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Estimation of Sex from Hand Dimensions in an Indigenous Karbi Adult Population of Assam, India

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ABSTRACT Personal identification is one of the most important elements in any medico-legal and forensic investigation. It is a challenging task for both the forensic experts and physical anthropologists when identifications of unknown dismembered remains are involved. The aim and objectives of the present investigation was to determine sex by using hand length (HL) and hand breadth (HB) among an indigenous adult Karbi tribe of Karbi Anglong, Assam, India. The present community based cross-sectional investigation was undertaken among 320 unrelated adult Karbi individuals (160 males;160 females) between the age-group of 20-50 years, using stratified random sampling method. The anthropometric measurements of HL and HB were collected using standard procedures. The statistical analysis of descriptive statistics, ANOVA, binary logistic regression (BLR) and AUC-ROC were performed using SPSS (version 16.0). The results indicate that mean of LHL, RHL, LHB, RHB, LHI and RHI were observed to be significantly higher among men than women ($p<0.01$). The investigation highlights the existence of sexual dimorphism in HL and HB ($p<0.01$). The mean bilateral difference was found to be statistically not significant in both sexes in HL and HB ($p>0.05$). The BLR analysis showed that HB was found to be significantly more associated with sex estimation than the HL in both sexes ($p<0.01$). The AUC-ROC analysis was performed to test the predictive accuracy in sex estimation after predicting the probability of HL and HB. The AUC-ROC analysis showed that combined HB than HL have more accuracy over a single hand dimension measure (for example, LHL, RHL, LBH and RHB) to determine the sex ($p<0.01$).The equation of the present investigation may prove to be useful in sex estimation of an adult individual when any fragmented or mutilated body parts are brought for the forensic science and medico-legal investigations.

INTRODUCTION

Personal identification is one of the most important elements in any medico-legal and forensic investigations and it is a challenging task for both the forensic scientists and forensic anthropologists. There are greater chances of finding any fragmented, mutilated and decomposed body segments from any man-made mass disasters or explosions and/or crime scenes in modern world, where the human body is partially or completely mutilated by the murderers in order to dispose off the identity of a person (Kanchan and Rastogi 2009; Kanchan et al. 2010a,b; Rongpi and Mondal 2019). The forensic experts and forensic anthropologists in such cases can give a tentative identification and estimations of unknown remains such as identification of sex, age, stature and ethnicity from the remains of the human body (Robling and Ubelaker 1997; Sen and Ghosh 2008; Jee et al. 2015; Sen et al. 2015; Kim et al. 2018; Rongpi and Mondal 2019). Sex estimation is one of the most important elements in the identification of an individual or population. It is a simple task to determine the sex when the whole body is available as the internal and external genitalia can directly suggest the sex of an individual (Asha et al. 2012; Varu et al. 2016; Caplova et al. 2017). The problem arises when the body parts found are in a fragmented or mutilated state in mass disasters, accidents, explosions and crime scenes (Agnihotri et al. 2005; Rani et al. 2011; Uhrová et al. 2015; Pal et al. 2016; Bindurani et al. 2017). Sometimes a forensic anthropologist works with skeletonised or badly decomposed body segments and collect osteometric data, which is generally straight forward in population (Sarode et al. 2009; García-

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Parra et al. 2014; Jee et al. 2015; Curate et al. 2017; Monum et al. 2017; Ubelaker and DeGaglia 2017; Sah and Jeelani 2019).

