Original Article

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Anatomy Section

Estimation of Stature using Upper Limb Dimensions among the Adolescent Population of Kolkata: An Analytical Cross-sectional Study

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ABSTRACT

Introduction: Apart from age, sex and racial affiliation, the estimation of stature from human extremities is an important step in developing a biological profile for identifying an unknown individual, especially when the body found is either dismembered, mutilated, or disfigured.

Aim: To estimate the stature from upper arm dimensions such as arm span, Hand Length (HL) and Hand Breadth (HB) in the adolescent age group of the West Bengal population.

Materials and Methods: The present analytical cross-sectional study was conducted at a school in Kolkata from January 2023 to March 2023, involving 120 adolescent school-going boys aged 10-16 years. The arm span, HL and HB of both right and left hands were measured using standard anthropometric procedures. The Pearson's correlation coefficient was used to assess the relationship between stature and various upper limb dimensions. The significance of differences was tested using an independent t-test.

Results: The mean age of the study population was 12.05 years. The mean of arm span was 145.83 cm and, mean of HB (right and left sides) and; HL (right and left sides) were 7.52953 cm and 7.52955 cm; 16.13221 cm and 16.13218 cm, respectively. Univariate linear regression analysis showed that all variables, including arm span, HB and HL were significant predictors of stature (p-value <0.01). Multivariate analysis demonstrated that arm span (R2=89.81%) and HL (R2=75.69%) had the highest prediction accuracy for stature.

Conclusion: All variables (arm span, HL and HB) were found to be statistically significant predictors of stature, with arm span and HL having the highest prediction accuracy. These measurements of upper limbs and regression equations can be used for the identification of unknown human remains, particularly in cases of dismembered bodies.

Keywords: Anthropology, Human identification, Linear regression, Styloid processes of radius and ulna, Upper extremity

INTRODUCTION

Identification and determination of stature, i.e., anthropometry, are vital aspects of the medical field, especially forensic medicine. Identification refers to the task of determining the identity of an individual, whether living or deceased, with the help of specific characteristics or features [1]. One such parameter is stature, which is crucial for personal identification. Given the increasing incidence of mass destruction in today's world, such as bombings, accidents, and natural calamities like earthquakes and floods, as well as, cases of murder and homicide where mutilated and dismembered body parts are found. The identification and determination of stature are challenging tasks for anatomists, forensic specialists and anthropologists [2,3].

Several studies have been published on estimating the stature of skeletal remains [1-4]. Two methods of stature estimation have been established: the mathematical method and the anatomical method [5]. In the anatomical method, the entire skeleton and various correlation factors are required to estimate an individual's stature. However, the mathematical method requires only single bones or body parts and makes use of regression formulas or multiplication factors to estimate stature [5,6]. In cases where an entire skeleton or long bone is unavailable, such as when bodies are dismembered or mutilated during conflicts, mass disasters, or as a result of criminal actions, the development of standard calculations using different parts of the human skeleton is a practical alternative [6,7].

Another important aspect is that stature varies among individuals based on race, sex, age, genetic factors and nutritional status. The aim of the present study was to identify an individual by calculating the stature from upper arm dimensions such as arm span, HL, and HB in the adolescent age group of the West Bengal population in India. A previous study was conducted in which stature was calculated from the lower limb population in adolescent boys in the Kolkata population [8].

MATERIALS AND METHODS

The present analytical cross-sectional study was conducted at a boys' school in Kolkata, India, from January 2023 to March 2023 among 120 adolescent school-going boys. Proper consent was obtained from the Institutional Ethical Committee (IPGMER/IEC/2022/253) and school authority, as well as, from the parents/guardians of the children through a consent form written in the local, lucid regional (in this case, Bengali) language.

Inclusion criteria: Boys of adolescent age group without the above-mentioned criteria were included in the study.

Exclusion criteria: Boys with any fracture in the upper limb region, or suffering from boils, burns, or any associated congenital abnormalities, or with any absence or amputated part or whole of the upper limb, were excluded from the study.

Study Procedure

Sampling was conducted using the complete enumeration method. Shoes, socks, and bulky clothing were removed prior to all measurements. All measurements were taken in a well-lit

room. Each measurement was repeated three times by two trained undergraduate medical students to minimise any observer's bias, and the mean reading of all the measurements was recorded. All measurements related to length and height were taken in centimetres.

The subjects were instructed to stand straight against a wall with their heels in contact with the wall, hands and face looking anteriorly. The height of the subjects was defined as the straight distance from the most inferior part of the heel to the vertex of the head, with the vertex marked by a pencil, and the distance measured using a measuring tape [7]. All upper limb measurements were taken from both the Right (R) and Left (L) sides. The anthropometric measurement points for the measurements in the study are detailed in the following sections.

