centimeters to an accuracy of 1 mm. Mean and standard deviations for standing height, sitting height and neck length were calculated in each age group for both sexes. Percentile charts for neck length with relation to age were drawn for both sexes, plotting 5th and 95th percentiles.

Neck length as a percentage of standing

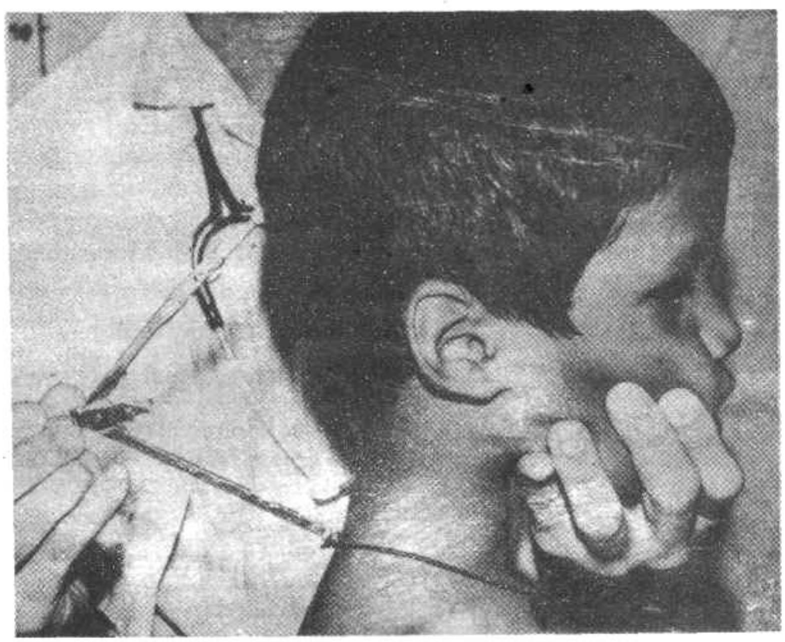


Fig. 1. Measurement of neck length.

and sitting height and the inverse ratio of height to neck length was calculated along with mean and standard deviation.

Linear regression analysis was done to study the correlation between neck length and height and neck length and sitting height. The equation representing the linear regression were calculated for each relationship and shown graphically. Statistical analysis was performed using Minitab software.

A group of 30 randomly selected normal children from the outpatient department were studied to validate the above results. Each was subjected to similar measurements and the values plotted on the graphs. Dysmorphic and genetic syndromes with obvious short necks were measured similarly and the values plotted in the graphs to evaluate their usefulness in the diagnosis of short neck. These included cases of mucopolysaccharidoses, Klippel-Feil anomalad, spondyloepiphyseal dysplasia, Turner syndrome and others.

Results

Tables la & 1b show neck length at different ages along with mean, standard deviation and 95% confidence intervals separately for males and females, respectively. *Figs. 2a & 2b* show neck length percentiles (5th and 95th) for males and females constructed from the data in *Tables Ia & Ib.*

Table II shows neck length as a percentage of standing and sitting heights along with mean and standard deviation. The mean inverse ratio of height to neck length was 8.39 ± 1.70 irrespective of age and sex.

