Estimation of Stature & Gender from Thumb Indices in Indian Population

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Abstract

Background: Human characteristics like stature and gender identification on basis of human remains is a crucial element of any medicolegal investigation and is especially important in the field of forensic anthropometry. Thus, this study was undertaken with the aim of determining stature and gender by using thumb indices in the Indian population.

Material & Methods: 568 adults (294 males and 274 females) belonging age between 18-25 years participated in the present study. Thumb length, breadth, thickness and circumference were measured by time to time calibrated measuring tape and digital vernier caliper. Unpaired 't' test, Person Correlation Coefficient, Linear and Logistic regression methods used to analyze the data.

Results: This study showed significant correlation of thumb indices with stature & gender.

Conclusion: The stature and gender identification models are helpful to forensic experts and crime scene authorities to determine the stature and gender of an isolated thumb.

Key Words: *Stature, Gender, Thumb length, breadth, thickness & circumference*

Introduction

Stature or body height is one of the most important and useful anthropometric parameters that determines an individual's physical identity [1]. When a complete dead body is discovered, determining the individual's stature is relatively simple; however, when only parts of the body are available, determining the individual's stature is difficult [2]. Estimating an individual's stature from skeletal material or mutilated or amputated limbs or parts of limbs has obvious importance in personal identification in the events of murders, accidents, or natural disasters primarily concerned with forensic identification analysis. Many factors, such as racial and nutritional factors, play an important role in human development and growth, necessitating the use of different nomograms for different populations [3]. Until now, most studies on stature estimation have focused on the length of bones such as the femur, tibia, humerus, radius, and so on. There is very little data on work done in an Indian population to determine gender and stature using dimensions of different

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parts of the upper limb. As a result, the purpose of this research is to fill those gaps. This research will look into the possibility of using thumb indices to determine gender and stature in an Indian population.

Material and Methods

This cross-sectional study was conducted in the Krishna Institute of Medical Sciences (KIMS), Karad from year 2018-2020. According to standard ethics drawn by ethical committee for human experimentation, 568 adults (294 male and 274 female) aged 18-25 years participated in the present study. Individuals with no obvious deformities, injury, fracture, amputation or history of any surgical procedure of hand or previous history of trauma to hands, feet, spine and limbs were excluded from the study. Data on age, sex and height were collected from each of the participant. Height, thumb length and thumb circumference were measured by measuring tape in centimeters while thumb breadth and thumb thickness were measured by Digital Vernier Caliper in millimeters. The measurements in millimeters were further converted into centimeters. Thumb length was measured from proximal flexion crease of the thumb to tip [4]. Thumb breadth was measured from the most lateral to the most medial point of interphalangeal joint of thumb [4]. Thumb thickness was measured from middle of the dorsal aspect of interphalangeal joint to middle of palmar aspect of interphalangeal joint. Thumb circumference was measured from the superficial distance around the edge of interphalangeal joint [4].Stature i.e. natural height of person was measured with the individual standing barefoot on platform of stadiometer with the upper back buttock and heels pressed against the upright position of the instrument. Head was positioned in Frankfort plane, and head plate was brought into firm contact with vertex [1].

Statistical Analysis

All measurements are summarized into mean and standard deviation (SD). Correlation of height with each of the thumb measurements was determined by Pearson's Correlation Coefficient (r). Backward Linear Regression analysis was performed to estimate the height of the individual with most significant and statistically important thumb indices. Receiver Operating Characteristic (ROC) Curve analysis was performed to determine the cut-off value for each of the thumb measurement, with high sensitivity and specificity, that discriminating between male and female population. The measurements were categorized on basis of these cut-off values. These categorized variables were utilized in identification of gender. Backward-Wald Binary Logistic Regression analysis was further carried out to develop the model estimating gender. Data was analyzed using SPSS-20 version.

Results

The data collected from 294 males and 274 females aged between 18-25 years were analyzed using SPSS software. The mean height of 294 male participants was 172.4 cm with standard derivation 7.0 cm, while the mean height of 274 female participants was 159.8cm with standard derivation 7.1 cm, as seen in the graph (Fig.1).Males were significantly taller than females (Unpaired t test = 21.419, $p<0.001$), according to the comparison.

