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Original Article

Anatomy Section

Estimation of Stature using Lower Limb Dimensions among Adolescent Population of Kolkata: A Cross-sectional Study

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ABSTRACT

Introduction: Apart from age, sex and racial affiliation, estimation of stature from human extremities is an important step in developing a biological profile for identification of an unknown individual especially when the body found is either dismembered, mutilated, or disfigured. Stature estimation plays an important role in developing a biological profile for human identification and provides as a valuable indicator for an unknown individual in a population.

Aim: To identify stature using various lower limb dimensions.

Materials and Methods: This analytical, cross-sectional study was conducted at Kolkata based school from March 2019 to September 2019 amongst 120 adolescent school going boys aged 10-16 yrs of age. The lower limb length, knee height, navicular height, foot length and foot breadth were taken by using standard anthropometric procedures. Pearson correlation coefficient was used for assessing relationship between stature and various lower limb dimensions. Significance of differences was tested using independent t-test.

Results: This study showed that all variables of both right and left side were significant predictors of stature (p<0.01).While taking the prediction accuracy, lower limb length (right, R^2=89.7%, and left, R^2=89.7%), knee height (right, R^2=55.4%, and left, R^2=55.5%), foot breadth (right, R^2=58.0%, and left, R^2=56.8%) provided the highest prediction accuracy for stature. Following multivariate linear regression model, only four variables- lower limb length (both right and left side), foot breadth (both right and left side) significantly (p<0.001) contributed to prediction model for stature with the use of regression equations.

Conclusion: All variables (lower limb length, knee height, foot length and breadth, navicular height) were found to be statistically significant predictors of stature. Amongst all these variables lower limb length, knee height and foot breadth provided highest prediction accuracy. These measurements of lower limbs and regression equations can be used for identification of unknown human remains, particularly in cases of dismembered bodies.

Keywords: Anthropology, Foot navicular bone, Human identification, Linear regression, Lower extremity, Multivariate analysis

INTRODUCTION

Estimation of stature from lower extremity dimensions has long been a matter of great importance and conjecture. Studies pertaining to dimensions of vertebral column, lower extremity provide a substantial tool for stature estimation and significant associations have been found between the stature and individual body parts [1-3]. It is an important step in developing a biological profile for human identification and provide a valuable indicator for an unknown individual in a population [4]. Apart from age, sex and racial affiliation, this becomes an indispensable tool when the body found is either dismembered, mutilated, disfigured or even decomposed, and helps in narrowing down the identity of a missing person [5]. The quartet of stature, age, race and gender form the mainstay to build up the anthropometric databases. The relationship between height and different body parts has always been an interesting subject for both anthropologists and anatomists. It is also very useful for forensic medicine experts in providing them with a statistical database for anthropometric measurements in future studies [6-9].

Many studies have been done till now to examine the relationship between human stature and various body measurements like upper and lower limb dimensions among adult population, but there is a scarcity of data amongst adolescent population [2,3,6,8,9,10]. Thus, the present study was conducted on adolescent school going children in a Kolkata based school, attempting to shed light on this pertinent topic and seeks to unravel any possible existing correlation between various lower limb dimensions and stature which may aid in the critical process of identification in forensic sciences and anthropometry in the near future.

MATERIALS AND METHODS

This analytical, cross-sectional study was conducted at Kolkata-based boys school from March 2019 to September 2019 amongst 120 adolescent school going boys. Proper consent was obtained from the Institution Ethical Committee (IPGME&R/IEC/2022/250) and school authority as well as the parents / guardians of the children in a consent form written in local, lucid regional (here Bengali) language.

Inclusion and Exclusion criteria: Boys having any fracture over lower limb region, or suffering from boils, burns, or any associated congenital abnormalities or any absence/amputated part or whole of lower limb, were excluded from the study. Boys of adolescent age group without having the above mentioned criteria were included.

Study Procedure

Sampling was done by complete enumeration method. Shoes, socks and bulky clothing were removed prior to all measurements. All measurements were taken in a well lit room. The subjects were thoroughly explained all the procedures beforehand in simple, easy-to-understand local language. Each measurement was repeated three times by two trained undergraduate medical students to remove observer's bias if any and the mean reading of all the measurements was recorded. All readings related to length and height were taken in centimetres (cm).

