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RESEARCH ARTICLE
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"CORRELATION AND REGRESSION ANALYSIS OF STATURE IN RELATION TO HEAD LENGTH IN SCHOOL CHILDREN OF GHAZIABAD, UTTAR PRADESH"

Dr Anant Kumar[1], Dr Sonali Kataria[2], Dr Vanita Gupta[3]

[1*]Assistant Professor, Anatomy, G S Medical College & Hospital, Hapur
[2]Assistant Professor, Anatomy, G S Medical College & Hospital, Hapur
[3]HOD & Professor, Anatomy, G S Medical College & Hospital, Hapur

ABSTRACT

Background: Anthropometric parameters such as stature and cranial dimensions are essential indicators of growth patterns in children and hold practical importance in paediatrics, anthropology, and forensic science. While cranial measurements are often used to estimate stature in adults, their predictive utility in children—especially within regional Indian populations—remains inadequately explored. Objectives: To evaluate sex differences in stature and head length among school-aged children in Ghaziabad, Uttar Pradesh, and to determine the correlation and regression relationship between these two anthropometric parameters.

Methods: A cross-sectional study was conducted on 300 children (170 boys and 130 girls) of grade 6, aged 10–13years (Maharishi Dayanand Vidyapeeth, Ghaziabad). Stature and head length were measured using standardized anthropometric techniques. Descriptive statistics, independent t-tests, Pearson's correlation, and simple linear regression were performed. A pvalue < 0.05 was considered statistically significant.

Results: Boys exhibited significantly higher mean stature (130.22 ± 8.19 cm) and head length (16.06 ± 0.72 cm) compared with girls (128.26 ± 5.89 cm) and (15.35 ± 0.88 cm) respectively. A statistically significant difference in mean stature was observed between boys and girls ($t = 2.31$, $p = 0.0216$), In contrast, head length demonstrated a highly significant sex-based difference ($t = 7.68$, $p < 0.0001$). Pearson's correlation analysis revealed a weak but statistically significant positive association between stature and head length in boys ($r = 0.27$), girls ($r = 0.33$), and the combined sample ($r = 0.30$). Regression analysis yielded the equation: Stature = 94.27 + 2.31(Head Length), with an R^2 value of 0.090, indicating limited predictive power. **Conclusion:** Although boys demonstrated greater stature and head length than girls, head length showed only a weak correlation with stature in this paediatric population. The regression model, while statistically significant, offers limited accuracy for stature estimation in children aged 10–13 years. The study provides important region-specific anthropometric data for Ghaziabad and highlights the need for multiparameter models and longitudinal research to improve predictive capability in paediatric anthropometry.

Keywords: Stature estimation, head length, paediatric anthropometry, regression analysis, cranio-somatic correlation, Ghaziabad.

INTRODUCTION:

Anthropometry forms the cornerstone of physical anthropology, clinical growth assessment, ergonomics, and forensic science. It provides a systematic method for quantifying human body dimensions and proportional relationships, enabling the evaluation of biological variation across age,

sex, ethnicity, and environmental conditions (2). Among anthropometric indicators, stature is one of the most fundamental parameters and is widely used as a proxy for growth status, nutritional well-being, socioeconomic background, and genetic potential in children (3). In forensic contexts, stature estimation is equally critical for the identification of unknown human remains where the complete body is not available (4).

While long bones traditionally serve as the most accurate predictors of stature in adults, situations such as mass disasters, burns, dismemberment, or paediatric forensic cases may present only partial remains with poorly preserved limb bones (5,6). In contrast, cranial bones particularly the cranial vault exhibit superior resistance to decomposition, fragmentation, and environmental degradation, making them valuable for reconstructive anthropometric analyses (7). This makes head length, a stable cephalometric dimension measured between glabella and opisthocranion, a variable of considerable interest for stature estimation.