Arm span: The distance between the middle fingertips on each hand when the subject was instructed to stand against a wall with stretched arms out, as far as, they could reach [7].

Hand length: HL was measured as the distance between the middle point of the line connecting the styloid processes and the tip of digit III (middle finger) [7].

Hand breadth: HB was measured as the distance between the distal tips of metacarpals II and V, with the fingers of the left hand touching each other [7].

STATISTICAL ANALYSIS

The data were analysed using Statistical Package for the Social Sciences (SPSS) software version 16.0 for Windows and Microsoft Office Excel 2010. Descriptive statistical analysis for various upper limb dimensions was performed. The relationship between height and various upper limb dimensions was determined by Pearson's correlation analysis. Linear regression analysis and multiple regression analysis were used to calculate equations for stature estimation and to achieve the best possible estimate.

RESULTS

The mean age of the study population was 12.05 years. HL and HB were recorded bilaterally, but arm span- the distance between the tips of the middle fingers of the outstretched hand is a single value. The mean values of arm span, HB (right and left sides), and HL (right and left sides) were 145.83 cm; 7.52953 cm and 7.52955 cm; 16.13221 cm and 16.13218 cm, respectively [Table/Fig-1].

Parameters	Minimum	Maximum	Mean	Standard deviation
Weight (kg)	21.9	69.3	38.89	0.82958
Height	119.4	167	144.123	10.1708
Arm span	123.2	173	145.8336	0.95852
Hand Length (HL) (R)	13.2	19.5	16.13221	0.11524
Hand Length (HL) (L)	13.18	18.98	16.13218	0.11529
Hand Breadth (HB) (R)	5	9.5	7.52953	0.06665
Hand Breadth (HB) (L)	4.8	9.48	7.52955	0.06665

[Table/Fig-1]: Descriptive statistics: stature and upper limb measurements (cm).

In the univariate linear regression analysis, arm span, HB, HL of both sides, as well as, weight were significant predictors of stature (p-value <0.01) [Table/Fig-2]. When considering prediction accuracy, arm span (R^2=89.81%) and HL (R2= 75.69% for right and R2=75.69% for left) provided the highest prediction accuracy for stature, while HB (R2=49.67% for right and R2=49.65% for left) produced less than 50%. Linear regression graphs (x-axis:variables; y-axis:height) for arm span, HL (both right and left), and HB (for right and left hands) were shown in [Table/Fig-3-7].

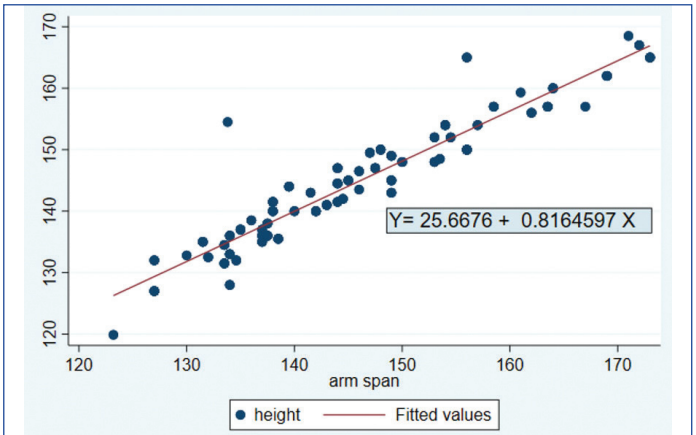
The linear regression equations are as follows:

Height=25.6676+0.8164597 * Arm span

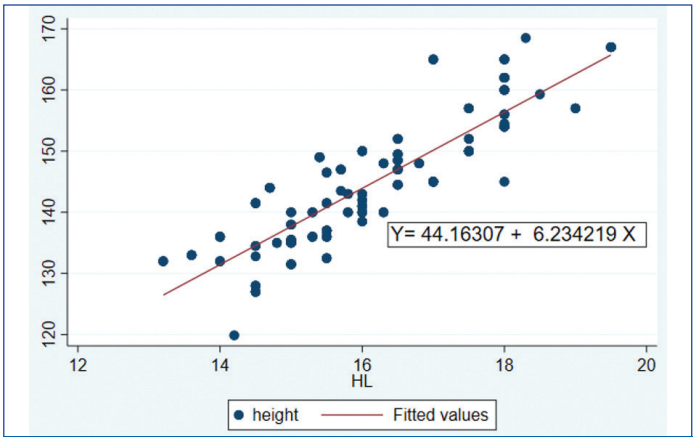
Height=44.16307+6.234219 * HL (right)