The estimation of stature or sex from various linear measurements, such as hand and foot dimensions, is the easiest components for personal identification in forensic science and medico-legal aspects (Kanchan et al. 2010a,b; Sen et al. 2011; Dey and Kapoor 2015; Jee et al. a,b 2015; Sen et al. 2015; Kim et al. 2018; Asadujjaman et al. 2019; Singh et al. 2019a). It is common to find fragmented body parts, such as hand and foot in disaster, crime scene, explosions, airplane and train accidents (Kanchan et al. 2010a,b; Jee et al. 2015; Bindurani et al. 2017; Singh and Yadav 2017; Kim et al. 2018; Zulkifly et al. 2018; Asadujjaman et al. 2019; Rongpi and Mondal 2019; Singh et al. 2019b). In such cases, estimation of the sex as well as stature from the fragmented body parts bears an utmost importance in the field of forensic science and medico-legal aspects. Several research investigations have reported sex determination using different body segments in adult individuals (Kanchan and Rastogi 2009; Sen et al. 2011; Dey and Kapoor 2015; Sen et al. 2015; Varu et al. 2015; Bindurani et al. 2017; Singh and Yadav 2017; Zulkifly et al. 2018; Asadujjaman et al. 2019). However, the number of such studies carried out in the region is so far negligible. Therefore, the needs of region/population-specific investigations are necessary owing to ethnic variations present in different regions of the world (Robling and Ubelaker 1997; Singla et al. 2012). India has an enormous number of ethnic and genetic diversity due to the composition of numbers of ethnic/indigenous elements.

Aims and Objectives

The aims and objectives of the present investigation are to investigate the sex-specific association and bilateral differences in hand length and hand breadth and also derive the predictive model of sex determination using these anthropometric measurements of hand dimensions in adult Karbi individuals of Assam, Northeast India.

MATERIAL AND METHODS

The present community based cross-sectional investigation was carried among the 320 unrelated adult Karbi individuals (160 males and 160 females) between the age groups 20-50 years of age. They are ethnically an endogamous Mongoloid tribal population belonging to the Tebeto-Burman linguistic family group (Kumar et al. 2004; Rongpi and Mondal 2019). They are a distinct tribal population separated from the major ethnic group of Bodo Kachari and Sonowal Kachari tribal population of Assam, Northeast India (Kumar et al. 2004). They are mainly distributed in the districts of Karbi Anglong, Dima Hasao, Kamrup, Morigaon, Nagaon, Golaghat, Lakhimpur, Sonitpur and Cachar of Assam and the states of Arunachal Pradesh, Meghalaya and Nagaland of northeast India. However, they are mostly concentrated in the district of Karbi Anglong. The district Karbi Anglong is the largest among the 33 districts of Assam. It covers the total area of 10,434 square kilometres with a population of 9,56,313 individuals (male: 4,90,167; females: 4,66,146) according to the 2011 census. The overall literacy rate of the district is 69.25 percent (male: 76.14%; female: 62.00%). Initially, a total 350 Karbi adult individuals aged 20-50 years of age were identified and approached by using stratified random sampling method. The research participants having any sign of significant disease, physical or orthopaedic deformity, and metabolic or developmental disorder, which could have affected the general growth were not included in the present investigation. The research participants were identified as the indigenous Karbi tribe by identifying their physical and cultural features and recording their surnames in the present investigation. The nature and purpose of the present investigation was explained to the research participants in detail and an informed consent was obtained before collection of anthropometric and socio-economic data. Necessary permission for the present research investigation was obtained from the local village authorities, traditional village headmen, local level community leaders and the Department of Anthropology, Assam University (Diphu Campus). The present research investigation was carried out according to the ethical guidelines for human research as laid down in Helsinki Declaration (Touitou et al. 2004; Portaluppi et al. 2010). The participation of the research participants in the present research investigation was purely voluntary in nature. They were the permanent residents of the Karbi dom-

inated villages, namely, Taralangso, Chephongkimi, Rongchedon, Dikrenglangso, Rongjangphong, Rongkimi, Rongkangjang of Lumbajong Block, Diphu sub-division, Karbi Anglong district of Assam. These villages were selected due to homogeneity and distribution of poulation and easy accessibility by road using purposive/ convenient sampling method. These villages are situated at a distance of approximately 20-25 km southwest of Diphu sub-division town of Karbi Anglong, Assam in northeast India (Fig. 1).

