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Original Article

Forensic Section

Estimation of Sex From Index and Ring Finger Lengths in An Indigenous Population of Eastern India

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ABSTRACT

Introduction: Forensic anthropology involves the identification of human remains for medico-legal purposes. Estimation of sex is an essential element of medico-legal investigations when identification of unknown dismembered remains is involved. **Aim:** The present study was conducted with an aim to estimate sex from index and ring finger lengths of adult individuals belonging to an indigenous population of eastern India.

Materials and Methods: A total of 500 unrelated adult individuals (18-60 years) from the Rajbanshi population (males: 250, females: 250) took part in the study. A total of 400 (males: 200, 200 female) participants were randomly used to develop sex estimation models using Binary Logistic Regression Analysis (BLR). A separate group of 200 adults (18-60 years) from the Karbi tribal population (males 100, females 100) were included to validate the results obtained on the Rajbanshi population. The univarate and bivariate models derived on the study group (n=400) were tested on hold-out sample of Rajbanshi participants (n=100) and the other test population of the Karbi (n=200) participants.

Results: The results indicate that Index Finger Length (IFL) and Ring Finger Length (RFL) of both hands were significantly longer in males as compared to females. The ring finger was longer than the index finger in both sexes. The study successfully highlights the existence of sex differences in IFL and RFL ($p<0.05$). No sex differences were however, observed for the index and ring finger ratio. The predictive accuracy of IFL and RFL in sex estimation ranged between 70%-75% (in the hold out sample from the Rajbanshi population) and 60-66% (in the test sample from the Karbi population). A Receiver Operating Curve (ROC) analysis was performed to test the predictive accuracy after predicting the probability of IFL and RFL in sex estimation. The predicted probabilities using ROC analysis were observed to be higher on the left side and in multivariate analysis.

Conclusion: The study concludes that sex estimation from index and ring finger lengths could be of utility when more reliable means of sex estimation are not available during medico-legal investigations.

Keywords: Forensic anthropology, Index finger length, Index-ring finger ratio, Ring finger length, Sex estimation, Rajbanshi

INTRODUCTION

Identification of human remains is an essential element in medico-legal investigations. One of the key tasks for the forensic anthropologist is the identification of dismembered, mutilated and fragmentary remains. The identification processes employed typically consists of age and sex assessment, determination of stature of the deceased, and comparisons with the ante-mortem data. The process of identification is usually encountered in cases of mass disasters, explosions, and assault cases where the body is dismembered and establishing the identity of the victim poses a challenge for investigators [1]. It is here that accurate sexing of the human remains has the potential to primarily narrow down the search to a particular sex thereby giving sense of direction to the ongoing forensic investigation.

There is a need for regional studies in the process of identification of human remains as the human species inhabit diverse environments all over the earth and exhibit a lot of racial and ethnic variations. It has been observed that India, as a country, consists of a large number of ethnic and indigenous elements and these have enormous amounts of ethnic and genetic diversity [2-6]. It is a vast country with varied geographical conditions and body compositions of these elements differ with race, sex and geographical locations. It is now recognized that the Indian population consists of 4693 communities with several thousand endogamous groups [7], with a population of more than 1.22 billion, India has the largest number of indigenous people in the world.

Dismembered remains including the terminal parts of the human body such as hands and feet are often found in cases of mass disasters and homicides [8]. Studies have focused on the role of hand and foot measurements in establishing the biological profile of individuals in forensic investigations [9-16]. Besides the lengths of the fingers such as Index Finger Length (IFL) and ring finger length (RFL), finger ratios have also been used for predicting sex of an individual. The finger ratio is an established sexually dimorphic biometric population marker [17-20]. This ratio is related to prenatal estrogen and testosterone levels and genetically controlled by the HOX genes [21]. Literature on the index and ring finger ratio in sex prediction has shown variable results in terms of its forensic significance. It is observed that the IFL and RFL ratios differ between populations and its utility appear to be limited in forensic case work [22,23]. A limited number of studies on the issue of sex estimation from IFL and RFL was found in course of a detailed literature search of the databases “Pubmed” and “Science Citation Index, Thomsen Reuters” [18,19,24,25]. Among these studies, only two of them have reported the usefulness of index and ring finger lengths as a determinant of sex amongst different adult and sub-adult Indians [24,25]. Apparently the need to estimate sex of an individual using a part of the hand or fingers arises when only part of a hand is available for examination. Such studies are lacking for one of the largest indigenous populations of eastern India, the “Rajbanshi”. Given the above, the present study has been undertaken to investigate sexual dimorphism in the lengths of index and ring fingers and to derive models for estimating sex using these measurements.