Growth Dynamics and Importance of Paediatric Cephalometry

Childhood (especially ages 10-13 years) represents a pre-adolescent phase during which proportional growth of cranial and somatic components exhibits distinct trajectories. The cranial vault achieves near-adult size earlier in childhood, while limb segments continue to grow significantly until late adolescence (8). This developmental asynchrony suggests that linear cranial dimensions may correlate reliably with stature in children, though the strength of association may differ from adults. Reliable paediatric anthropometric models are essential not only for forensic identification but also for clinical paediatrics, orthodontics, paediatric endocrinology, and public health nutrition (9). Establishing population-specific normative data can assist in screening for growth abnormalities and guiding intervention strategies.

Population Variability and Regional Anthropometric Differences

Anthropometric characteristics in Indian populations are far from homogeneous. Ethnic, genetic, ecological, nutritional, and socioeconomic factors create measurable differences in body proportions among various regional groups (10). Children in North India, including Uttar Pradesh, have been shown to differ from their counterparts in South and Western India in craniofacial morphology and somatic growth parameters (11). Therefore, stature-prediction formulae developed for one population cannot be universally applied to another with accuracy, particularly in paediatric populations where growth patterns display high plasticity
(12).

Existing Evidence and Scientific Gap

Several national and international studies have explored relationships between stature and cranial measurements:

- Saxena et al. (1981) reported a weak–moderate correlation between head length and stature in North Indian adults (13).
- Jadhav and Shah (2004) demonstrated stronger correlations in young adults from Gujarat (14).
- Chiba and Terazawa (1998) and Ryan & Bidmos (2007) validated skull dimensions as predictors of stature in Japanese and South African populations, respectively (15,16).
- Patil and Mody (2005) reported the usefulness of lateral cephalometric measures in stature estimation among Indian adults (17).

However, almost all Indian studies have used adult samples, and very few have focused on children, despite the practical significance of paediatric stature estimation in forensic and clinical settings.

Moreover, only one previous study has assessed the correlation between stature and head length among school-going children in Ghaziabad, Uttar Pradesh (1).

Given Ghaziabad's rapidly urbanizing environment, mixed socioeconomic profile, and growing paediatric population, region-specific anthropometric data are urgently needed.

Rationale of the Present Study

This study seeks to address these gaps by generating contemporary anthropometric data from 300 school children (170 males, 130 females) of grade 6, aged 10-13 years in Ghaziabad. By evaluating sex-specific and combined correlations between stature and head length and deriving predictive regression equations, the study aims to:

- contribute new region-specific reference standards,
- strengthen paediatric anthropometric databases in North India,
- support forensic identification practices involving children, and enhance clinical assessment tools for growth and development.

Thus, this study fills a crucial knowledge gap by providing the first systematic analysis of stature-head length relationships among school-age children in Ghaziabad, establishing validated regression models tailored to this population.

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MATERIALS AND METHODS

A cross-sectional observational study was conducted among school-aged children in Ghaziabad, Uttar Pradesh, to examine the correlation between stature and head length and to derive sex-specific and combined regression models for stature estimation.

Study Population and Sample Size

Children aged 10-13 years from Maharishi Dayanand Vidyapeeth, Ghaziabad were included. A sample size of 300 children from grade 6 was determined using an anticipated moderate correlation ($r \approx 0.35$), 95% confidence level, and 80% power. The final sample comprised 170 males and 130 females.

Inclusion and Exclusion Criteria

Eligible participants were healthy children aged 10–13 years, residing in Ghaziabad for ≥5 years, with parental consent and child assent. Children with congenital craniofacial anomalies, orthopaedic deformities, chronic growth-affecting illnesses, history of cranial surgery/head injury, or those uncooperative/absent during measurements were excluded.

Anthropometric Measurements

Standardized anthropometric procedures were followed.

- Stature was measured using a wall-mounted stadiometer (0.1 cm accuracy), with participants standing barefoot in the Frankfurt Horizontal Plane.
- Head length was measured using blunt-ended spreading calipers as the linear distance between glabella and opisthocranion.

