DOI: 10.7860/JCDR/2019/38438.12720

Estimation of Stature from Hand Dimension among Indigenous Karbi Tribal Population of Assam, Northeast India

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ABSTRACT

Introduction: Estimation of stature is an important parameter in the personal identification from human remains such as hand, foot and limbs in forensic examination in the field of Forensic Anthropology.

Aim: To understand the relationship between stature and hand dimensions among indigenous Karbi tribal population of Assam, Northeast India.

Materials and Methods: The present community based cross-sectional investigation was carried out among 300 (150 males and 150 females) adults of Karbi population of age group 20-50 years of Karbi Anglong, Assam, India. Anthropometric measurements of stature, Hand Length (HL) and Hand Breadth (HB) were collected using standard anthropometric procedures. Descriptive statistics, paired t-test, ANOVA, Pearson correlation and regression analysis were applied using SPSS (version, 17.0).

Results: The results indicated that female individuals exhibit significantly smaller stature and hand dimensions than their male counterparts ($p<0.05$). Using ANOVA, there were statistically significant differences in stature, HL and HB ($p<0.05$) between sexes. The bilateral difference was found to be statistically significant in HL and HB ($p<0.05$), but the difference found was not significant in HL among females ($p>0.05$). The Pearson correlation analysis showed that anthropometric measures of stature are positively correlated with LHL, RHL, LHB and RHB ($p<0.01$). The results showed that the sex-specific regression equations in linear and multiple linear equations showed significant coefficient correlation with stature and LHL, RHL, LHB and RHB ($p<0.01$). The mean differences between the actual and estimated stature using derived equations of hand dimensions were observed to be statistically not significant ($p>0.05$).

Conclusion: The present study has successfully reported the possible relationships and estimation of stature from the HL and HB. Similar studies are also recommended for ethnic/population specific equation and/or utilise and validation of equations to estimate the stature from HL and HB.

Keywords: Anthropometry, Forensic anthropology, Forensic science

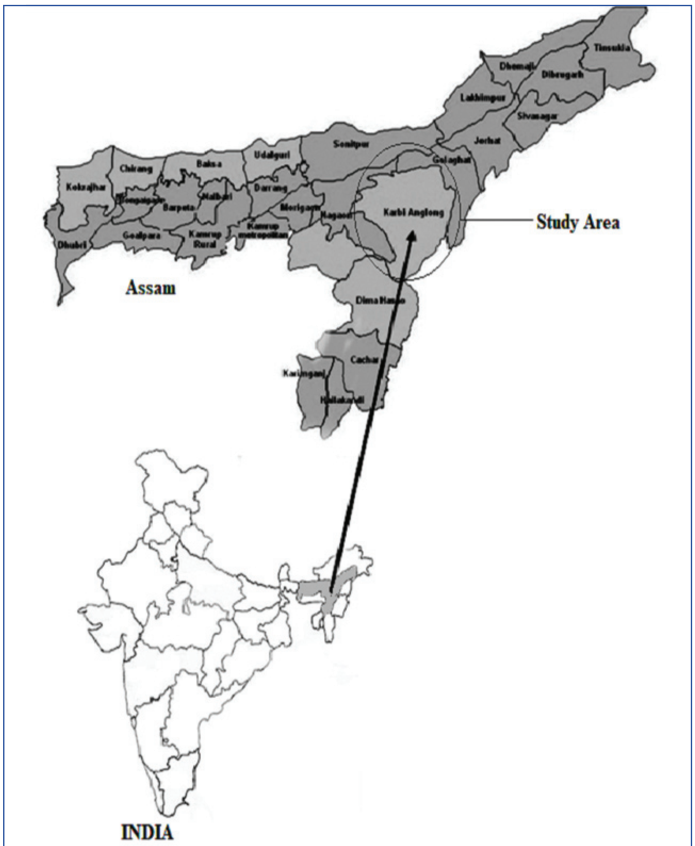
INTRODUCTION

Hand dimensions are used to estimate stature which helps to reconstruct a biological profile in the process of personal identification. Estimation of stature is considered to be a significant component of biological profile, thus it is considered as an important parameter in the personal identification of human remains in Forensic Sciences [1,2]. The knowledge of Forensic Anthropology is being used in forensic science for the service of mankind. Beyond the elimination of the non-human elements, identification processes undertake to provide opinions regarding the estimation of sex, age, ethnicity, stature and similar other characteristics of an individual/ population involved as may lead to the personal identifications [3]. The Forensic Anthropologist typically uses osteological, dental data, isolated extremities and human remains to identify the characteristic of unknown individuals and serve as evidence in medico-legal cases [4,5]. The smaller bones of hand and feet (e.g., metacarpals, metatarsals and phalanges) do pose a difficulty in identification, but the species of the bone's origin can be determined by precipitation test, if organic material, in the form of tissue or blood, is still present [6]. Personal identification from dismembered, mutilated and fragmented body parts sometimes becomes a challenging task for both the forensic experts and physical anthropologists; in such cases, complete identification becomes unlikely and partial identification assumes importance to proceed into further investigations. In case of mass disasters, explosions and assault cases, the problems of identifying a person's identity becomes very difficult when the body discovered is in the mutilated or dismembered form. In order to provide valuable information about an individual, several studies on hand and foot dimensions have been extensively carried out by researchers (e.g., stature and sex) when an individual hand or foot in a mutilated form is recovered and brought for forensic investigations [7-9].