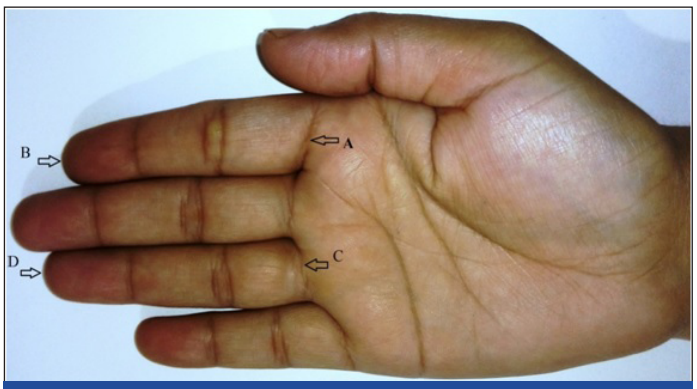
MATERIALS AND METHODS

Nature of study area and participants: The present cross-sectional study was carried out among 500 unrelated individuals

(250 males and 250 females) belonging to the Rajbanshi population of West Bengal. The Rajbanshi caste group has been selected for the present study due to its numerically larger strength, and the fact that they also appear to satisfy the condition of moderate numerical size as compared to the surrounding populations [10,14]. The individuals selected for the present study were identified as belonging to the Rajbanshi population by observing their physical features, cultural features and by recording their surnames. This data was subsequently verified from the official records of the Gram Panchayat (a local village level governing authority). The Rajbanshi individuals who participated in the present study were unrelated to one another and were the residents of a homogenous Rajbanshi-inhabited village named 'Kachuaboalmari' located in Nandanpur Gram Panchayat, Sadar Block, Police Station Kotwali, District Jalpaiguri, West Bengal, India and were aged between 18 and 60 years (mean age of males = 41.63±11.60 years, mean age of females = 37.67±11.49 years). By unrelated individuals, it is meant that consanguine relatives of them such as brother-brother, sister-sister, mother-son, mother-daughter, father-son and father-daughter were not included in the study. The participants were selected using a stratified random sampling method. The participants were free from any physical deformity of hands and fingers. The nature of the study was explained to the participants in detail and an informed consent was taken from each of them prior to recording their measurements.

Furthermore, a total of 200 (100 males and 100 females) adult individuals belonging to the tribal Karbi population of Assam aged between 18 and 60 years were included to validate the accuracy of the statistical models that were derived in the present study. They were also selected using a random sampling method from two villages namely Rongriso and Plimplamlamgso located in the district Diphu Karbi-Anglong. The present study has been conducted in accordance with the ethical standards of human experiments as laid down in the Helsinki Declaration of 2000 [26]. Necessary permissions and clearances of the study protocol were obtained from the Department of Anthropology, University of North Bengal, the Nandanpur Gram Panchayat, Sadar block of Jalpaiguri district of West Bengal, the village level governing authorities of Rongriso and Plimplamlamgso villages of Karbi-Anglong, Assam.