Figure 3 shows the age-independent

TABLE IA - *Neck Length at Different Ages (Males)*

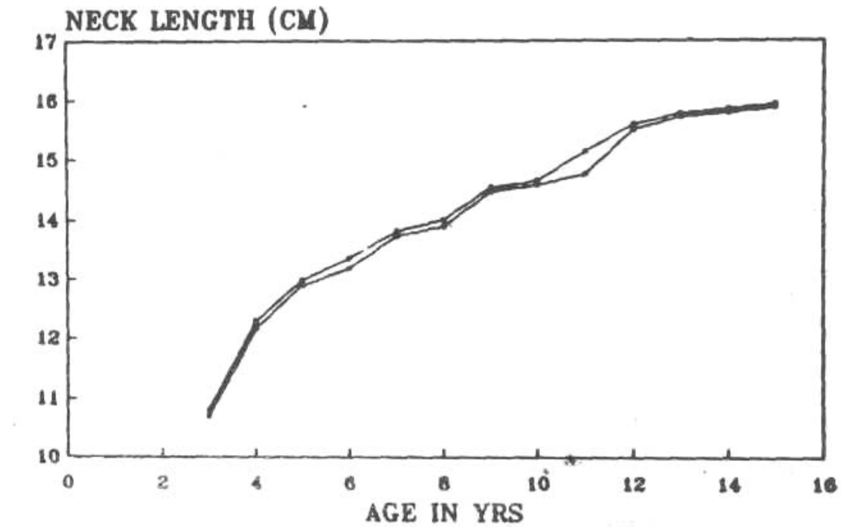
Age (yrs)	n	Mean	SD	SEM	95% CI
3	119	10.74	0.35	0.03	10.67-10.80
4	103	12.22	0.38	0.03	12.14-12.29
5	114	12.93	0.30	0.02	12.87 -12.98
6	104	13.26	0.51	0.05	13.16-13.36
7	108	13.76	0.24	0.02	13.71-13.81
8	102	13.94	0.34	0.03	13.87-14.01
9	99	14.50	0.21	0.02	14.45-14.54
10	103	14.60	0.21	0.02	14.56-14.64
11	100	15.44	4.11	0.41	14.63-16.26
12	105	15.54	0.27	0.02	15.49-15.60
13	104	15.74	0.16	0.01	15.71-15.77
14	104	15.82	0.17	0.01	15.79-15.86
15	104	15.90	0.19	0.01	15.86-15.94

correlation between neck length and standing height. The slope of the graph ($p < 0.001$) gave the following linear regression equation:

Neck length = 10 + (0.0349 x height).

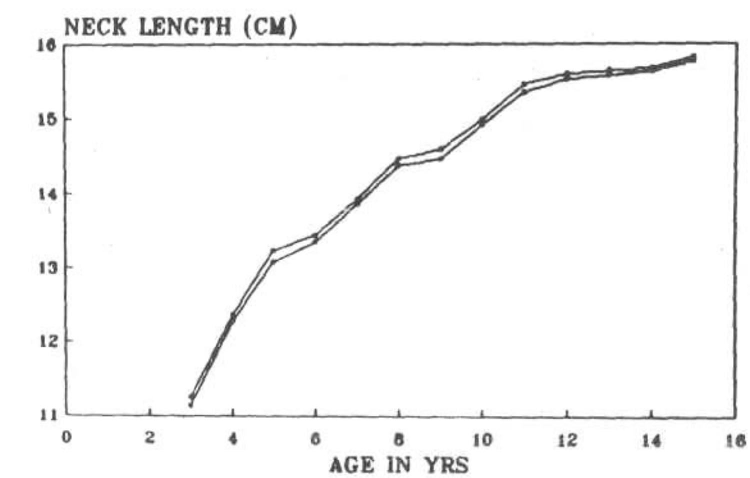
Figure 4 shows the correlation between neck length and sitting height. The slope of the graph ($p < 0.001$) gave the following linear regression equation:

Neck length = 9.65 + (0.0669 x sitting height)



Lines are 5th and 95th percentile

Fig. 2a. Percentile chart for neck length (males).



Lines are 5th and 95th percentiles

Fig. 2b. Percentile chart for neck length (females).

TABLE **IB**-*Neck Length at Different Ages (Females)*

Age (yrs)	n	Mean	SD	SEM	95% CI
3	109	11.19	0.34	0.03	11.13-11.26
4	107	12.31	0.27	0.02	12.26-12.37
5	103	13.15	0.47	0.04	13.06-13.24
6	104	13.39	0.31	0.03	13.33-13.45
7	102	13.89	0.23	0.02	13.84-13.93
8	113	14.41	0.29	0.02	14.36-14.47
9	103	14.53	0.39	.0.03	14.45-14.61
10	98	14.94	0.21	0.02	14.90-14.99
11	100	15.41	0.33	0.03	15.34-15.47
12	105	15.56	0.23	0.02	15.52-15.61
13	104	15.60	0.19	0.01	15.57- 15.64
14	103	15.65	0.14	0.01	15.62-15.68
15	103	15.79	0.15	0.01	15.76-15.82