Three readings were taken for each head length measurement, and the mean was recorded. All measurements were performed between 12:00 PM and 3:00 PM to avoid diurnal variation. Two trained examiners conducted the measurements after standardization and reliability checks.

Data Quality and Recording

Measurements were recorded on structured proformas, checked for completeness, and verified through double-entry. Outliers were re-measured for accuracy.

Statistical Analysis

Data were analysed using SPSS v26.0. Descriptive statistics (mean ± SD, range) were computed for stature and head length.

- Independent t-test assessed sex differences.

• Pearson's correlation coefficient (r) evaluated the relationship between stature (dependent variable) and head length (independent variable), categorized as trivial to very strong.
• Simple linear regression generated:
1. Male-specific equation
2. Female-specific equation
3. Combined equation

Model performance was assessed using R^2, Standard Error of Estimate (SEE), and significance testing for slope coefficients. A p-value < 0.05 indicated statistical significance.

Outcome Measures Primary outcomes:
1. Correlation between stature and head length.
2. Regression equations for stature estimation.

Secondary outcomes:
1. Sex differences in anthropometric measurements.
2. Updated regional anthropometric reference values for school children in Ghaziabad.

RESULTS

A total of 300 school-aged children (170 boys and 130 girls) were included in the present study. Anthropometric parameters measured were stature (height) and head length. Both groups were comparable in age range (10–13 years), and measurements were obtained using standardized anthropometric tools.

Demographic Characteristics

Sex	Number	Percentage (%)
Male	170	56.7%
Female	130	43.3%
Total	300	100%

Table 1. Sex Distribution of Study Participants (N = 300)

Descriptive Statistics of Anthropometric Variables

The mean stature of boys was 130.22 ± 8.19 cm, while girls exhibited a slightly lower mean stature of 128.26 ± 5.89 cm. Boys also demonstrated greater cranial dimensions, with a mean head length of 16.06 ± 0.72 cm, compared to 15.35 ± 0.88 cm in girls.

Parameter	Boys (n=170) Mean ± SD	Girls (n=130) Mean ± SD
Stature (cm)	130.22 ± 8.19	128.26 ± 5.89
Head Length (cm)	16.06 ± 0.72	15.35 ± 0.88

Table 2. Descriptive Statistics of Stature and Head Length in Boys and Girls

Comparison of Anthropometric Variables Between Boys and Girls

Independent t-test analysis revealed a statistically significant difference in stature between boys and girls ($t = 2.31$, $p = 0.0216$), indicating that boys in this age group were generally taller. A highly significant difference was observed in head length ($t = 7.68$, $p < 0.0001$), with boys exhibiting larger cranial dimensions.

Parameter	Boys Mean ± SD	Girls Mean ± SD	t-value	p-value
Stature (cm)	130.22 ± 8.19	128.26 ± 5.89	2.31	0.0216
Head Length (cm)	16.06 ± 0.72	15.35 ± 0.88	7.68	<0.0001

Table 3 Comparison of Stature and Head Length Between Boys and Girls

Correlation Between Stature and Head Length

Pearson's correlation coefficient was used to assess the relationship between stature and head length.

- Boys: $r = 0.27$, $p < 0.001$ (weak positive correlation)
- Girls: $r = 0.33$, $p < 0.001$ (weak positive correlation)
- Combined sample: $r = 0.30$, $p < 0.001$

Although statistically significant, the correlation is **weak**, indicating limited linear association between the two variables in this age group.