Collection of Socio-economic and Demographic Data

Several socio-economic and demographic data were collected during the course of the present investigation. The demographic data including age, sex, marital status, monthly income, family income, family expenditure, family type, number of earning members, family size, dependent children, birth order, occupation, education, type of sanitation, type of house, number

Fig. 1. The Map showing the location of study area Karbi Anglong Assam, Northeast India

of living rooms, livestock and vehicles owned were recorded from each Karbi household using survey methods. Certain habits include alcohol consumption, smoking, use of tobacco and chewing of betel nuts were also recorded from each of the research participants. The age of the participant were recorded as per the voter identity card, birth certificates and driving license issued by the Government authorities.

Anthropometric Measurements and Records

Four anthropological measurements were obtained from the participants according to the standard procedures (Singh and Bhasin 1989; Hall et al. 2007). The measurements taken are:

a. Left Hand length (LHL)
b. Right Hand length (RHL)
c. Left Hand breadth (LHB)
d. Right Hand breadth (RHB)

Hand length (HL) is measured from the midpoint of the distal transverse crease of the wrist (that is, extending from ulnar to radial side) to the most anterior projection of the skin of the middle finger (that is, inter stylion line). Hand breadth (HB) is measured as a distance between the radial side of the second metacarpophalyngeal joint (metacarpal rediale) and the ulnar side of the fifth metacarpophalyngeal joint (metacarpal ulnale). A sliding caliper was utilised to determine length of LHL, RHL, LHB and RHB. These anthropometric measurements were recorded nearest to millimetre. However, the research participants covered under the present research investigation were also measured with ample precision in order to avoid any systematic errors in the process of anthropometric measurements collection (Harris and Smith 2009). The hand index (HI) was calculated by using the following equation:

$$\text{Handindex (HI)} = \frac{\text{Hand Breadth (HB)}}{\text{Hand Length (HL)}} \times 100$$

The technical errors of measurements {TEM= $\sqrt{(\sum D^2/2N)}$}, where D= Difference between anthropometric measurements, N= the numbers of individual measured), which is an accuracy index and measures the standard deviation between repeated anthropometric measures have been determined to check the consistency of the anthropometric data. Even though a 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= standard deviation of all the measurements] (Ulijaszek and Kerr 1999), the TEM was calculated for the repeatedly taken measurements were obtained from 50 randomly selected adult Karbi individuals by authors DR and NM. Very high reliability (R) was found (R>0.984) in TEM analysis in height, LHL, RHL, LHB and RHB and values were found to be within the acceptable limits (R=0.95). Hence, the measurements taken were reliable and TEM values were not incorporated into further statistical procedures. Therefore, the anthropometric measurements collected in this investigation are found to be reliable and reproducible.

Statistical Analysis

The statistical analysis was performed using the statistical package for social science (SPSS, Version, 16.0). The data obtained was statistically analysed using relevant statistical constants including descriptive analysis [mean, standard deviation (±SD) and range], one-way analysis of variance (ANOVA), binary logistic regression (BLR) and Area Under Curve-Receiver Operating Curve (AUC-ROC) analysis. The ANOVA was utilised to assess the bilateral difference and sex-differences in hand dimensions (HL and HB). The BLR analysis was performed to assess the predictive accuracy to determine the sex of the individual from HL and HB. Sectioning point or cut-off point in the BLR analysis was 0.5. In BLR analysis for estimation of sex of the individuals, all scores greater than 0.5 for the derived value of function (Y) were classified as female, and scores below 0.5 as males. The Receiver Operating Characteristic (ROC) curve was plotted for determination of the predictive efficacy of the screening measures for correctly identifying individuals/variables on basis of their classification by the reference analysis. The AUC was considered to be the predictive accuracy of HL and HB in sex estimation. A p-value of <0.05 and <0.01 levels were considered to be statistically significant.