Parameters	Pearson's correlation	p-value
Weight	0.7155	**<0.01**
Arm span	0.9477**	**<0.01**
Hand Length (HL) (R)	0.8700**	**<0.01**
Hand Length (HL) (L)	0.87**	**<0.01**
Hand Breadth (HB) (R)	0.7048**	**<0.01**
Hand Breadth (HB) (L)	0.7047	**<0.01**

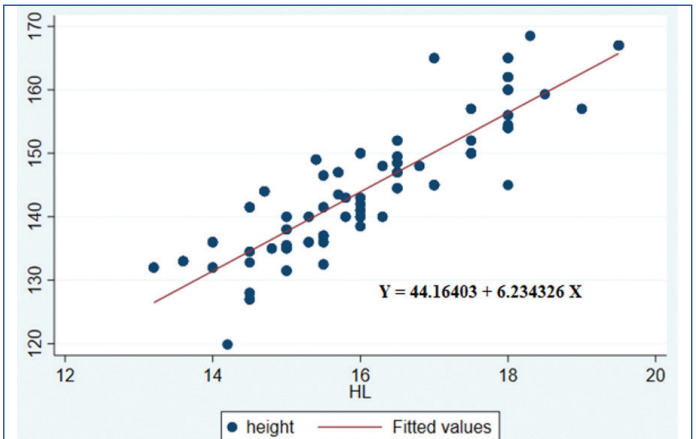
[Table/Fig-2]: Univariate stature prediction (linear regression analysis).
**Correlation is significant at the 0.01 level (2 tailed); The p-value in bold font indicates statistically significant values



[Table/Fig-3]: Graph depicting the linear regression between height/stature and arm span (x-axis=arm span; y-axis=stature).



[Table/Fig-4]: Graph depicting the linear regression between height/stature and Hand Length (HL) (Right) (x-axis=HL; y-axis=stature).



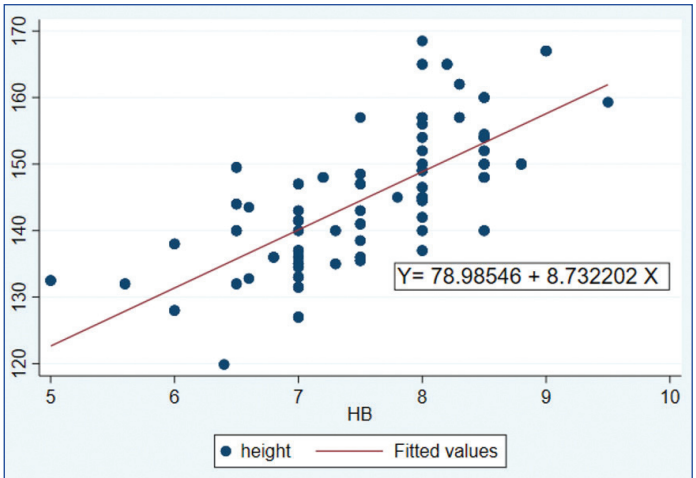
[Table/Fig-5]: Graph depicting the linear regression between height/stature and Hand Length (HL) (left) (x-axis=HL; y-axis=stature).

Height=44.16403+6.234326 * HL (left)

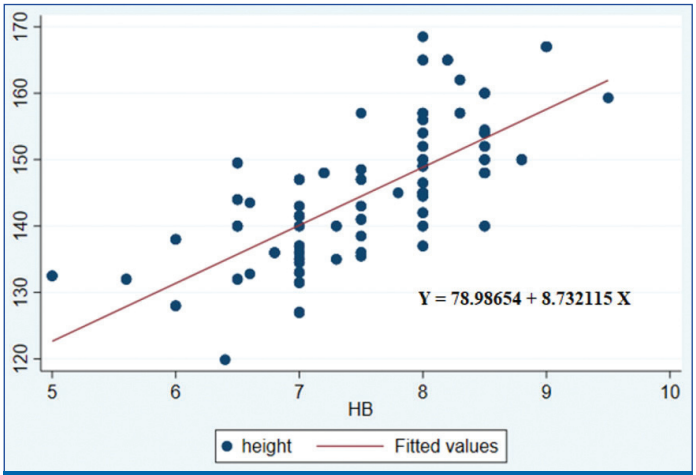
Height=78.98546+8.732202 * HB (right)

Height=78.98654+8.732115 * HB (left)

Height=118.3487327+0.715460833 * Weight



[Table/Fig-6]: Graph depicting the linear regression between height/stature and Hand Breadth (HB) (Right) (x-axis=HB; y-axis=stature).



[Table/Fig-7]: Shows the graph depicting the linear regression between height/stature and Hand Breadth (HB) (left) (x-axis=HB; y-axis=stature).