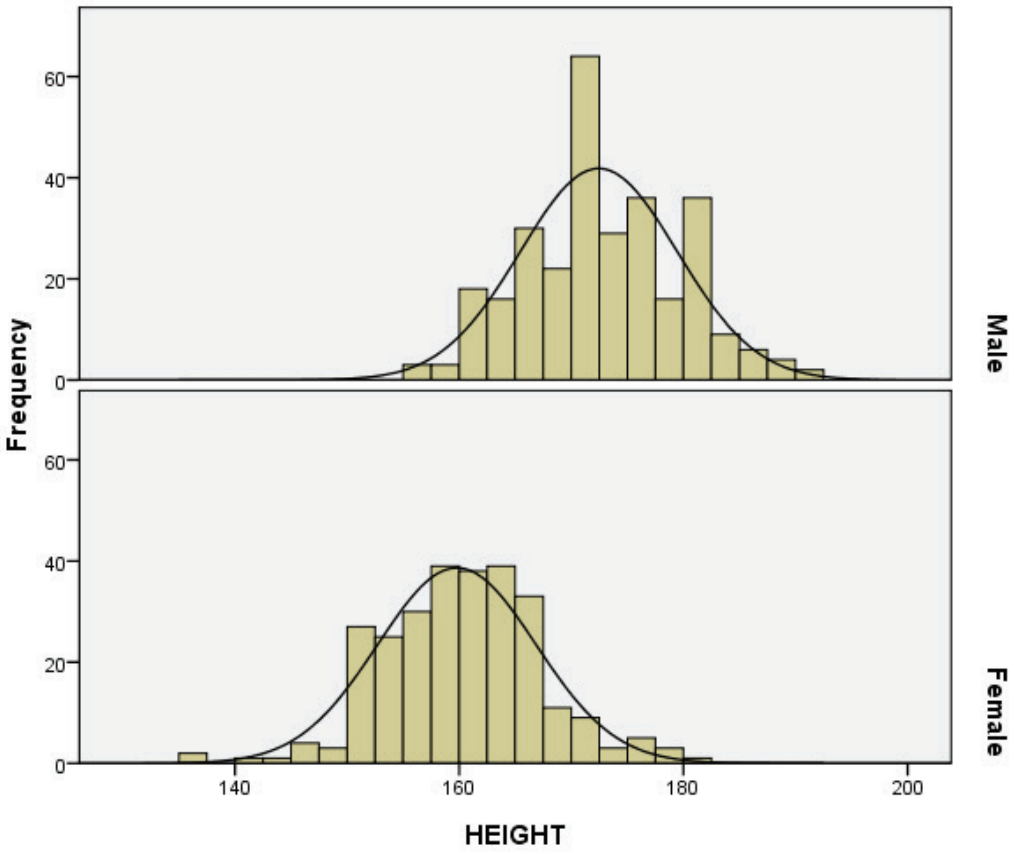

Fig 1: Graphical presentation of heights of males & females

In both male and female populations, there was a strong significant correlation between stature and right and left thumb lengths (Table1). Male stature was also correlated to the circumferences of the right and left thumbs, while female stature was correlated to the breadth and thickness of the right and left thumbs.

Table1: Correlation coefficient (r) between stature & thumb indices of males & female.

Gender	Stature	TLRT	TLLT	TBRT	TBLT	TTRT	TTLT	TCRT	TCLT
Male	r	.380**	.382**	-.010	-.017	.000	-.001	.171**	.169**
	p	.000	.000	.860	.768	.987	.985	.003	.004
Female	r	.370**	.374**	.121*	.126*	.121*	.126*	.070	.063
	p	.000	.000	.046	.037	.045	.038	.249	.301

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
TLRT: Right Thumb Length, **TLLT**: Left Thumb Length, **TBRT**: Right Thumb Breadth, **TBLT**: Left Thumb Breadth, **TTRT**: Right Thumb Thickness, **TTLT**: Left Thumb Thickness, **TCRT**: Right Thumb Circumference, **TCLT**: Left Thumb Circumference.