Table 1: Descriptive statistics of hand dimensions measures among adult Karbi individuals

Measurements	*Male (N=160)*			*Female (N=160)*		
	Mean	*±SD*	*Range*	*Mean*	*±SD*	*Range*
LHL	17.76	0.80	15.70-20.60	16.56	0.76	14.30-18.50
RHL	17.71	0.78	15.90-20.60	16.51	0.79	14.20-18.70
LHB	8.24	0.44	7.20- 9.60	7.47	0.42	6.30- 8.70
RHB	8.31	0.39	7.10- 9.40	7.56	0.41	6.40- 8.70

RESULTS

Descriptive Statistics of Hand Length and Hand Breadth among Adult Population

The mean, standard deviation and range of LHL, RHL, LHB and RHB are depicted in Table 1. It is evident from the Table that the mean LHL for males is 17.76±0.80 cm and ranged from 15.70 cm to 20.60 cm, whereas in case of females the mean LHL was 16.56±0.76 cm and ranged from 14.30 cm to 18.50 cm. The mean RHL for male is 17.71±0.78 cm and varied from 15.90 cm to 20.60 cm whereas in case of the females, the mean RHL is 16.51±0.79 cm and varied from 14.20 cm to 18.70 cm. This shows that the mean LHL is greater than the RHL in both the cases of male and female individuals. The mean LHB was observed to be higher among males and females at 8.24±0.44 cm and 7.47±0.42 cm, and ranged from 7.20 cm to 9.60 cm and 6.30 cm to 8.70 cm, respectively. The mean of RHB among males and females was 8.31±0.39 cm and 7.56±0.41 cm, and varied from 7.10 cm to 9.40 cm and 6.40 cm to 8.70 cm, respectively.

Descriptive Statistics of Hand Index among Adult Karbi Population

The mean, standard deviation (SD) and range of HI are depicted in Table 2. It is evident from the table that the average of LHI was 46.45 ± 2.57 and varied from 39.68 to 54.55 among the male individuals. On the other hand, the average of LHI among the females was 45.18 ± 2.41 and varied from 36.63 to 50.29. The mean values of RHI among the male and female individuals were 47.01 ± 2.34 and 45.73 ± 2.35 and ranged from 40.54 to 53.29 and 37.65 to 50.98, respectively. The results show that the RHI tends to be greater than the LHI in both the males and females, thus showing sexual dimorphisms.

Table 3: Sex specific mean difference in hand dimensions among the adult Karbi individuals

Measurements	*F- Value*	*d.f.*	*p-value*
LHL	191.589	1, 319	0.00
RHL	171.164	1, 319	0.00
LHB	259.817	1, 319	0.00
RHB	282.707	1, 319	0.00

Sex Specific Mean Differences in Hand Dimensions among Adults Population

The sex specific mean differences in hand dimensions are depicted in Table 3. Using ANOVA, the F-value was found to be statistically significant ($p<0.05$) for LHL (F-value =191.59; d.f. = 1, 319), RHL (F-value = 171.16; d.f. =1.319), LHB (F value = 259.82, d.f. = 1, 319) and RHB (F-value = 282.71, d.f. = 1, 319). The sex-specific

Table 4: Sex-specific mean difference in hand index (HI) among Karbi individuals (N=160)

Measurements	*F- Value*	*d.f.*	*p-value*
LHI	20.56	1, 319	0.00
RHI	23.38	1, 319	0.00

Table 2: Descriptive statistics of hand index (HI) among the adult Karbi individuals

Measurements	*Male (N=160)*			*Female (N=160)*		
	Mean	*±SD*	*Range*	*Mean*	*±SD*	*Range*
LHI	46.45	2.57	39.68-54.55	45.19	2.41	36.63-50.29
RHI	47.00	2.34	40.54-53.29	45.73	2.35	37.65-50.98

Table 5: Bilateral mean difference in hand dimensions among the adults Karbi individuals

Measurements	*Male (N=160)*			*Female (N=160)*		
	F-value	*d.f.*	*p- value*	*F-value*	*d.f.*	*p- value*
Hand Length	0.41	1, 319	0.52	0.00	1, 319	0.99
Hand Breadth	2.42	1, 319	0.12	3.83	1, 319	0.51

mean difference in HI is depicted in Table 4. The F-value of HI was found to be statistically significant for LHI (F-value = 20.56; d.f. = 1, 319) and RHI (F-value = 23.38; d.f. = 1, 319).