The subject was made to stand straight against a wall with heels in contact with the wall, hands and face looking anteriorly. The height of the subject was defined as the straight distance from the most inferior part of the heel to the vertex of the head, the vertex was marked by a pencil and the distance was measured using a measuring tape [10]. The Lower Limb Length (LLL) was measured as the distance between the anterior superior iliac spine and the medial malleolus with the help of a tape [10]. Both right and left side values were noted for each individual. For the Knee Height (KH), the subject was made to sit straight in a chair and the distance between the heel of the foot and a point on the thigh 2 inches behind the patella was noted to the nearest 0.1 cm [10]. Bilateral readings were taken. For the Navicular Height (NVH), the subject remained seated comfortably on the chair and was asked to place the foot firmly on the floor; the navicular tuberosity was palpated, marked with a marker and the perpendicular distance between the floor and navicular tuberosity was measured with a measuring tape in centimetres (cm.) of both the sides [10].

For the Foot Length (FL), the most prominent point on the posterior most aspect of the heel was marked; and the distance between this point and the tip of the longest toe was measured with a measuring tape bilaterally [11-13]. Subject remained seated on a chair. The Foot Breadth (FB) was measured as the distance from the most medial point on the head of the first metatarsal to the most lateral point on the head of fifth metatarsal, in sitting posture of both sides, using vernier calipers [11-13].

STATISTICAL ANALYSIS

Data was analysed using Statistical Package for the Social Sciences (SPSS) 16 for windows and MS office Excel 2010. Descriptive statistical analysis for various lower limb dimensions was done and significance of differences was tested using independent t-test. The relationship between height and various lower 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 reach the best estimate possible. A p-value of less than <0.05 is statistically significant.

RESULTS

Mean age of study population was 12.5 years with the mean height of 144.123 cm. Descriptive statistical analysis (mean, standard deviation, minimum and maximum) of lower limb measurements are shown in [Table/Fig-1]. The mean values of LLL, KH, NVH, FL, and FB were 79.261 cm and 79.251 cm, 33.249 cm and 33.243 cm, 4.475 cm and 4.464 cm, 23.425 cm and 23.425 cm, 9.659 cm and 9.667 cm right and left accordingly. No statistically significant bilateral differences (p>0.05) were found for lower limb measurements.

Parameters	Minimum	Maximum	Mean	Standard deviation	t-value and p-value
Height	119.4	167	144.123	10.1708	----
LLL (Right)	67.0	94.1	79.261	6.6330	t=0.00818 p>0.05
LLL (Left)	66.7	94.1	79.251	6.6418	
KH (Right)	27.9	42.0	33.249	3.0263	t=0.01195 p>0.05
KH (Left)	27.7	42.0	33.243	3.0356	
NVH (Right)	2.5	7.0	4.475	0.8732	t=0.07257 p>0.05
NVH (Left)	2.5	7.0	4.464	0.8733	
FL (Right)	10.5	28	23.425	2.5760	t=0.993 p>0.05
FL (Left)	10.5	28.0	23.425	2.5760	
FB (Right)	7.6	12.0	9.659	0.8653	t=-0.05285 p>0.05
FB (Left)	8.0	12.0	9.667	0.8477	

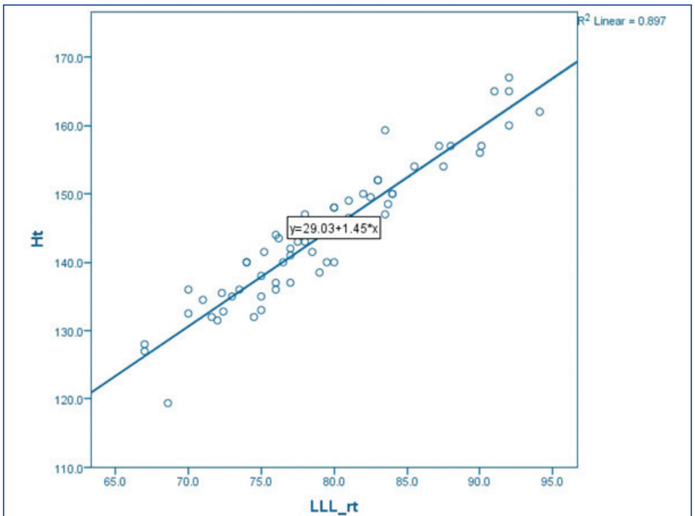
[Table/Fig-1]: Descriptive statistics: stature, lower limb measurements (cm).
LLL: Lower limb length; KH: Knee height; FL: Foot length; FB: Foot breath; NVH: Navicular height; t: Independent t-test value

Univariate linear regression analysis is shown in, all variables; LLL, KH, FL, FB, NVH of both right and left side were significant predictors of stature (p<0.01) [Table/Fig-2].