The male population had significantly higher values in all dimensions than female population. Males have significantly higher right and left thumb lengths, breadths, thicknesses, and circumferences than females (Table 2).

Table 2: Gender wise Mean and SD of thumb indices.

Thumb Indices	Male		Female		Unpaired test t value	p value
	Mean	SD	Mean	SD		
TLRT	6.86	0.59	6.04	0.44	18.698	<0.001
TLLT	6.84	0.58	6.02	0.44	18.744	<0.001
TBRT	1.91	0.42	1.52	0.13	14.830	<0.001
TBLT	1.91	0.43	1.52	0.13	14.793	<0.001
TTRT	1.67	0.37	1.36	0.11	13.621	<0.001
TTLT	1.68	0.37	1.36	0.11	13.769	<0.001
TCRT	6.51	0.54	5.62	0.36	23.155	<0.001
TCLT	6.48	0.53	5.59	0.37	23.125	<0.001

Using right and left thumb indices, backward linear regression analysis was used to estimate male and female stature. The ANOVA F results for all regression models revealed that for both genders, the estimation of the dependent variable 'Stature' using right and left thumb indices is statistically significant ($p<0.05$), indicating that it is significantly most accurate.

Male:

Stature = 141.438 + 4.519×TLRT; ANOVA F=49.415, $p<0.001$; Adjusted R^2=0.142

Stature = 140.836 + 4.623×TLLT; ANOVA F=49.856, $p<0.001$; Adjusted R^2=0.143

Stature = 142.373 + 51.859×TBRT + 4.565×TLLT – 52.460×TBLT; ANOVA F=19.307, $p<0.001$; Adjusted R^2=0.158

Female:

Stature = 123.835 + 5.951×TLRT; ANOVA F=43.156, $p<0.001$; Adjusted R^2=0.134

Stature = 123.658 + 5.998×TLLT; ANOVA F=44.289, $p<0.001$; Adjusted R^2=0.137

Stature = 119.732 – 126.711×TBRT + 6.082×TLLT + 128.927×TBLT; ANOVA F=17.168, $p<0.001$; Adjusted R^2=0.151

Irrespective of Gender:

Stature = 101.229 + 6.774×TLRT + 1.992×TBRT + 2.941×TCRT; ANOVA F=144.985, $p<0.001$; Adjusted R^2=0.432

Stature = 100.704 + 6.928×TLLT + 2.636×TTLT + 2.807×TCLT; ANOVA F=145.889, $p<0.001$; Adjusted R^2=0.434

Stature = 100.691 – 32.216×TTRT + 2.876×TCRT + 6.894×TLLT + 34.658×TTLT; ANOVA F=110.755, p<0.001; Adjusted R^2=0.436

In each above, the first model is based on right thumb measurements, second model is based on left thumb measurements and third model is based on both thumb measurements to estimate the stature.

The gender discriminating demarking points, i.e. cut-off values of each right and left thumb measurement, were determined using Receiver Operating Characteristic (ROC) Curve analysis (Table 3). These are the values that indicate a high level of sensitivity and specificity.

Table 3: Classification of observed female and male as per cut-off value of thumb indices.

Thumb Indices	Cut-off as per ROC Curve	Gender as per cut-off	Observed Gender		Total n=568
			Female n=274	Male n=294	
TLRT	<6.35	Female	218	45	263
	≥6.35	Male	56	249	305
TBRT	<1.68	Female	250	38	288
	≥1.68	Male	24	256	280
TTRT	<1.49	Female	235	42	277
	≥1.49	Male	39	252	291
TCRT	<6.05	Female	230	49	279
	≥6.05	Male	44	245	289
TLLT	<6.4	Female	219	51	270
	≥6.4	Male	55	243	298
TBLT	<1.68	Female	248	38	286
	≥1.68	Male	26	256	282
TTLT	<1.48	Female	231	34	265
	≥1.48	Male	43	260	303
TCLT	<5.95	Female	210	26	236
	≥5.95	Male	64	268	332

To estimate the gender, a logistic regression model was created using categorical thumb indices (Table 3)

as independent variables. These models were created using the backward Wald method.