Bilateral Mean Difference in Hand Dimensions among Adults Population

The bilateral mean differences in HL and HB among male and female Karbi individuals are evaluated by using ANOVA and the results of statistical analysis are depicted in Table 5. No significant bilateral difference was found in HL and HB ($p>0.05$) in both the male and female individuals. When HL is taken into consideration, the F-value was found to be 0.41 (d.f. = 1,319; $p>0.05$) and 0.00 (d.f. = 1, 319; $p>0.05$) in males and females, respectively. When HB is taken into consideration, the F-value was found to be 2.42 (d.f. = 1, 319, $p>0.05$) and 3.83 (d.f. = 1, 319; $p>0.05$) in males and females, respectively.

Binary Logistic Regression and Estimation of Sex among Adults Population

Results of binary logistic regression and estimation of sex among the adult Karbi individuals is depicted in Table 6. The table represents the association of LHL, RHL, LHB, and RHB with sex of the individual. As depicted in the table, the LHL (Wald: 81.48) has greater association with sex, than the RHL (Wald: 78.34). On the other hand, when hand breadth is taken into consideration, it is found that the RHB (Wald: 81.80) has greater association with sex than the LHB (Wald: 86.75). The predictive models in bivariate models were also observed to be statistically significant in HL and HB (in both hands) ($p<0.01$).

Table 6: Binary logistic regression and estimation of sex among the adult Karbi individuals (N=320)

Measurements	*Logistic regression equations*	*Wald*	*p- value*
LHL	34.23–1.997-(LHL)	81.480	0.000
RHL	32.627–1.906-(RHL)	78.340	0.000
LHB	33.880–4.320-(LHB)	81.797	0.000
RHB	36.639–4.611-(RHB)	86.748	0.000
LHL	45.226-1.162 (LHL)-–3.222-(LHB)	LHL: 21.775	0.000
LHB		LHB: 41.150	
RHL	45.094 -0.929(RHL) –3.671 (RHB)	RHL: 14.048	0.000
RHB		RHB: 47.768	

Table 7: ROC-AUC analysis of hand dimensions measurements among the adult Karbi individuals (N=320)

Measurements	*AUC*	*SE*	*95% confidence interval*		*P-value*
			Lower bound	*Upper bound*	
LHL	0.865	0.020	0.826	0.903	0.000
RHL	0.849	0.021	0.808	0.891	0.000
LHB	0.899	0.017	0.866	0.933	0.000
RHB	0.908	0.016	0.876	0.940	0.000
LHL+LHB	0.911	0.016	0.880	0.941	0.000
RHL+RHB	0.902	0.016	0.870	0.935	0.000