The stature estimation plays a prime role in personal identification which is often required in medico-legal practice. Sometimes, parts of soft tissues can be found disposed of in the open, in ditches, or rubbish dumps or dismembered remains and these materials are brought to the forensic pathologist for examinations. The importance of height depends on the availability of the ante-mortem height of the deceased. Age at which the height was recorded is important because height is likely to decline with increasing age (especially during late adulthood), due to atrophic changes occurring in disc cartilages. Thus, the post-mortem height is liable to fluctuate by some centimeters on either side of the ante-mortem height. Due to the presence of ethnic population and genetic variations in different regions of the world, it is very important that regional/ population specific studies are needed [8,10]. Several studies have been subsequently carried out by researchers around the globe in order to obtain the prediction of stature from different body dimensions for different ethnic populations [7-9,11-19]. India having a population of more than 84 million individuals has the largest number of indigenous population in the world and therefore the need for differential equation for the estimation of stature from different body dimensions is necessary for each such group. Subsequently, several studies on stature estimation from different body dimensions were reported among various populations in India [7-9,16,17,20-22]. Several researchers have already reported the estimate stature from hand dimensions [1,16,19-21,23-34]. Although, several research studies have been reported on different populations in India but studies are almost non-existed among the population of North-eastern region of India. Therefore the present investigation was carried out with an aim to determine the relationship between stature, Hand Length (HL) and Hand Breadth (HB) and to the estimation of stature from HL and HB among adult Karbi indigenous tribal population of Northeast India.

MATERIALS AND METHODS

The present community-based cross-sectional investigation was conducted among 300 unrelated (150 males; 150 females) indigenous Karbi tribal individuals (aged from 20-50 years) of Karbi Anglong district of Assam, Northeast India. Ethnically, the Karbi belongs to an endogamous Mongoloid tribal population which is a Tibeto-Burman linguistic family. They occupy the districts of Karbi Anglong, Dima Hasao, Marigaon, Kamrup, Golaghat, Nagaon, Lakhimpur, Cachar and Sonitpur of Assam and the states of Arunachal Pradesh, Nagaland and Meghalaya of Northeast India. However, they are mostly found to be concentrated in the district of Karbi Anglong (25°33/N to 26°35/N latitude and 92°10/E to 93°50/E longitude) [Table/Fig-1]. This district is the largest of 32 districts of the state of Assam and covers a total area of 10,434 sq km. According to the National Census of 2011, the district had a total population of 9,56,313 individuals (males: 4,90,167; females: 4,66,146) with an average literacy rate of 69.25% (males: 76,14%; females: 62.00%). The Karbi population was selected for the present investigation because of its widespread distribution of population in the district Karbi Anglong. Initially, a total of 340 Karbi individuals aged 20-50 years were approached by using random sampling for the necessary participation in the study. All the subjects included in the study were physically fit and free from any physical deformities of the limbs. The subjects were also interviewed informally regarding any previous physical injury and/or operation, or any trauma in the either hand which was also taken into consideration during the time of examination. The subjects who were having any kind of abnormalities, injuries or surgical episodes were excluded from the study. Out of 340, 40 individuals (11.76%) declined or avoided to take further part in the study due to limb deformities and physical deformities.



[Table/Fig-1]: Showing the location of study area Karbi Anglong Assam, Northeast India.

A written consent was also obtained from the research participants who took part in the study before the collection of relevant information and anthropometric measurements. The participants were informed about the purpose and scope of the present study. The participation of the subjects in the present investigation was purely voluntary in nature. Necessary study permissions were also taken from the local village level authorities and traditional village headmen. The present study was conducted following the ethical guidelines of human experiments as laid down in the Helsinki Declaration [35]. The anthropometric data were collected during the period from September 2015 to August 2016. Moreover, all the individuals included in this study were engaged in agriculture, thereby controlling the twin factors of physical activity and nutritional condition to a large extent. The age of the participants was recorded and verified from the age certificates (e.g., birth certificates) and other age-related proofs (e.g., voter identification cards, driving license) issued by the Government authorities. The populations were identified as the Karbi tribal population by observing their physical appearance and cultural features and recording their surnames. These were subsequently verified from the official records. All the individuals were the residents of the Karbi dominated villages viz., Taralangso, Chephongkimi, Rongchedon, Rongkimi, Dikrenglangso and Rongjangphong of Diphu sub-division, Karbi Anglong district of Assam, Northeast India. These villages were selected due to homogeneity and easy accessibility by road. The villages were situated at a distance of approximately 25 km south-west of Diphu sub-division town of Karbi Anglong.