The model skeleton for gender estimation from thumb indices is as follows:

$$\text{GENDER PROBABILITY} = \frac{e^{g(x)}}{1+e^{g(x)}}$$

Model 1: Estimation of gender from right thumb indices.

g(x) = 1.645×TLRT + 2.562×TBRT + 2.007×TTRT + 1.72×TCRT – 3.611

The length, breadth, thickness, and circumference of the right thumb were found to be significantly correlated with gender in model 1.

The gender estimates based on right thumb indices were very similar to the real gender values. This model 1 had an overall correct classification percentage of 91.9 %, with 93.1% of females and 90.8 % of males correctly classified. (Table 4)

Model 2: Estimation of gender from left thumb indices.

g(x) = 1.091×TLLT + 2.182×TBLT + 2.327×TTLT + 2.213×TCLT – 4.109

Gender was also found to be significantly correlated with the length, breadth, thickness, and circumference of the left thumb in model 2.

The gender estimates based on left thumb indices were very similar to the real gender values. Model 2 had an overall accurate classification percentage of 91.7 %, with 90.9 % for females and 92.5 % for males. (Table 4)

Model 3: Estimation of gender from right and left thumb indices.

g(x) = 1.206×TLRT + 2.307×TBRT + 2.298×TTLT + 2.136×TCLT – 4.128

Gender was found to be significantly correlated with right thumb length, breadth, thickness, and circumference in model 3.

The gender estimates based on right and left thumb indices were very similar to the real gender values. Model 3 had an overall accurate classification percentage of 91.7 %, with 91.2 % for females and 92.2 % for males. (Table 4)

Table4: Predicted gender percentage by thumb indices.

Observed Gender	Predicted Gender						Percentage Correct		
	Female			Male					
	RTI	LTI	RTI & LTI	RTI	LTI	RTI & LTI	RTI	LTI	RTI & LTI
Female	255	249	250	19	25	24	93.1	90.9	91.2
Male	27	22	23	267	272	271	90.8	92.5	92.2
Overall Percentage							91.9	91.7	91.7
RTI : Right Thumb Indices, LTI : Left Thumb Indices.									

The values of the independent variables, i.e. of thumb indices, should be entered in the model as per specified in the Table 5. If calculated GENDER PROBABILITY value turns<0.5, it implies the thumb measurements represents Female; otherwise Male. All the three logistic regression models developed for gender estimation revealed that they could estimate gender with more than 91% of accuracy.

Table 5 : Gender probability in male and female

Thumb Indices	Measurement	Value to be entered in calculation of g(x)
TLRT	<6.35	0
	≥6.35	1
TBRT	<1.68	0
	≥1.68	1
TTRT	<1.49	0
	≥1.49	1
TCRT	<6.05	0
	≥6.05	1
TLLT	<6.4	0
	≥6.4	1
TBLT	<1.68	0
	≥1.68	1
TTLT	<1.48	0
	≥1.48	1
TCLT	<5.95	0
	≥5.95	1

Discussions

Mass disasters, such as wars, acts of terrorism, and natural disasters, are becoming more common, posing challenges for investigators in establishing identification from isolated upper extremity long bones. There has been a lot of work put into identifying the bones. Many studies have used hand as well as the lengths of the middle, index, and ring fingers, to measure stature [4-6]. Vijaya Kumari N discovered an important association between stature and the length of both thumbs. Males have a slightly higher

correlation between length of left thumb and stature, while Females have a greater correlation between the length of their right thumb and their stature [7]. Kumar L. noticed a correlation between the length of thumb and stature. The correlation coefficient varied between 0.240 and 0.256[8]. In a study by Prerna et al., the right thumb had a correlation coefficient of 0.635 and the left thumb had a correlation coefficient of 0.245 in males, while the right thumb had a correlation coefficient of 0.212 and the left thumb had a correlation coefficient of 0.197 in females [9]. In contrast, Sen et al. found that index finger length had a higher correlation coefficient to estimate height than ring finger length [6,7]. Habib et al. analyzed 159 Egyptians aged 18 to 25 years and observed that males' little fingers were unrelated to stature [10]. Just a few studies have used the length of the thumb to estimate stature and gender [7,11]. And the bulk of the studies were confined to the teenage population. As a result, research into the relationship between stature and thumb length in various geographical locations is required, which could be extended to the adult population.