TABLE II-*Neck Length as a Percentage of Height and Sitting Height*

	n	Mean (%)	SD	SEM	95% CI
$\frac{NL \times 100}{Ht}$ %	2724	12.70	4.58	0.08	12.53-12.88
$\frac{NL \times 100}{SH}$ %	2724	21.11	6.73	0.12	20.86-21.36

NL = Neck length
SH = Sitting height
Ht = Standing height

Figures 3 & 4 also show the plots of 30 randomly selected normal children to test applicability of the linear correlation. Most of the values fall in close proximity to the values plotted for the original study population scattered around the regression line. *Table III & TV* show the data for male and females, respectively.

Figures 5 & 6 show the same regression lines with the plots of the children with genetic and dysmorphic syndromes. The data is shown in *Table V.* It can be seen that

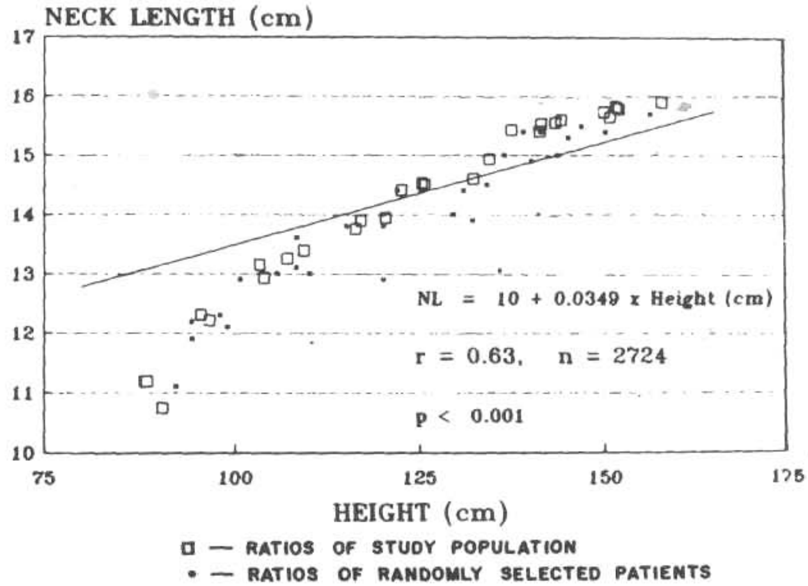


Fig. 3. Linear regression correlation-neck length and standing height: showing means of the ratios of study population and randomly selected normal patients.

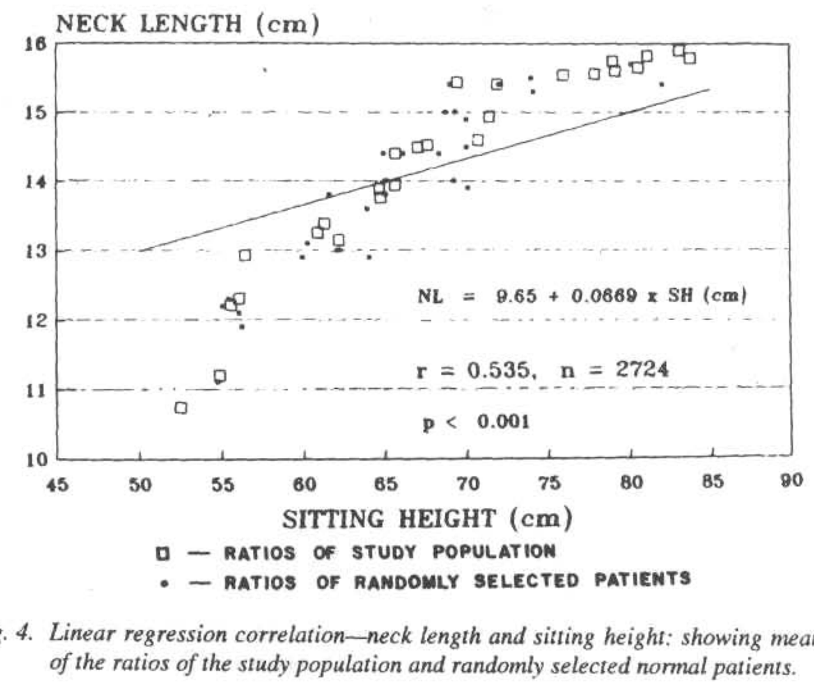


Fig. 4. Linear regression correlation—neck length and sitting height: showing means of the ratios of the study population and randomly selected normal patients.