Anthropometric Measurements Recorded

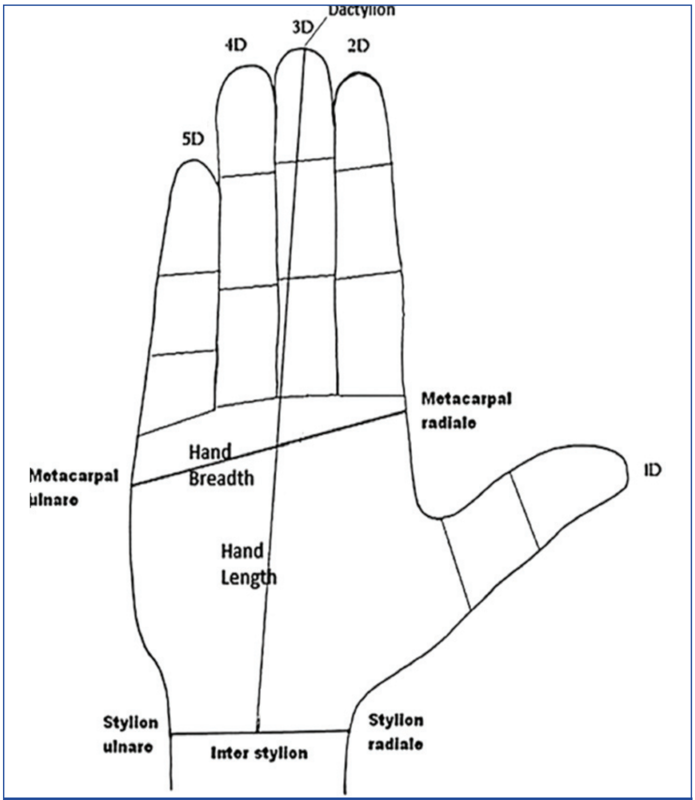
Five anthropometric measurements were recorded from the subjects following the standard anthropometric procedures [36,37]. The measurements taken are as follows:

a) Stature/height
b) Length of Left Hand (LHL)
c) Length of Right Hand (RHL)
d) Breadth of Left Hand (LHB)
e) Breadth of Right Hand (RHB)

Stature was recorded with the help of an anthropometric rod placed in the vertical distance from the vertex to floor with the head oriented in the Frankfurt horizontal plane. HL is measured from the midpoint of the distal transverse crease of the wrist (i.e., extending from ulnar to radial side) to the most anterior projection of the skin of the middle finger (e.g., inter stylion line). HB is measured as a distance between the radial side of the second metacarpophalyngeal joint (e.g., metacarpal rediale) and the ulnar side of the fifth metacarpophalangeal joint (e.g., metacarpal ulnale).

The descriptions of the relevant landmarks associated with HL and HB were shown in [Table/Fig-2]. A slide caliper was used to measure the length of LHL, RHL, LHB and RHB. All anthropometric measurements were recorded with accuracy nearest to 0.1 cm. The participants were barefooted at the time of recording the measurements. Owing to the diurnal variation in stature [38], the subjects were measured during the morning hours prior to leaving for their work. However, the subjects covered under this present study were also measured with ample precision to avoid any possible systematic errors and define the landmarks in the process of anthropometric data collection. However, repeated/multiple measurements were also performed to check the possible reliability of the anthropometric measurements in field situations by both the authors.

The technical errors of measurement {$TEM=\sqrt{(\sum D^2/2N)}$}, where D=Difference between the anthropometric measurements, N=the number of individuals measured) which is an accuracy index and measures the standard deviation between repeated measures which [39] have been determined to check the consistency of the



[Table/Fig-2]: Showing the landmarks involved to Hand Length (HL) and Hand Breadth (HB).

data. Even though number of methods of measuring inconsistency are available, the preferred method involves calculation of relative TEM and subsequent determination of the coefficient of reliability [$R=\{1-(TEM)^2/SD^2\}$], (SD=the standard deviation of all the measurements) [37]. The TEM were calculated from multiple measurements obtained from the 30 randomly selected Karbi individuals. Very high reliability (R) (R>0.98) was obtained in TEM analysis in height, LHL, RHL, LHB and RHB and values were found to be within the acceptable limits of R=0.95 [37]. Hence the measurements were expected to be reliable and TEM values were not incorporated into further statistical procedures.