In this analysis, we looked at both the right and left thumb indices when estimating gender and stature. In an Indian population, we found an important correlation between stature and thumb indices, as well as a correlation between gender and thumb indices. Our findings revealed a strong significant correlation between stature and right and left thumb lengths in both male and female populations. Male stature was also correlated to the circumferences of the right and left thumbs, while female stature was correlated to the width and thickness of the right and left thumbs. The ANOVA F results for both regression models revealed that the estimation of the dependent variable 'Stature' using left and right thumb indices is statistically significant ($p<0.05$) for both genders. In this analysis, statistically significant differences were found between the male and female groups in all parameters, with male measurements being higher than female measurements.

To estimate gender from index and ring finger lengths, Krishan et al. used the sectioning point and binary logistic regression methods. The accurate predictive percentages for the right and left hands were 80.7% and 82.2%, respectively [12]. Jee et al. examined 29 hand measurements in 321 Koreans for gender estimation. When using the sectioning point process, accuracy from index finger length was found to be 65.9% for males and 70.1% for females. Discriminant feature analysis yielded 83.2% accuracy when the three lengths of the thumb, index, and middle finger were used [4].

When analyzed according to gender, all of the parameters in present study were strongly correlated with the right and left thumb indices. All of the gender prediction models produced provided a strong and most accurate estimate of the study population. Anthropometric measurements of the right and left thumb indices for the Indian population are highlighted in this study. These measurements were used to create models for gender estimation. The model's success rates are discussed. Model 1 had a 91.9% overall correct classified percentage, with 93.1 % of females and 90.8 % of males, using right thumb indices to estimate gender (Table 4). Model 2 had a 91.7% overall correct classified percentage, with 90.9 % for females and 92.5 % for males, using left thumb indices to estimate gender (Table 4). Model 3 correctly classified 91.2% of females and 92.2% of males using right and left thumb indices, resulting in an overall accurate classification percentage of 91.7% (Table 4).

Receiver Operating Characteristic Curve analysis was performed to identify the gender cut-off values of each right and left thumb measurements. These categorized variables were used in identification of gender (Table 3).

It was possible to achieve the aim of this research, which was to find correct stature and gender discriminators using thumb indices. The length, breadth, circumferences, and thickness of all thumb parameters were all found to be significantly related to gender. Furthermore, previous research did not consider the breadth, thickness, and circumference of thumb indices when deciding gender. When the breadth, thickness, and circumferences of thumb indices are considered in addition to thumb length, enhanced gender determination accuracy is achieved. This was rarely studied in previous research.

Conclusion

Various anthropometric criteria with different levels of precision are used to assess gender and stature. As a result, we tested the accuracy of thumb indices to predict stature and gender.

All three gender estimation logistic regression models showed that they were able to estimate gender with greater than 91% accuracy.

Receiver Operating Characteristic Curve analysis found useful to identify the gender cut-off values of each right and left thumb measurements.

The length, width, thickness, and circumference of thumb indices can be used for more precise gender and stature determination, according to a study conducted on an Indian population.

Furthermore, the regression model equations obtained are valid for stature and gender estimations for a given value of thumb measurement.

So, even if only the thumb is available, regression model equations are capable to estimate an individual's stature and gender. To verify the accuracy of regression model equations in various geographical locations more research must be conducted.

These models are useful for anatomists, forensic anthropologists, forensic pathologists, archaeologists, and forensic medicine investigators in gender and stature identification purposes, which may be considered as surrogate method in situations where DNA analysis is difficult for economic or other reasons, such as war and mass disasters.

Acknowledgement: We would like to express our appreciation to everyone who took part in this research.

Informed consent: was taken.

Ethical approval: taken Krishna Institute of Medical Sciences Deemed To Be University, Karad (KIMSDU/IEC/01/2018 dated 02/02/2018).

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