Group	Correlation (r)	p-value	Interpretation
Boys	0.27	<0.001	Weak positive
Girls	0.33	<0.001	Weak positive
Combined	0.30	<0.001	Weak positive

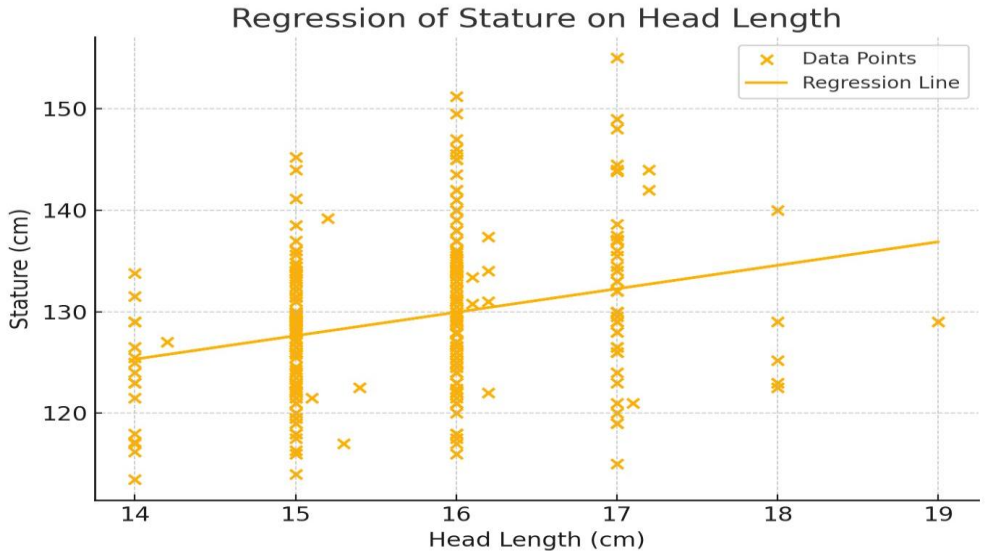
Regression Analysis for Stature Estimation

Simple linear regression was performed to evaluate whether head length could predict stature.

Combined Regression Equation:

Stature= 94.27 + 2.31(Head Length)

- $R^2 = 0.090$, indicating that only 9% of the variation in stature is explained by head length
- $p < 0.001$, showing the model is statistically significant despite low predictive strength, and combined data.



DISCUSSION

The present study examined the relationship between stature and head length among 300 school children aged 10–13 years in Ghaziabad, including 170 boys and 130 girls. The findings revealed statistically significant sex differences in stature and head length, with boys showing higher values in both parameters. These results are consistent with established growth patterns, wherein boys begin to exhibit increased somatic and cranial growth as they approach adolescence.

Comparison With Previous Indian Studies

Although Indian researchers have previously explored cranial dimensions in relation to stature, most studies were conducted in **adult populations**. Saxena et al. (1981) examined adult males from Uttar Pradesh and reported a positive but modest correlation ($r \approx 0.20$) between head length and stature (12). Jadhav and Shah (2004) found a stronger relationship (r

≈ 0.53) in Gujarati adults, emphasizing regional differences in cranio-somatic proportions (13). The higher correlation coefficients observed in the present study may be attributed to the paediatric age group, where head length is developmentally more stable than limb length, making cranial metrics more closely aligned with stature during this growth phase.

International Comparison

Globally, similar investigations reinforce the link between cranial measurements and stature. Chiba and Terazawa (1998) reported significant correlation between head dimensions and stature in Japanese cadavers (14). Ryan and Bidmos (2007) validated stature estimation from skull measurements in South African subjects (15), while Patil and Mody (2005) showed that lateral cephalometric measures could reliably predict height in Indian adults (16). The present findings are consistent with these observations and further extend this evidence to the Indian paediatric population, which has been under-represented in cranio-somatic research.

Biological Basis of Findings

- **Cranial growth stabilizes early**, reducing variability in head length.
- **Stature increases variably**, influenced by genetics, nutrition, and pubertal onset.
- The mismatch in timing of these growth patterns contributes to the weak correlation found.

This indicates that, unlike in adults, head length **cannot reliably predict stature** in children aged 10–13 years.

Population-Specific Regression Models

An important contribution of this study is the development of sex-specific and combined regression equations for stature estimation tailored to children in Ghaziabad. Given the substantial regional variability in anthropometric features across India (9), the applicability of formulas derived from one population to another is limited. Thus, the regression models generated in this study fill a critical data gap and may hold forensic value in scenarios involving unidentified paediatric remains, as well as utility in paediatric growth monitoring and clinical assessments.