Anthropometric measurements recorded: The anthropometric measurements were recorded following the procedures of Singh and Bhasin [27]. The measurements recorded were length of index finger of left hand (LIFL), length of index finger of right hand (RIFL), length of ring finger of left hand (LRFL) and length of ring finger of right hand (RRFL). The IFL and RFL were measured as the linear distance between the midpoint of the proximal most flexion crease of the base, and the anterior most points of the index and ring finger (tip) in the midline on the palmer surface respectively [Table/Fig-1]. A sliding caliper was utilized to measure the lengths of the fingers. Care was taken to observe that there was no abduction or adduction at the wrist joint. The index and ring finger ratio was calculated for both hands by dividing IFL by RFL (IFL÷RFL). All the anthropometric



[Table/Fig-1]: Landmarks of anthropometric measurements of IFL (A-B) and RFL (C-D)

Measurement	Intra-observer		Inter-observer	
	TEM %	Coefficient of Reliability (R)	TEM%	Coefficient of Reliability (R)
LIF (mm)	0.058	0.97	0.057	0.97
LRF (mm)	0.055	0.98	0.052	0.98
RIF (mm)	0.059	0.98	0.050	0.98
RRF (mm)	0.066	0.96	0.053	0.98

[Table/Fig-2]: Technical Errors of Measurement (TEM) of finger lengths
LIFL – Left index finger length, RIFL – Right index finger length, LRFL – Left ring finger length, RRFL – Right ring finger length

measurements were recorded to the nearest 0.1 cm. The technical error of measurement (TEM) was determined to check the consistency and reliability for the intra-observer and inter-observer differences in connection with the measurements [28,29]. TEM was calculated as TEM= $\sqrt{(\sum D^2/2N)}$, where 'D' is the difference between the measurements, and 'N' is the number of individuals measured. For estimating TEM in the present study, LIFL, RIFL, LRFL and RRFL were measured in 30 randomly selected Rajbanshi adult individuals other than those included in the present study by two of the authors (AG and NM). The coefficient of reliability (R) (R= $\{1-(TEM)^2/SD^2\}$, SD= standard deviation of the measurements) were subsequently determined from the measurements [Table/Fig-2]. Very high values of 'R' (>0.96) were obtained for all the anthropometric measurements and these were appreciably higher than the cut-off value of 0.95 [29]. Thus, the anthropometric measurements obtained in the present study by AG and NM was reliable, reproducible and free from any observer bias, and TEM was not taken into consideration for further statistical analysis. All the measurements for the present study were subsequently recorded by AG. The systematic errors due to the shift in the style or landmark interpretations or between instruments (e.g., sliding caliper) were also tested using the standard procedure [30]. Similarly, the differences in the anthropometric measurements were evaluated with repeated measures and sessions using one-way ANOVA and the mean differences were observed to be statistically not significant (p>0.05).

STATISTICAL ANALYSIS

The statistical analysis was done using the Statistical Package for Social Sciences (SPSS version 17.0, Chicago, Illinois, USA). A p-value of less than 0.05 was considered to be statistically significant. One-way analysis of variance (ANOVA) based on the general linear model was performed to compare sex differences in IFL, RFL, and index-ring finger ratio (left and right) between sexes. Two-way ANOVA using general linear model was also performed to control the influence of age-sexes on IFL, RFL and index-ring finger ratio (left and right). The bilateral differences were also evaluated between measurements in right and left hands using ANOVA. The study sample (n=500) was randomly split into two groups based on random number table; the first group comprised of 400 participants (200 males and 200 females) on which the statistical analysis was performed to derive sex discriminating models and the second group of 100 participants (50 males and 50 females) was designated as 'hold out sample' on which the validity of derived models were tested. The analysed group and test group were balanced for ethnic origin/age and sex variations. The binary logistic regression (BLR) analysis was employed to derive the predicting models for estimation of sex from IFL and RFL. The accuracy of models derived using BLR analysis from the 400 participants was tested on the hold out study sample from the same population. The accuracy of derived models were also tested on the other sample drawn from a different unrelated population group (in this case Karbi) comprising of 200 participants (100 males and 100 females) which was designated as 'test group'. These samples were taken into consideration using the random sampling method to test the accuracy of the derived models in BLR analysis. Sectioning point in logistic regression analysis was 0.5. In BLR analysis for estimation of sex; all scores greater than