STATISTICAL ANALYSIS

All statistical analysis was done using the statistical package for social science (SPSS, Version, 17.0). The data obtained was statistically analysed using statistical constants which includes correlation, regression, paired sample t-test and one-way analysis of variance (ANOVA). Linear and step-wise multiple regression equations were formulated separately for each sex and entire sample together to find out whether a single equation could be used for all age groups or independent equation would be required separately for the individual age group to estimate stature using HL and HB. Efforts were also made to formulate multiplication factors based equations by using HL, HB and age as continuous variables to improve the accuracy for estimation of stature among individuals. Linear regression was used for estimating the stature from LHL, RHL, LHB and RHB. Step-wise multiple regressions were also done to estimate stature from a combination of these variables. ANOVA was utilised to assess bilateral differences in LHL, RHL, LHB and RHB. To understand the sex differences between Karbi male and female individuals in stature, LHL, RHL, LHB and RHB, ANOVA and paired t-test were utilised. A p-value of <0.05 and <0.01 were considered to be statistically significant, while p>0.05 was considered to be statistically not significant.

RESULTS

The sex-specific mean, standard deviation (SD) and range of stature, LHL, RHL, LHB and RHB among adult Karbi individuals are presented in [Table/Fig-3]. It was observed that in the case of the male individuals, LHL ranged from 10.59% to 13.87% of stature, LHB ranged from 4.85% to 5.89% of stature; RHL varied between 10.46% and 13.76% of stature and RHB varied between 4.79% and 5.73% of stature. It was also observed that LHL ranged from 10.50% to 11.12% of stature, LHB ranged from 4.62% to 5.37% of stature, RHL varied between 10.43% and 11.54% of stature and RHB varied between 4.66% and 5.37% of stature in the case of female individuals. Therefore, it is apparent that male Karbi individuals have longer HL related to their stature than female individuals, but when HB was taken into consideration, the females have broader HB as compared to male counterparts in relation to their stature. Following the classification of stature proposed by Martin and Saller [40]. It is observed that the majority of the Karbi male and female individuals fall in the 'short to medium' but the Karbi female individuals were found to be slightly shorter than the male Karbi counterparts [40]. The Pearson correlation coefficient analysis between the anthropometric variables showed statistically significant coefficient between the stature and LHL (r=0.694), RHL (r=0.693), LHB (r=0.621) and RHB (r=0.639) (p<0.01). Similarly, statistically significant correlation coefficient values were obtained between the stature and LHL (r=0.453), RHL (r=0.452), LHB (r=0.235) and RHB (r=0.239) (p<0.01) among males and stature and LHL (r=0.578), RHL (r=0.587), LHB (r=0.335) and RHB (r=0.329) (p<0.01) among female individuals.

Measurement (cm)		Mean±SD	SE	95% CI for Mean		Minimum	Maximum
				Lower	Upper		
Male (N=150)	LHL	17.85±1.06	0.08	17.68	18.02	15.70	24.70
	RHL	17.81±1.04	0.08	17.65	17.98	15.50	24.50
	HL	17.83±1.05	0.08	17.66	18.00	15.80	20.60
	LHB	8.25±0.49	0.04	8.17	8.33	7.20	10.50
	RHB	8.34±0.46	0.03	8.26	8.41	7.10	10.20
	HB	8.29±0.46	0.03	8.22	8.37	7.15	10.35
	Stature	161.68±5.35	0.44	160.81	162.54	148.20	178.00
Female (N=150)	LHL	16.58±0.76	0.06	16.46	16.70	14.30	18.50
	RHL	16.57±0.79	0.06	16.44	16.70	14.20	18.70
	HL	16.57±0.79	0.06	16.45	16.70	14.25	18.60
	LHB	7.45±0.41	0.03	7.38	7.52	6.30	8.70
	RHB	7.53±0.38	0.03	7.47	7.55	6.35	8.70
	HB	7.49±0.38	0.03	7.48	7.56	6.35	8.70
	Stature	151.09±4.78	0.39	150.33	151.87	136.10	162.00
Unknown (N=300)	LHL	17.22±1.12	0.06	17.09	17.34	14.30	24.70
	RHL	17.19±1.11	0.06	17.06	17.32	14.20	24.50
	HL	17.20±1.11	0.06	17.07	17.33	14.25	20.60
	LHB	7.85±0.60	0.03	7.78	7.92	6.30	10.50
	RHB	7.93±0.58	0.03	7.87	8.00	6.40	10.20
	HB	7.89±0.58	0.03	7.83	7.96	6.35	10.35
	Stature	156.39±7.33	0.42	155.56	157.23	136.10	178.00

[Table/Fig-3]: Descriptive statistics of the stature and hand dimension measures among adult Karbi individuals (N=300).
Mean and Standard Deviation; SD: Standard deviation; SE: Standard error; CI: Confidence interval

Sex Differences in Stature, LHL, RHL, LHB and RHB

It is evident that the females exhibit slightly smaller stature and smaller HL and HB with respect to LHL, RHL, LHB and RHB as compared to the males Karbi counterparts. Utilising the paired sample t-test, it was further observed that there were statistically significant differences (p<0.01) between the sexes, when HL, LHL, RHL, HB, LHB, RHB and stature are considered among Karbi individuals [Table/Fig-4]. Therefore, the results showed that adult Karbi male and female individuals significantly differed in HL rather than HB, thereby indicating sexual dimorphism (p<0.05).