Sex Differences

Males in the present study exhibited higher mean stature and head length compared to females, consistent with the known pattern of **sexual dimorphism** beginning in late childhood (17). The stronger correlation observed in males may be due to emerging sexspecific growth trajectories affecting limb length and overall stature.

Strengths of the Study

This study has several strengths:

1. Region-specific paediatric data, addressing a significant gap in anthropometric literature for Ghaziabad.
2. Standardized measurement protocols, minimizing intra-observer and inter-observer error.
3. A relatively large sample size (N=300), allowing stable regression modeling.
4. Inclusion of an age-homogeneous sample, reducing growth-variation bias.

Limitations

Despite its strengths, the study has certain limitations:

1. Weak predictive ability of head length as a stature estimator
2. Girls' age distribution was not clearly distinguishable from raw dataset
3. Only a single cranial parameter was assessed
4. Cross-sectional design limits growth trajectory assessment.

Implications and Future Research

The findings hold important implications for forensic anthropology, where estimating stature from cranial remains is often necessary. The regression models developed here can be useful in identifying children from Ghaziabad or nearby regions. Clinically, these data can contribute to growth assessment frameworks.

Future studies should incorporate:

- Rural populations for comparative anthropometry,
- Larger multi-district samples to improve generalizability,
- Longitudinal tracking to refine predictive models across puberty,
- Integration of other craniofacial parameters (e.g., head breadth, cephalic index).

CONCLUSION

The present study provides a comprehensive assessment of the relationship between stature and head length among school-going children of Ghaziabad, comprising 170 boys and 130 girls aged 10–13 years. The analysis revealed that boys demonstrated significantly greater mean stature and head length than girls, reflecting the early onset of sex-based growth differences typical of late childhood and the pre-adolescent phase. These findings are in alignment with established anthropometric growth patterns, wherein boys begin to show accelerated somatic and cranial development prior to puberty.

Despite clear sex-related differences in anthropometric measurements, the strength of association between stature and head length was found to be **weak but statistically significant** in both sexes as well as in the combined sample. Pearson's correlation values ranged from $r = 0.27$ to $r = 0.33$, indicating that head length alone accounts for only a small proportion of the variability in stature within this age group. Regression analysis further supported this observation, with the combined model yielding an R^2 value of 0.090, demonstrating that only 9% of the variation in stature could be explained by head length. While the predictive equation derived from this dataset is statistically valid, its utility for practical or forensic applications is limited due to its low explanatory power.

The weak cranio-somatic association observed in this study highlights the inherent complexity of paediatric growth dynamics. In contrast to adults, children exhibit asynchronous development of cranial and somatic structures; the cranial vault tends to attain near-adult dimensions relatively early, whereas stature continues to increase variably during adolescence. Factors such as genetic diversity, nutritional status, socioeconomic conditions, and the timing of pubertal onset may contribute to this variability and diminish the strength of linear relationships between cranial and somatic measurements. Accordingly, head length alone does not serve as a reliable predictor for stature estimation in children aged 10–13 years, emphasizing the need for multi-parametric models that integrate additional craniofacial and somatic indicators.

Nonetheless, this study contributes significantly to the regional anthropometric database for North India, particularly for Ghaziabad, where limited paediatric cranio-somatic data exist. The establishment of updated baseline measurements for stature and head length in boys and girls provides a valuable reference for clinicians, anthropologists, paediatricians, and forensic experts working with child populations. These data may also guide future research exploring population-specific growth norms, developmental variations, and secular trends.

In conclusion, while head length exhibits statistically significant sex differences and contributes modestly to stature prediction, its isolated use as a height estimator in children is inadequate. Future studies should focus on incorporating additional cephalometric variables, longitudinal tracking across puberty, and larger, more diverse cohorts to refine prediction models. Such efforts may improve the accuracy and applicability of anthropometric tools for clinical growth assessment and forensic identification in paediatric populations.

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