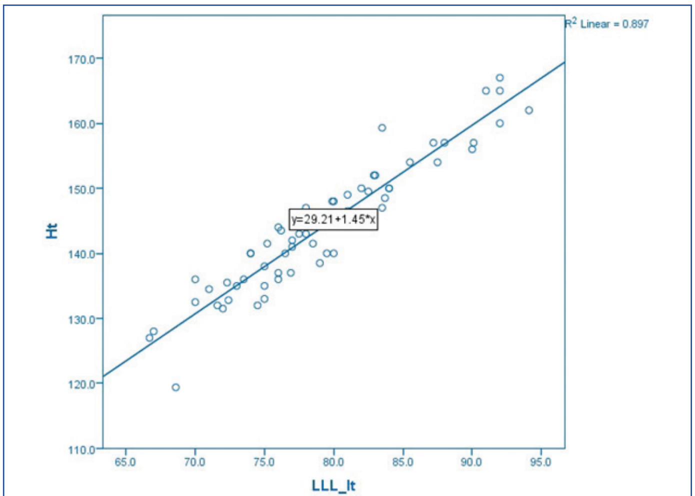
While taking the prediction accuracy, LLL (right, R^2=89.7%, and left, R^2=89.7%), KH (right, R^2=55.4%, and left, R^2=55.5%), FB (right, R^2=58.0%, and left, R^2=56.8%) provided the highest prediction accuracy for stature while other variables produced less than 50%. Linear regression graphs (y-axis- height, x-axis- variables) with regression equations for LLL, KH, FB were shown in [Table/Fig-3-8]. From are of multivariate linear regression model, only four variables LLL (both right and left side), FB (both right and left side) significantly ($p<0.001$) contributed to prediction model for stature while remaining variables made contributions that were not statistically significant ($p>0.05$). The prediction accuracy (R2) for right and left side were 92.55% and 92.02% accordingly [Table/Fig-9,10].

Parameters	Pearson's correlation	p-value	Inference
LLL (Right)	0.947**	<0.001	S
LLL (Left)	0.947**	<0.001	S
KH (Right)	0.744**	<0.001	S
KH (Left)	0.745**	<0.001	S
FL (Right)	0.481**	<0.001	S
FL (Left)	0.481**	<0.001	S
FB (Right)	0.761**	<0.001	S
FB (Left)	0.761**	<0.001	S
NVH (Right)	0.629**	<0.001	S
NVH (Left)	0.635**	<0.001	S

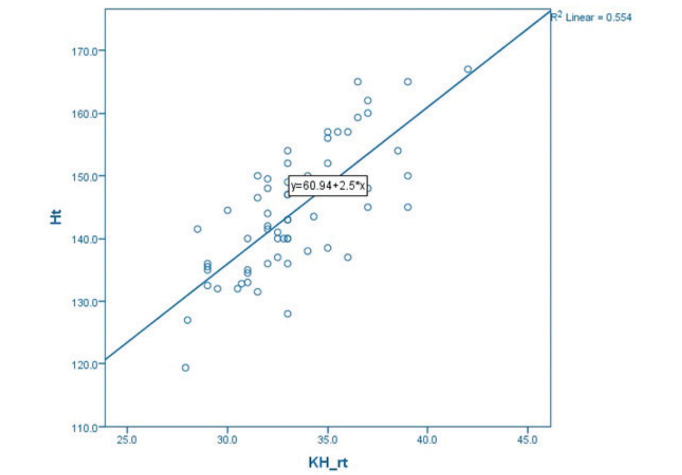
[Table/Fig-2]: Univariate stature prediction (linear regression analysis).
**Correlation is significant at the 0.01 level (2 tailed); LLL: Lower limb length; KH: Knee height; FL: Foot length; FB: Foot breath; NVH: Navicular height; S: Significant