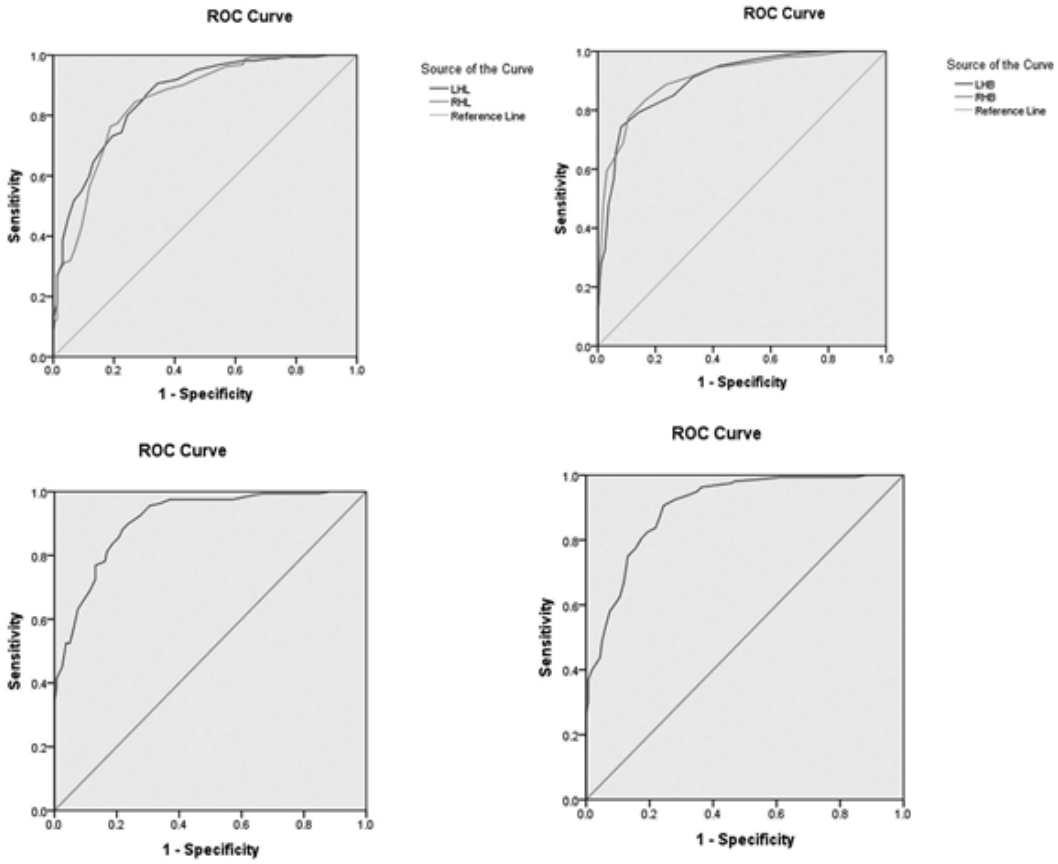

Fig. 2. ROC-AUC analysis indicating the predictive probability from HL and HB on both sides for estimation of sex among adult Karbi individuals

ROC-AUC Analysis and Predictive Accuracy of Hand Dimensions in Sex Estimation among Adults Population

Receiver Operating Curve and Area Under the Curve (ROC-AUC) analysis results of predictive accuracy of HL and HB in sex estimation are depicted in Table 7. The ROC-AUC analysis showed that LHL (86.5%) and RHB (90.8%) have greater potential for discriminating sex over RHL (84.9%) and LHB (89.9%) ($p<0.01$). The HL and HB together have an increased potential of discriminating sex in the left (91.1%) and right hands (90.2%) ($p<0.01$). The associations of HL and HB in sex estimation using ROC-AUC are also shown in Figure 2.

DISCUSSION

Forensic anthropology deals with the assessment of ethnicity and personal identification of human remains in legal investigations. The anthropometry is the most commonly utilised technique in personal identification (for example, age, sex and stature), although several methods (for example, finger print, dental and radiological examinations, etc.) are available in forensic science or forensic anthropology and medico-legal investigations (Robling and Ubelaker 1997; Hall et al. 2007; Sen et al. 2015; Kim et al. 2018; Zulkifly et al. 2018; Gupta et al. 2019; Rongpi and Mondal 2019). It is the single most portable, universally applicable, inexpensive and non-invasive technique widely used and adopted by