TABLE *III-Randomly Selected Population to Validate the, Results (Males)*

No.	Age (yr)	Ht (cm)	SH (cm)	NL (cm)	Ht / NL	SH / NL	NL % of Ht	NL % of SH
1	4	94.1	55.0	12.2	7.7	4.5	13.0	22.2
2	6	108.2	60.2	13.1	8.2	4.6	12.1	21.7
3	6	110.0	62.1	13.0	8.4	4.7	11.8	20.9
4	6	100.7	59.9	12.9	7.8	4.6	12.8	21.5.
5	7	105.5	62.0	13.0	8.1	4.7	12.3	20.9
6	7	120.1	64.0	12.9	9.4	4.9	10.7	20.1
7	7	115.0	61.5	13:8	8.3	4.4	12.7	22.4
8	7	108.3	63.9	13.6	8.0	4.7	12.5	21.2
9	8	120.0	65.0	13.8	8.6	4.7	11.5	21.2
10	10	129.5	69.2	14.0	9.2	4.9	10.8	20.2
11	10	132.1	70.1	13.9	9.5	5.0	10.5	19.8
12	10	134.0	70.0	14.5	9.2	4.8	10.8	20.7
13	10	130.9	168.3	14.4	9.0	4.7	11.0	21.0
14	12	141.3	72.0	15.4	9.1	4.6	10.8	21.3
15	12	145.0	74.1	15.3	9.4	4.8	10.5	20.6

SH = Sitting height; NL = Neek length; Ht = Standing height

TABLE **IV**-*Randomly Selected Population to Validate the Results (Females)*

No.	Age (yr)	Ht (cm)	SH (cm)	NL (cm)	Ht / NL	SH / NL	NL % of Ht	NL % of SH
1	3	92.0	54.7	11.1	8.2	4.9	12.0	20.2
2	4	94.2	56.2	11.9	7.9	4.7	12.6	21.1
3	4	99.0	56.0	12.1	8.1	4.6	12.2	21.6
4	4	98.0	55.4	12.3	7.9	4.5	12.5	22.2
5	7	120.0	65.0	13.8	8.6	4;7	11.5	21.2
6	8	120.0	65.0	14.0	8.5	4.6	11.6	21.5
7	8	122.0	64.9	14.4	8.4	4.5	11.8	22.1
8	9	125.2	66.1	14.4	8.6	4.5	11.5	21.7
9	11	140.0	70,0	14.9	9.3	4.6	10.6	21.2
10	11	136.4	69.3	15.0	9.0	4.6	10.9	21.6
11	11	139.0	69.0	15.4	9.0	4.4	11.0	22.3
12	11	143.5	68.7	15.0	9.5	4.5	10.2	21.8
13	12	146.8	74.0	15.5	9.4	4.7	10.5	20.9
14	15	156.2	80.1	15.7	9.4	5.1	10.0	19.6
15	15	150.1	82.0	15.4	9.7	5.3	10.2	18.8

SH = Sitting height, NL = Neek length, Ht = Standing height, the values fall far below the lines.

Discussion

No clinical definition of short neck exists in literature to date. The present study is the first attempt to create standards, percentiles and ratios for neck length in children using strict measurement criteria. The school population chosen would reasonably represent a cross-section of healthy urban children in whom documented birth dates could be obtained from school records. The lower age of 3 years was chosen for logistic feasibility of measuring the neck with the child standing still in the desired position. It was also found, before the study actually commenced; that accurate localization of the bony points used for measuring neck length was difficult in very young infants and toddlers. The occipital protuberance is