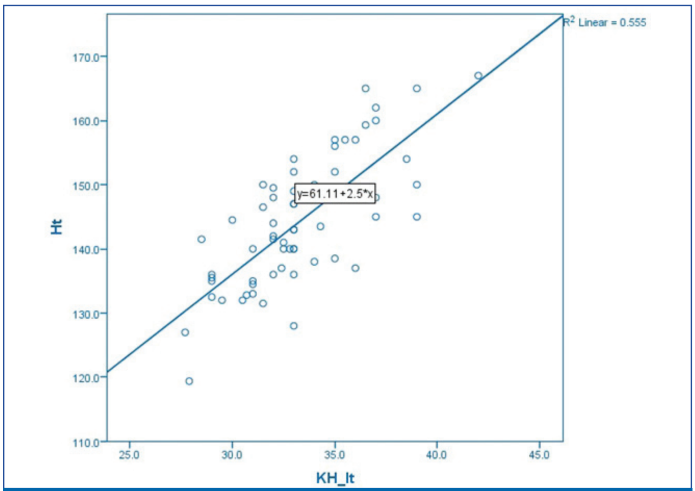
[Table/Fig-3]: Linear regression between height (Ht) and right (rt) Lower limb length (LLL).



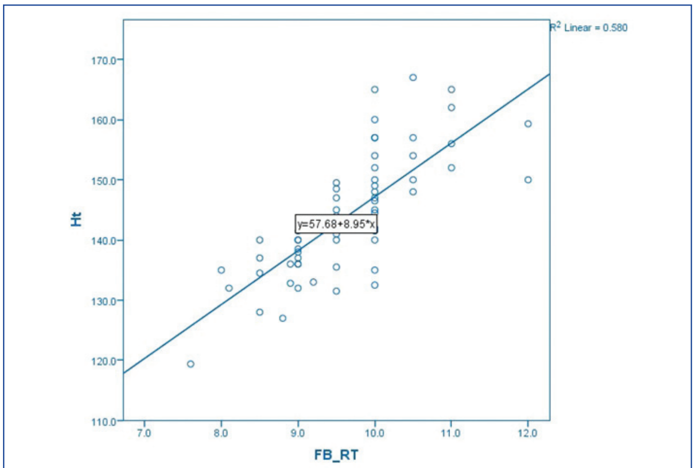
[Table/Fig-4]: Linear regression between height (Ht) and left (lt) Lower limb length (LLL).



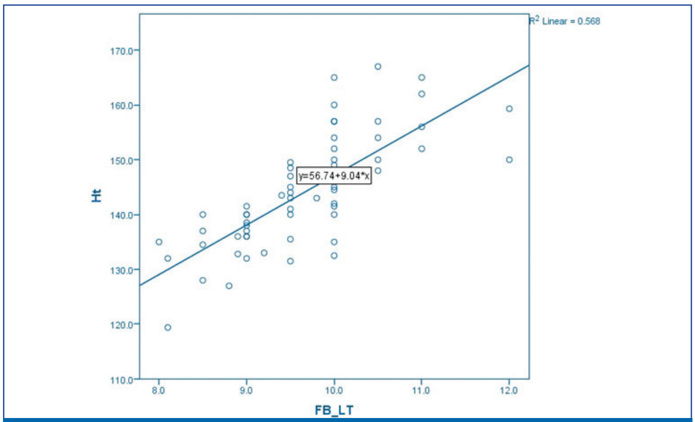
[Table/Fig-5]: Linear regression between height (Ht) and right (rt) Knee height (KH).



[Table/Fig-6]: Linear regression between height (Ht) and left (lt) Knee height (KH).



[Table/Fig-7]: Linear regression between height (Ht) and right (Rt) Foot breath (FB).



[Table/Fig-8]: Linear regression between height (Ht) and left (Rt) Foot breath (FB).

Term*	Coef	SE coef	t-value	p-value	Inference
LLL	1.134506	0.0950139	11.94	<0.001	S
KH	0.2749972	0.1935214	1.42	0.161	NS
FL	0.0250971	0.0155089	1.62	0.111	NS
FB	2.032117	0.6293411	3.23	0.002	S
NVH	0.5805401	0.5673807	1.02	0.311	NS

[Table/Fig-9]: Multiple regression analysis of right side variables.
LLL: Lower limb length; KH: Knee height; FL: Foot length; FB: Foot breath; NVH: Navicular height; S: Significant; NS: not significant; Coef: Coefficient; SE: Standard error; *Model is good fit with p<0.01; R2 (coefficient of determination)= 92.55%

Term*	Coef	SE coef	t-value	p-value	Inference
LLL	1.158359	0.0983641	11.78	<0.001	S
KH	0.2250958	0.197264	1.14	0.259	NS
FL	-0.0938176	0.186283	-0.50	0.617	NS
FB	2.059393	0.7107441	2.90	0.005	S
NVH	0.6605588	0.5901549	1.12	0.268	NS