Measurements (cm)	Independent t-test		ANOVA	
	t-value	p-value	F-value	p-value
LHL	11.894	<0.001	141.47	<0.001
RHL	11.592	<0.001	134.37	<0.001
HL	11.822	<0.001	139.76	<0.001
LHB	15.122	<0.001	228.68	<0.001
RHB	16.239	<0.001	263.71	<0.001
HB	16.107	<0.001	259.44	<0.001
Stature	18.063	<0.001	326.28	<0.001

[Table/Fig-4]: Sex specific mean difference in stature and hand dimension measures among adult Karbi individuals.
Independent t-test; One-way Analysis of Variance

Bilateral Differences in LHL, RHL, LHB and RHB

The bilateral differences in HL and HB among males and females Karbi individuals were evaluated using paired sample t-test analysis and the results of the statistical analysis is depicted in [Table/Fig-5]. It is evident from the table that the bilateral differences in HL (in males) and HB (in both males and females) were found to be statistically significant (p<0.05). The bilateral differences were also found to be statistically significant for unknown sex hand dimensions of HL and HB among Karbi individuals (p<0.05).

Sex	Measurements	t-value	d.f.	p-value
Male (N=150)	HL	2.282	149	0.024
	HB	-4.873	149	<0.001
Female (N=150)	HL	0.600	149	0.549
	HB	-5.031	149	<0.001
Unknown (N=300)	HL	2.018	299	0.044
	HB	-7.006	299	<0.001

[Table/Fig-5]: Bilateral mean difference between the hand dimension measures among adult Karbi individuals.
Paired t-test Analysis

Linear Regression of Stature on HL, LHL, RHL, HB, LHB and RHB

Simple linear regression analysis was done to estimate the stature from the studied variables. Stature was taken as the dependent variable and HL, LHL, RHL, HB, LHB and RHB as the independent variables in linear regression analysis. The regression equations for the estimation of stature from HL, LHL, RHL, HB, LHB and RHB among Karbi male and female individuals in the present study are depicted in [Table/Fig-6]. In all the cases, the regression coefficients were statistically significant (p<0.05) and the values for the R and R^2 regression equations are also given in [Table/Fig-6]. Therefore, the stature was thus observed to be dependent on HL, LHL, RHL, HB, LHB and RHB.

Male Karbi Individuals (N=150)

The regression coefficient for stature on HL was 0.46 (t-value=6.22, d.f. 149; p<0.01), which was statistically significant. In case of stature on LHL, the regression coefficient of 0.45 was also statistically significant (t-value=6.18, d.f. 149; p<0.01) and stature on RHL, the regression coefficient of 0.45 was also found statistically significant (t-value=6.16, d.f. 149; p<0.01). In case of stature on HB was taken into consideration, the regression coefficient of 0.24 was statistically significant (t-value=3.05, d.f. 149; p<0.01). In case of stature on the LHB, the regression coefficient of 0.24 was again found statistically significant (t-value=2.49, d.f. 149; p<0.01) and stature on RHB, the regression coefficient of 0.24 was found statistically significant (t-value=2.99, d.f. 149; p<0.01).

Female Karbi Individuals (N=150)

The regression coefficient for stature on HL was 0.59 (t-value=8.85, d.f.149, p<0.01). In case of stature on LHL, the regression coefficient of 0.58 was also statistically significant (t-value=8.61,

Measurements (cm)		Regression models	R	R^2	S.E.E	t-value	p-value
Male (N=150)	LHL	121.143+2.271(LHL)	0.453	0.206	4.786	6.187	<0.001
	RHL	120.318+2.322(RHL)	0.452	0.204	4.789	6.165	<0.001
	HL	120.328+2.319(HL)	0.455	0.207	4.782	6.215	<0.001
	LHB	140.718+2.54(LHB)	0.235	0.055	5.218	2.497	<0.001
	RHB	138.698+2.756(RHB)	0.239	0.057	5.214	2.990	<0.001
	HB	138.604+2.781(HB)	0.243	0.059	5.208	3.049	<0.001
Female (N=150)	LHL	90.552+3.65(LHL)	0.578	0.334	3.915	8.609	<0.001
	RHL	92.876+3.513(RHL)	0.587	0.345	3.882	8.823	<0.001
	HL	90.592+3.650(HL)	0.588	0.346	3.879	8.845	<0.001
	LHB	122.359+3.885(LHB)	0.335	0.112	4.519	4.321	<0.001
	RHB	120.561+4.051(RHB)	0.329	0.108	4.528	4.242	<0.001
	HB	119.535+4.210(HB)	0.343	0.118	4.505	4.440	<0.001
Unknown (N=300)	LHL	78.359+4.523(LHL)	0.694	0.481	5.289	16.624	<0.001
	RHL	78.142+4.551(RHL)	0.693	0.480	5.295	16.593	<0.001
	HL	77.527+4.583(HL)	0.697	0.485	5.269	16.757	<0.001
	LHB	97.504+7.497(LHB)	0.621	0.385	5.758	13.667	<0.001
	RHB	93.347+7.941(RHB)	0.635	0.403	5.670	14.187	<0.001
	HB	93.597+7.594(HB)	0.637	0.406	5.658	14.280	<0.001