medical scientists and forensic anthropologists to estimate body size and proportions for the purpose of identification of the body compositions, sex, skeleton and stature in individuals or population (Portaluppi et al. 2010; Ozaslan et al. 2006; Kanchan and Krishan, 2011; Sen et al. 2015; Jeanson et al. 2017; Arifi et al. 2018; Kim et al. 2018; Rhiu and Kim 2019; Rongpi and Mondal 2019; Gupta et al. 2019). This technique has a prime role and provides quick confirmation and reliable estimation and identification of human materials in case of victims in mass disasters, accidents and crime scenes (Rani et al. 2011; Varu et al. 2016; Zulkifly et al. 2018). Dismembered hands or hand impressions are a common type of physical evidence recovered and/or easily obtained in disaster victim identifications and crime scene investigations. Several research investigations have been carried out to determine the sex of an individual by taking the measurements of hand dimensions (for example HL and HB) (Aboul-Hagag et al. 2011; Sen et al. 2011; Uhrova et al. 2015; Ibrahim et al. 2016; Caplova et al. 2017; Singh and Yadav 2017; Arifi et al. 2018; Rongpi and Mondal 2019), foot dimensions (foot length and foot breadth) (Singh and Bhasin 1989; Singh and Phookan 1993; Kanchan and Rastogi 2009; Pal et al. 2016; Singh and Yadav 2017; Zulkifly et al. 2018; Adelakun et al. 2019; Singh et al. 2019b), fingers (index or ring finger) and phalanges (Robling and Ubelaker 1997; Kanchan et al. 2013; Barrett and Case 2014; Bakholdina et al. 2016; Gupta et al. 2017; Singh et al. 2019b). There is almost a complete absence of such forensic investigation among the ethnic and indigenous population of northeast India. The detailed literature search has yielded very few validations of sample equations of the investigation on the estimation of stature and/or sex from the index finger, ring finger, hand and foot dimensions among the population of northeast India (Singh and Phookan 1993; Robling and Ubelaker 1997; Singla et al. 2012; Sen et al. 2014; Rongpi and Mondal 2019).

It is a well-known fact that contemporary India is composed of a sizeable number of ethnic and indigenous tribal population elements having greater amounts of population, ethnic diversity and genetic variation (Majumder 1998; Indian Genome Variation Consortium. 2008). Therefore, there is a need for regional investigations on biological parameters (stature/height, hand and foot dimensions) or sex estimations are to be emphasised since long owing to the ethnic population and genetic variations are present in different regions of the world (Telkka 1950). The individual hand, when recovered and brought for forensic examination, can provide valuable information about the age, sex and stature of the person (Robling and Ubelaker 1997; Sen et al. 2014; Jeanson et al. 2017; Adelakun et al. 2019; Singh et al. 2019a,b). There are several research investigations, which have been undertaken to establish the relation between sex and hand dimensions in terms of HL and HB in adults (Sen et al. 2011; Asha et al. 2012; Uhrova et al. 2015; Ibrahim et al. 2016; Varu et al. 2016; Caplova et al. 2017; Gupta et al. 2017; Singh and Yadav 2017; Sah and Jeelani 2019). The results of the present investigation showed that the male hands are significantly larger compared to the female counterparts thus showing sexual dimorphism on the basis of hand length (HL) ($p<0.05$) (Table 1). When hand breadth (HB) is considered, males hand breadth (HB) are significantly broader compared to the females thus showing that sexual dimorphism exists on the basis of hand breadth (HB) ($p<0.05$) (Table 1). However, HL and HB are dependent on body size and thus the hand index was derived, as it is independent and not related with either age or stature and more reliable to determine sex from human remains. The average hand index in males was 47.73 whereas the female hand index was 45.46 (Table 2). Several research investigations have been carried out on sex determination from hand dimensions (HL and HB) and also suggest the findings that males have significantly larger hand dimensions than the females counterparts (Aboul-Hagag et al. 2011; Rani et al. 2011; Sen et al. 2011; Asha et al. 2012; Ibrahim et al. 2016; Varu et al. 2016; Caplova et al. 2017; Gupta et al. 2017; Singh and Yadav 2017; Sah and Jeelani 2019). Results of the present investigation showed sex-specific mean differences in HL and HB ($p<0.05$) (Table 3). Therefore, the present investigation extends the findings of the previous investigation to explore the data using hand dimensions (HL and HB). The sex-specific mean values were significantly higher among males than females in both LHI and RHI among the adult Karbi individuals ($p<0.01$) (Table 4). The mean difference in the