[Table/Fig-10]: Multiple regression analysis of left side variables.
LLL: Lower limb length; KH: Knee height; FL: Foot length; FB: Foot breath; NVH: Navicular height; S: Significant; NS: Not significant; Coef: Coefficient; SE: Standard error; *Model is good fit with p<0.01; R2 (coefficient of determination)=92.02%

Multiple Regression equation taking right side dimensions were derived as:

HT = 22.16392 + 0.5805401 NVH +1.134506 LLL +0.2749972 KH +0.0250971 FL + 2.032117 FB

Multiple Regression equation taking left side dimensions were derived as:

HT = 24.17964 + 0.6605588 NVH +1.158359 LLL +0.2250958 KH-0.0938176 FL + 2.059393 FB

DISCUSSION

From different studies, it had been understood that various factors such as gender, ethnic group and study methods influence stature equations [14-17]. In this study no statistical significant bilateral differences were recorded which is in accordance with Uhrova P et al., and Zeybek G et al., [9,17].

In the present study, lower limb length showed the largest correlation with stature which is in accordance with the studies carried by Krishan K et al., Moshkdanian G et al., and Jervas E et al., in 2016 [18-20]. Correlation between stature and knee height showed better results than navicular height and foot length.

Amongst foot parameters used for stature estimation in this study, foot breadth provided more accurate prediction for stature whereas the studies done by Paul CW et al., Saharan RA et al., Ekezie J et al., Alabi SA et al., showed foot length as more accurate prediction of stature [21-24].

This study had shown significant correlation between stature and various lower limb dimensions amongst which the lower limb length, and foot breadth provided the reliability and accuracy in stature estimation with the use of regression equations. Genetic factors are the mainstay of controlling stature although it is also influenced by other factors like, environmental, nutritional, socio-economic and climate which also affect the relationship between stature and variable anatomical measurements [25-29]. The findings of previous studies in respect of Pearson's correlation and p-value compared with the results of present study are represented in [Table/Fig-11] [17,19-22].

Limitation(s)

This study included only adolescent male school going children as it was done in a boys school of Kolkata. A plan to conduct another study amongst adolescent girl students followed by a comparison between the two studies is in the pipeline. Furthermore it will be

Parameters	Uhrova P et al., 2015 [17] n-120 (male) 18-24 years Slovakia		Moshkdanian G et al., 2014 [19] n-142 (male) 18-25 years Iran		Jervas E et al., 2016 [20] n- 88 (male) 18-43 years Nigeria		Paul CW et al., 2018 [21] n-300 (male) Adult Nigeria		Saharan RA et al., 2015 [22] n-250 (male) >18 years Mysore, India		Present study n-120 (male) Adolescent	
	r	p	r	p	r	p	r	p	r	p	r	p
RFL	0.71	<0.01					0.71	<0.001	0.72	<0.001	0.481	<0.001
LFL	0.71	<0.01					0.61	<0.001	0.72	<0.001	0.481	<0.001
RFB	0.41	<0.01					0.25	<0.001			0.761	<0.001
LFB	0.39	<0.01					0.29	<0.001			0.761	<0.001
RNH							0.39	<0.001			0.629	<0.001
LNH							0.64	<0.001			0.635	<0.001
RLLL			0.89	<0.001	0.52	<0.001					0.947	<0.001
LLLL											0.947	<0.001
RKH			0.78	<0.001	0.29	0.007					0.744	<0.001
LKH											0.745	<0.001

[Table/Fig-11]: The analysis of previous studies compared to present study [17,19-22].
correlation is significant at the 0.01 level (2 tailed); RLLL: Right lower limb length; LLLL: Left lower limb length; RKH: Right knee height; LKH: Left knee height; RFL: Right foot length; LFL: Left foot length; RFB: Right foot breath; LFB: Left foot breath; RNH: Right navicular height; LNH: Left navicular height; r: Pearson's correlation

followed up by a study regarding estimation of stature using upper limb dimensions. Only adolescent population was taken as study sample in this study. A comparison between the findings of adolescent population with the findings of adult population in near future is also intended to be undertaken.

CONCLUSION(S)

In the present study lower limb dimensions were used to predict stature among adolescent school going boys. All variables (lower limb length, knee height, foot length and breadth, navicular height) were found to be statistically significant predictors of stature. Amongst all these variables lower limb length, knee height and foot breadth provided highest prediction accuracy. Regression equations for stature estimation from all these variables were presented. These measurements of body parts and regression equations can be used for identification of unknown human remains, particularly in cases of dismembered bodies.

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