[Table/Fig-6]: Linear regression analysis and estimation of stature from hand dimension.
Linear Regression Analysis

d.f. 149, p<0.01) and stature on RHL, the regression coefficient of 0.58 was found statistically significant (t-value=8.82, d.f. 149, p<0.01). In case of stature on HB, the regression coefficient was 0.34 (t-value=4.44, d.f. 149, p<0.01). In case of stature on the LHB, the regression coefficient of 0.34 is again found statistically significant (t-value=4.32, d.f. 149, p<0.01) and RHB on stature, the regression coefficient of 0.33 is also found statistically significant (t-value=4.24, d.f. 149, p<0.01).

Unknown Karbi Individuals (N=300)

The regression coefficient for stature on HL was 0.69 (t-value=16.76, d.f. 299, p<0.01). In case of stature on LHL, the regression coefficient of 0.69 was also statistically significant (t-value=16.62, d.f. 299, p<0.01) and stature on RHL, the regression coefficient of 0.69 was found statistically significant (t-value=16.59, d.f. 299, p<0.01). In case of stature on HB, the regression coefficient was 0.64 (t-value=14.28, d.f. 299, p<0.01). In case of stature on the LHB, the regression coefficient of 0.62 is again found statistically significant (t-value=13.67, d.f. 299, p<0.01) and RHB on stature, the regression coefficient of 0.64 is also found statistically significant (t-value=14.18, d.f. 299, p<0.01).

Step-wise Multiple Regression of Stature Estimation on HL and HB of Karbi Individuals

Step-wise multiple regression equations for stature, regression coefficient and standard error on both HL and HB among the adult Karbi individuals are presented in [Table/Fig-7]. In all the cases, the

Measurements		Regression models	R	R^2	SEE	p-value
Male (N=150)	Left	122.510+2.374(LHL)-0.390(LHB)	0.454	0.206	4.800	<0.001
	Right	121.367+2.390(RHL)-0.271(RHB)	0.452	0.205	4.805	<0.001
	Unknown	121.742+2.419(HL)-0.386(HB)	0.456	0.208	4.796	<0.001
Female (N=150)	Left	87.403+3.402(LHL)+0.975(LHB)	0.582	0.339	3.911	<0.001
	Right	89.770+3.323(RHL)+0.831(RHB)	0.590	0.348	3.885	<0.001
	Unknown	87.288+3.418(HL)+0.954(HB)	0.592	0.350	3.878	<0.001
Unknown (N=300)	Left	74.192+3.323(LHL)+3.180(LHB)	0.719	0.516	5.116	<0.001
	Right	72.219+3.201(RHL)+3.670(RHB)	0.724	0.524	5.075	<0.001
	Unknown	72.446+3.240(HL)+3.570(HB)	0.725	0.525	5.068	<0.001

[Table/Fig-7]: Multiple linear regression analysis and estimation of stature from Hand Length (HL) and Hand Breadth (HB).
Multiple Linear Regression Analysis

			R	R^2	SEE	p-value
Male (N=150)	Left	121.459+2.212(LHL)+0.539(LHB)-0.118(Age)	0.497	0.247	4.690	<0.001
	Right	120.783+2.241(RHL)+0.530(RHB)-0.109(Age)	0.490	0.240	4.710	<0.001
	Unknown	120.666+2.244(RHL)+0.553(HB)-0.114(Age)	0.496	0.246	4.695	<0.001
Female (N=150)	Left	85.902+3.480(LHL)+1.279(LHB)-0.069(Age)	0.593	0.352	3.887	<0.001
	Right	88.619+3.361(RHL)+1.127(RHB)-0.058(Age)	0.598	0.357	3.872	<0.001
	Unknown	85.822+3.471(HL)+1.290(HB)-0.066(Age)	0.602	0.362	3.857	<0.001
Unknown (N=300)	Left	74.358+3.233(LHL)+3.842(LHB)-0.125(Age)	0.733	0.537	5.014	<0.001
	Right	72.541+3.121(RHL)+4.230(RHB)-0.111(Age)	0.735	0.541	4.990	<0.001
	Unknown	72.643+3.138(HL)+4.237(HB)-0.121(Age)	0.738	0.545	4.972	<0.001

[Table/Fig-8]: Multiple regression analysis and estimation of stature from Hand Length (HL), Hand Breadth (HB) and age among adults.
Multiple Linear Regression Analysis

regression coefficients were found statistically significant ($p<0.05$). It was observed that the values of the correlation coefficient R and the coefficient of determination (R^2) increased as the effects of both HL and HB came into force. The regression coefficients and R^2 were found to be higher on the right sides (e.g., RHL and RHB) in both male and female Karbi adult individuals.