TABLE V-*Selected Cases with Short Neck as a Dysmorphic Feature*

Age	Sex	Diagnosis	Ht (cm)	SH (cm)	NL (cm)	Ht/NL	SH/NL	NL as % of Ht	NL as % of SH
3	M	MPS	86.5	47	9.5	9.1	4.9	11.0	20.2
10	M	MPS	90.0	48	6.0	15.0	8.0	6.7	12.5
10	M	MPS	116.0	57	6.0	19.3	9.5	5.2	10.5
12	F	MPS	99.0	50	6.0	16.5	8.3	6.1	12.0
3	F	K-F	79.0	41	4.5	17.5	9.1	5.7	11.0
8	F	K-F	111.0	63	7.0	15.8	9.0	6.3	11.1
13	F	K-F	128.0	62	9.4	13.6	6.6	7.3	14.7
14	F	K-F	125.0	66	12.0	10.4	5.5	9.6	18.2
4	F	SED	75.0	46	7.2	10.4	6.3	9.6	15.6
10	F	SED	92.0	53	7.0	13.1	7.6	7.6	13.2
15	M	SED	121.0	58	8.0	15.1	7.2	6.6	14.8
14	F	TS	129.0	70	8.0	16.1	8.7	6.2	11.4
12	F	FDS	145.0	72	11.0	13.2	6.5	7.5	15.2
7	F	Hypo-c	100.5	58	8.0	12.6	7.2	8.0	13.7
8	F	Ach	96.0	44	6.0	16.0	7.3	6.2	13.6
7	F	OI	97.0	56	9.0	10.7	6.2	9.9	16.1

MPS = Mucopolysaccharidoses
SED = Spondylo epiphyseal dysplasia
OI = Osteogenesis Impcrfccta
Hypo-c = Hypochondroplasia
SH = Sitting height
FDS = Frontonasal dysplasia sequence
Ach = Achondroplasia
TS = Turner syndrome
KF = Klippel Feil syndrome
NL = Neck length
Ht = Standing, height

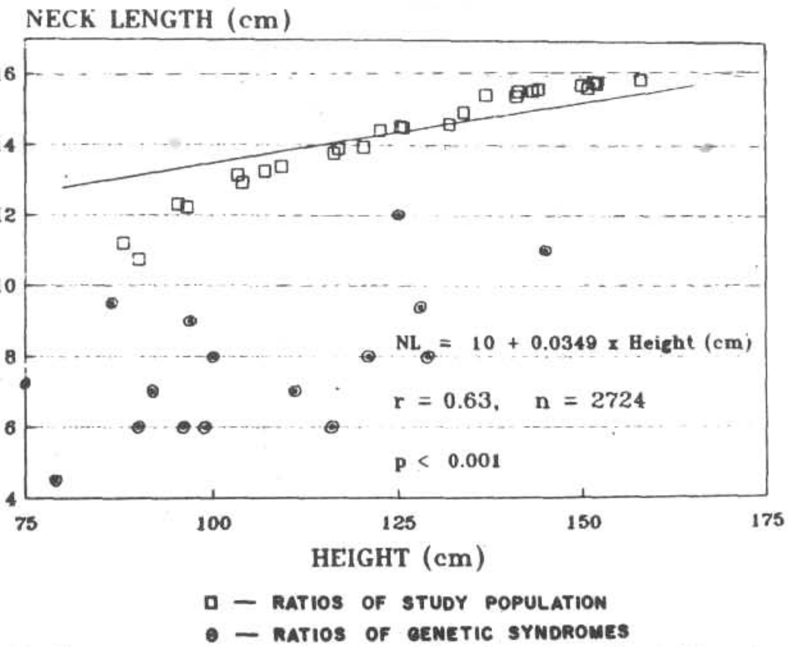


Fig. 5. Linear regression correlation–neck length and standing height–plots of patients with short neck syndromes.