hand indices was found to be larger in the right than the left hand with statistically significant value ($p<0.01$). Several researchers have reported statistically significant sex-specific mean differences in LHI and RHI among adults (Sen et al. 2011; Asha et al. 2012; Ibrahim et al. 2016; Varu et al. 2016; Gupta et al. 2017). The results of the bilateral mean differences were observed to be statistically insignificant in HL and HB in both the sexes ($p>0.05$) (Table 5). Several research investigations have reported statistically insignificant bilateral mean differences in HL and HB (Sen et al. 2011; Asha et al. 2012; Ibrahim et al. 2016).

The dismembered hand and/or hand dimensions evidence may play an important role in establishing the identity of a person in forensic studies or medico-legal investigations. Therefore, its examination is of prime importance in the population. The results of BLR analysis showed that HB was found to be significantly higher association with sex estimation than the HL in both sexes in Karbi adults ($p>0.01$) (Table 6). The LHL (Wald: 81.48) and the RHB (Wald: 86.75) shows greater association with sex than the RHL (Wald: 78.34) and LHB (Wald: 81.79). Therefore, the results of the present investigation indicate that hand dimensions (HL and HB) can be used to determine sex with higher accuracy and HB found to have relatively higher predictability than HL ($p<0.01$) (Table 6). Several investigations have been reported, which support the findings that hand dimensions showing the association with sex in individuals/population (Sen et al. 2011; Ishak et al. 2012; Ibrahim et al. 2016; Varu et al. 2016; Singh and Yadav 2017; Sah and Jeelani 2019; Zulkifly et al. 2018). The AUC-ROC analysis was performed to determine the predictive accuracy after predicting the probability of HL and HB in sex estimation in adults. The ROC-AUC analysis showed that LHL (86.5%) and RHB (90.8%) have greater potential for discriminating sex over RHL (84.9%) and LHB (89.9%) ($p<0.01$) (Table 7). The present investigation showed that in both the cases of male and female, HB is relatively a better discriminator of sex of the individuals than the HL. The AUC-ROC analysis showed that both HB than HL have more accuracy to determine the sex of the Karbi adult individuals ($p<0.01$) (Table 7).

CONCLUSION

It is worthwhile to mention here that the present research investigation is a pioneering study among the indigenous Karbi tribal population of Karbi Anglong, Assam in northeast India. The present cross-sectional investigation has been successful in determining the sex of the individuals from LHL, RHL, LHB and RHB. The hand dimension measures have shown the significant association with the sex determination of the individuals. The results of the present investigation showed that the hand dimensions (HL and HB) are relatively more reliable in sex determination, as HB showed significantly greater association with sex than the HL. Thus, it can be concluded that the hand dimensions (HL and HB) can be successfully used to estimate the sex of an individual when brought for forensic examination to solve various forensic and medico-legal cases of dismembered bodies often discovered in mass disaster and crime scenes.

RECOMMENDATIONS

The derived linear and multi-linear regression equations based on hand dimensions have shown significantly higher sensitivity and reliability to determine the sex of the individuals among Karbi adult population. Moreover, the identification of sex is indicated that the accuracy of hand dimensions (that is, HL and HB) for determination of sex may be population specific. Therefore, the present research investigation recommends the use and validation of the derived equations in the present investigation to determine the sex of the individuals from hand dimension (HL and HB) of the several other adult ethnic populations in India.

LIMITATIONS

The determination of sex of an indigenous Karbi tribal population in the present investigation is based on simple and linear anthropometric measurements rather than the advanced methods. Furthermore, the present research investigation is confined to only a particular ethnic population (that is, the Karbi tribe) to derive the logistic regression equations and AUC-ROC curve to determine the accuracy and sensitivity of the sex of the individuals. Hence, these equa-

tions may not give the desired results to the largely heterogeneous ethnic communities in the determination of sex in India and abroad.

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