Step-wise Multiple Regression of Stature Estimation on HL and HB adding Age as an Independent Variable

The results of step-wise multiple regression equations for stature on both HL and HB among the adult Karbi individuals adding age as an independent variable and correlation coefficient and standard errors are depicted in [Table/Fig-8]. The regression coefficients were also found statistically significant ($p<0.05$). It was further observed that the values of the correlation coefficient R and the coefficient of determination (R^2) increased as the effects of age came into force. Similarly, the regression coefficients and R^2 were found to be higher on the right sides (e.g., RHL and RHB) in both male and female Karbi adult individuals when age was introduced as independent variables with HL and HB ($p<0.01$).

DISCUSSION

India is known for its enormous ethnic population and genetic diversities are attributed to the existence of numbers of ethnic and/or genetic elements [41]. Stature/height varies with ethnic group/populations and is determined by the genetics of an individual, geographical location, environment and climatic conditions [8,9,13,37,42]. Therefore, a need for regional/ethnic or population specific studies on stature estimations are to be emphasised since long owing to the population/ethnic variations present in different parts of the world [10,43]. The anthropometric techniques are widely utilised to formulate the biological profile and personal identification despite of the several modern techniques (e.g., computer tomography and computer assisted superimposition). It is a single most portable, universally applicable, inexpensive and non-invasive technique widely used by biological anthropologists/forensic anthropologists and adopted by medical professionals to estimate body size and proportions for the purpose of identification of the body and skeletons [7-9,13,14,16,18-20,23,29,30,37,42,44]. This technique plays a pivotal role in the field of forensic anthropology and medico-legal cases in personal identification from human remains or population investigations. The estimation of stature from the different body segments includes long bones measurements, finger and phalanges and hand and foot dimensions have shown minimum errors and high predictability [8,15,42,44,45]. Several research studies have also estimated the stature in different ethnic groups/population using different hand dimensions in India [1,19-20,26,32]. There is almost a complete absence of forensic studies on stature estimation using hand dimensions among ethnic groups/populations of Assam, Northeast India. The detailed literature search using PUBMED/Google Scholar, has yielded very few research studies on the estimation of stature and sex from the index finger, ring finger and foot among population of Eastern/North-eastern India [8,9,11,18]. Moreover, results of the present investigation indicated that the hand dimensions (e.g., HL and HB) showed statistically significant positive correlation with stature in both sexes ($p<0.05$). The presence of a positive linearity between anthropometric variables (e.g., HL and HB) and the height/stature facilitates to the formulation of population-specific regression equations which can be utilised for the estimation of stature of an ethnic population. An individual materials (e.g., hand) or mutilated part when recovered and brought for forensic examination can provide valuable information about the age, sex, and stature of the person [19,42,45,46]. Several studies have been undertaken to establish correlation between stature and hand dimensions (e.g., HL and HB) from different ethnic communities/population [15,18-19,20,23,25-26,28,30,32,45]. This present study explored the anthropometric data using hand dimensions (e.g., HL and HB) and stature/height using linear and step-wise multiple regression models with HL, HB and age with the indicator among Karbi adults [Table/Fig-6-8]. These formulae are applicable to the ethnic groups/population from which the data have been collected due to inherent variations in these linear dimensions which may be attributed to biological and environmental factors [20,23]. The results showed that a statistically significant sex-differences were found between sexes in LHL, RHL, LHB, RHB and stature ($p<0.05$) [Table/Fig-4]. The results were in conformity with two studies conducted on the hand dimension in the different ethnic/populations [20,32], but sex-difference was observed to statistically significant in HL [20]. Krishan and Sharma reported a significant difference in HB, whereas no significant difference was observed in HL between the right and left sides [20]. Hence, it may be concluded that adult Karbi males and females differed with respect to RHL and LHB ($p<0.05$) but the differences were not found statistically significant in stature, LHB, and RHB ($p>0.05$), thereby also indicating sexual dimorphism respect to hand dimension [Table/Fig-5]. A significant difference was observed in HL among Indians females, west Europeans and natives of West Indies, while no such differences were found in HB [24]. Using paired sample t-test, the result of the present study indicated that there were statistically in significant differences observed in hand dimension in HL among females and total but the t-value was found to be statistically significant among males and female individuals in respect to HL (in males), HB (both males and females) Karbi individuals ($p>0.05$) [Table/Fig-5].