From [Table/Fig-8,9] of the multivariate linear regression model, only arm span and HL, along with weight (p-value <0.05) contributed to the prediction model for stature, while HB made a contribution that was not significant (p-value >0.05).

Multiple regression equation for the right-side is:

Height=28.22842216+0.078801917 * Weight+0.630996701 * Arm span+1.327504545 * HL (R)+0.021797391 * HB (R).

Multiple regression equation for left-side is:

Height=28.22842216+0.078801917 * Weight+0.630996701 * Arm span+1.327504367 * HL (L)+0.021795731 * HB (L).

Parameters	Coefficient	Standard error coefficient	p-value
Weight	0.078801917	0.0378	**<0.01**
Arm span	0.630996701	0.0800	**<0.01**
Hand Length (HL)	1.327504545	0.5521	**<0.01**
Hand Breadth (HB)	0.021797391	0.4276	0.95

[Table/Fig-8]: Multiple regression analysis of upper limb (right side) variables.

Parameters	Coefficient	Standard error coefficient	p-value
Weight	0.078801917	0.0378	**0.001**
Arm span	0.630996701	0.0800	**0.001**
Hand Length (HL)	1.327504367	0.5515	**0.001**
Hand Breadth (HB)	0.021795731	0.4271	0.95

[Table/Fig-9]: Multiple regression analysis of upper limb (left side) variables.

DISCUSSION

From various studies, it has been observed that different factors such as gender, ethnic group and study methods influence stature equations [8-12]. In the present study, arm span demonstrated the highest correlation with stature. [Table/Fig-10] presents the findings of previous studies [13-24]. The next highest correlation was found between stature and HL (r-value=0.87), which is very close to the work of Sanli SG et al., (r-value=0.722) in 2005; Habib SR and Kamal NN (r-value=0.697) in 2010, and Akhlaghi M et al., (r-value=0.696) in 2010 [16,22,23].

Name of the author	Year and place of the study	Pearson's correlation between arm span and stature	Pearson's correlation between HL and stature	Pearson's correlation between HB and stature
Bhatnagar DP et al., [13]	1984, India	----------	----------	----------
Abdel-Malek AK et al., [14]	1990, Egypt	----------	----------	0.39
Jasuja OP and Singh G [15]	2004, India	----------	0.452	----------
Sanli SG et al., [16]	2005, Turkey	----------	0.722	----------
Ozaslan A et al., [17]	2006, Turkey	----------	0.53	0.14
Krishan K and Sharma A [18]	2007, India	----------	----------	0.537
Rastogi P et al., [19]	2008, India	----------	0.664	0.592
Agnihotri AK et al., [20]	2008, India	----------	0.594	----------
Ilayperuma I et al., [21]	2009, Sri Lanka	----------	0.58	----------
Habib SR and Kamal NN [22]	2010, Egypt	----------	0.697	----------
Akhlaghi M et al., [23]	2010, Iran	----------	0.696	0.31
Uzun Ã et al., [24]	2019, Turkey	----------	0.339	0.248
Present study	2022, India	0.947	0.87	0.704

[Table/Fig-10]: Findings of previous studies with respect to Pearson's correlation as compared with the results of the present study [13-24].

In the present study, it was discovered that arm span has the highest correlation with stature (r-value=0.947), which is close to the value of r-value=0.89 reported by Supare MS et al., in 2015 [25]. The correlation between HB and stature in our study was also notable (r-value=0.704), similar to the findings of Rastogi P et al., in 2008 (r-value=0.592) and Krishan K and Sharma A (r-value=0.537) in 2007, both in India [18,19].

The present study has demonstrated a significant correlation between stature and various upper limb dimensions, among which the arm span and Hand length provided reliability and accuracy in stature estimation through the use of regression equations. Genetic factors, race and ethnicity are the main determinants of stature, although it is also influenced by other factors such as environmental, nutritional, socio-economic, and climatic changes, which also affect the relationship between stature and various anatomical measurements [12].

Limitation(s)

The present study included only adolescent male school-going children as it was conducted in a boys' school in Kolkata. Therefore, another study involving only adolescent female school-going children is to be conducted, and then a comparison between the two is in process. Only the adolescent population was taken as the study sample in the present study. A comparison between the findings of the adolescent population and the findings of the adult population in the near future is also intended to be undertaken.

CONCLUSION(S)

In the present study, upper limb dimensions were used to predict stature among adolescent school-going boys. All variables (arm span, HL and HB) were found to be statistically significant predictors of stature. Among all these variables of upper limb length, arm span and HL provided the highest prediction accuracy. These measurements of body parts and regression equations can be used

for the identification of unknown human remains, particularly in cases of dismembered bodies.

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