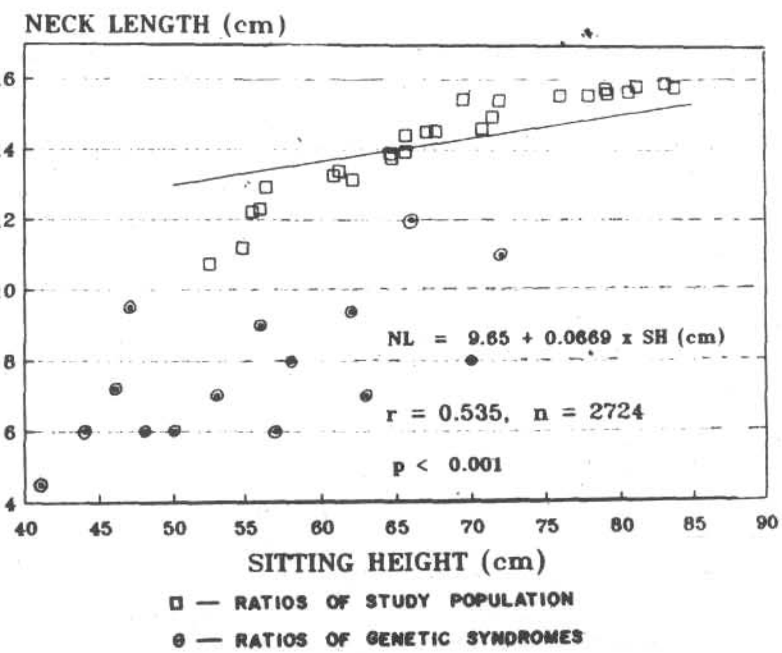


Fig. 6. Linear regression correlation of neck length and sitting height–plots of patients with short neck syndromes.

difficult to locate, especially with flattening or skull asymmetry. The C7 spine is difficult to palpate under the pad of fat and neck folds in young infants. The bony points chosen make for technical accuracy as they are identifiable and fixed unlike other more variable anatomical projections that may have been used.

The results reveal a steady increase in neck length with age and height, with rapid growth from 3 to 6 years, followed by a gradual falling off of the curves. As the study did not include children over 15 years, the exact time of cessation of growth of the neck cannot be pinpointed. It is also likewise difficult to comment on a second peak velocity of growth of the neck along with the pubertal growth spurt.

The 5th and 95th percentile lines for both sexes are close together indicating narrow variation. Another interesting finding is that, in each age group, the girls have higher values. These gradually equal and fall below the values for boys by 12 to 13 years. This needs to be confirmed by similar studies and may be partly a reflection of the earlier onset of puberty in girls; giving them a slight edge over boys at this time.

The percentage ratios of neck length to standing height of 12.7 ± 4.58 and neck length to sitting height of 21.11 ± 6.73 are useful figures for quick assessment of short neck in childhood and early adolescence. The mean inverse ratio of height to neck length of 8.37 ± 1.7, which is constant irrespective of age and sex, can be compared with an unpublished study of 100 normal children and adults aged 10 to 55 years. Bhatt MS—dissertation submitted to University of Bombay, 1975 on "Study of Craniovertebral anomalies"). The mean height to neck length ratio was 9.96-14.6 with a mean of 12.85. In contrast, the narrower range seen in the present study is probably statistically more accurate. The other study has only a total of 100 cases and has averaged values of a growing dynamic age group with a static adult population.

The linear relationship of neck length to standing and sitting height with their equations are probably the most significant statistical data available for practical use for dysmorphic diagnosis from this study and provide an age and sex-independent correlation between the measurements.

Our own attempt at validation with 30 randomly selected normal children indicate that the lines seem to work *(Figs. 3 & 4).* More children need to be studied and their measurements plotted for validation. The cases of short neck plotted way below *(Figs. 5 &6)* which seems to validate use of these correlations in the quantitative assessment of short neck.

Practical difficulties in the study were: *(i)* inter-observer variability of as much as 1 cm if the position of the external occipital protuberance was not clearly defined; *(ii)* Observer variability at different recordings with differing neck positions; and *(iii)* difficulty in getting younger children to hold the neck steady in the desired posture. These practical difficulties were anticipated and minimized by laying down strict criteria for head positioning, having a single observer perform all the measurements and eliminating infants and toddlers from the study.

For creation of universal standards, multiple ethnic groups must contribute to the data and include the whole adolescent age range. Socio-economic differences and deprivation are unlikely to cause significant deviations. The results of the present study are encouraging and provide a sound basis for creation of global standards to provide objective evidence of short neck.

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