The preponderance of existing studies observed that women have smaller body dimensions than men individuals. Several studies have been already reported the sexual dimorphism existed in the HL and HB in the both sexes [1,20,25-26,32]. The results of the present study support the fact that male individuals are genetically taller than female counterparts. Age of puberty being two years later in males as compared to females give them an additional period of physical growth and maturation [20,25]. As far as bilateral asymmetry in the HL and HB are concerned that descriptive statistics showed significant asymmetry in both HL (except in females) and HB of mean value, standard deviation are similar and differences were found to be statistically significant ($p>0.05$) [Table/Fig-5]. Similar results were also obtained by Krishan and Sharma [20] and Agnihotri et al., [32] for HL dimension, but their study showed significant asymmetry in HB in the studies ethnic population ($p<0.05$). The present study has reported significant coefficients (R) when the regression of stature on LHL, RHL, LHB and RHB and regression of HL and HB is also considered for estimation of stature in both sexes ($p<0.05$). Stature is thus significantly dependent on LHL, RHL, LHB and RHB ($p<0.05$) [Table/Fig-6]. The predictability was increased when multiple regressions were done and also when age was added as another variable. It was further observed that the values of the correlation coefficient (R) and the coefficient of determination (R^2) were found to be similar as the effects of both HL and HB came into force. For unknown cases, the values of R and R^2 also remained appreciably higher in both sexes in linear regressions when both HL and HB are coming into force. The results of the present study may conclude that the estimation of stature with LHL, RHL, LHB and RHB is possible in adults. In step-wise multiple regression equations, where age added as a predictor variable with HL and HB that showed a positive increase both R and R^2 in both male and female adult Karbi individuals. These estimations can, thus, play a prime role in case of identification cases involving the indigenous Karbi individuals and may apply for estimation in different ethnic communities in India [Table/Fig-6-8]. Present investigation has focused on the estimation of stature from population-specific equations (e.g., linear and multiple linear regression models) using hand dimension and the mean differences between the mean stature with estimated stature was observed to be statistically not significant ($p>0.05$) [Table/Fig-9].

Measurements (cm)		Estimated Stature Range	Mean Estimated stature±SD	t-value	p-value*
Male (N=150)	LHL	156.80-177.24	161.689±2.43	-0.021	>0.05
	RHL	157.24-177.21	161.683±2.42	-0.006	>0.05
	HL	156.97-177.38	161.685±2.44	-0.012	>0.05
	LHB	159.01-167.39	161.683±1.26	-0.004	>0.05
	RHB	158.27-166.81	161.683±1.28	-0.004	>0.05
	HB	158.49-167.39	161.678±1.30	-0.008	>0.05
Female (N=150)	LHL	1.42.72-158.05	151.048±2.76	0.014	>0.05
	RHL	142.76-158.57	151.093±2.81	-0.004	>0.05
	HL	142.60-158.48	159.099±2.81	-0.004	>0.05
	LHB	142.83-156.16	151.323±1.61	0.612	>0.05
	RHB	146.49-155.80	151.097±1.57	0.002	>0.05
	HB	146.27-156.16	151.096±1.64	0.006	>0.05
Unknown (N=300)	LHL	143.17-190.30	156.393±5.08	-0.009	>0.05
	RHL	142.77-189.64	156.388±5.08	0.003	>0.05
	HL	142.83-190.27	156.381±5.11	0.027	>0.05
	LHB	144.74-176.22	156.390±4.55	0.002	>0.05
	RHB	144.17-174.35	156.390±4.55	0.003	>0.05
	HB	144.09-175.90	156.390±4.67	-0.002	>0.05

[Table/Fig-9]: Estimated mean stature and comparison of actual from hand dimensions among Karbi adults.
Paired sample t-test Analysis; *p>0.05

LIMITATION

The anthropometric measurements on hand dimensions in the present investigation were obtained from living individuals may not provide accurate estimation of stature on skeletal remains. This could be the one of the limitation of the present investigation; therefore similar equations could be developed and/or tested using skeletal remains to estimate the stature in population.

CONCLUSION

It is worthwhile to mention here that the present cross-sectional investigation is a pioneering study among indigenous Karbi tribal individuals of Karbi Anglong, Assam Northeast India. The present study is successful in estimating stature from LHL, RHL, LHB and RHB. It has also successfully observed the possible relationships between the stature and hand dimensions as well as estimated bilateral differences and sex-differences with respect to anthropometric variables (e.g., HL and HB) on hand dimensions. Furthermore, similar studies are also recommended for ethnic/population specific equation and/or utilise and validation of equations to estimate the stature from HL and HB. The present study equations may be used to obtain the approximate height of an individual/population in case of the practical problems in order to obtain direct measurements of the body remain (e.g., dismembered fragments or amputee or accidental cases).

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help and co-operation of the research participants, heads of the community and local village headmen during the field work and data collection process. The authors also gratefully acknowledge the extended help and co-operation of the Department of Anthropology, Assam University Diphu Campus, Diphu, Assam, India.

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FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Aug 28, 2018**
Date of Peer Review: **Oct 12, 2018**
Date of Acceptance: **Dec 11, 2018**
Date of Publishing: **Mar 01, 2019**