Anthropometric measurements	Male (N=250)		Female (n=250)		Mean difference in anthropometric measurements using ANOVA			
	Range	Mean ±SD	Range	Mean ±SD	One-way ANOVA (F-value)	d.f.	Two-way ANOVA (F-value)	d.f.
RIFL (mm)	59-80	68.4 ±4.1	56-76	63.9 ±4.1	149.77**	1,499	1.46*	39
LIFL (mm)	57-81	68.6 ±4.0	50-76	63.7 ±4.1	178.97**	1,499	1.55*	39
RRFL (mm)	56-82	70.5 ±4.3	54-78	65.8 ±4.2	150.86**	1,499	1.46*	39
LRFL (mm)	58-85	71.3 ±4.4	54-80	66.1 ±4.6	171.59**	1,499	1.59*	39

[Table/Fig-3]: Descriptive statistics of index and ring finger lengths
RIFL – Right index finger length, LIFL – Left index finger length, RRFL – Right ring finger length, LRFL – Left ring finger length, S.D. – standard deviation, d.f.- degree of freedom, **p-value < 0.0001, *p-value>0.05

Left – Right	Male (N=250)				Female (N=250)			
	One-way ANOVA	d.f	Two-way ANOVA	d.f.	One-way ANOVA	d.f	Two-way ANOVA	d.f.
IFL (mm)	0.10*	1,499	0.10*	40	0.43	1,499	0.99*	40
RFL (mm)	0.12*	1,499	4.99**	40	0.58	1,499	0.11*	40

[Table/Fig-4]: Bilateral asymmetry in finger lengths.
IFL – Index finger length, RFL – Ring finger length, d.f.- degree of freedom; *p>0.05, **p<0.05

Variable	Male (N=250)		Female (n=250)		Mean differences			
	Range	Mean ± SD	Range	Mean ± SD	One-way ANOVA	d.f.	Two-way ANOVA	d.f.
RR	0.90-1.11	0.97± 0.03	0.88-1.13	0.97± 0.03	1.44*	1,499	0.87*	39
LR	0.84-1.06	0.96± 0.03	0.88-1.05	0.96± 0.03	0.01*	1,499	1.06*	39

[Table/Fig-5]: Descriptive statistics of index and ring finger ratio.
RR – Right index and ring finger ratio, LR – Left index and ring finger ratio, S.D. – standard deviation, d.f. degree of freedom; *p>0.05

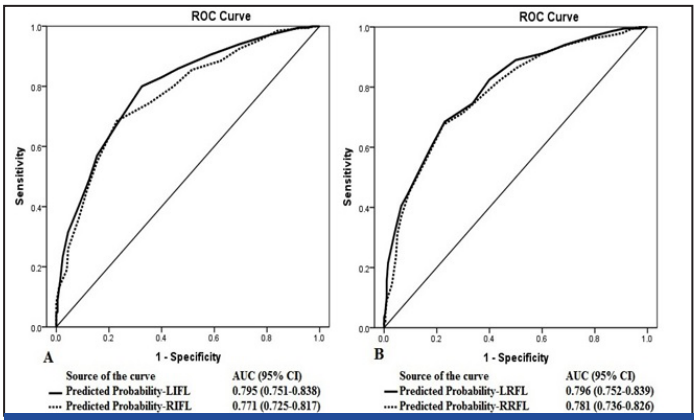
Measurements	Regression model	Wald	p-value
LIFL (mm)	18.829–2.851 (LIFL)	80.20	<0.001
LRFL (mm)	18.036–2.622 (LRFL)	79.22	<0.001
RIFL (mm)	16.737–2.530 (RIFL)	69.25	<0.001
RRFL (mm)	17.418– 2.556 (RRFL)	71.18	<0.001
LIFL, LRFL (mm)	19.712–1.514 (LIFL)–1.42(LRFL)	LIFL:6.703; LRFL:6.934	0.01
RIFL, RRFL (mm)	18.220–1.036(RIFL)–1.667(RRFL)	RIFL:6.703; RRFL:6.934	0.05

[Table/Fig-6]: Binary logistic regression analysis for estimation of sex from index and ring finger lengths in the analysed group from the Rajbanshi population (n=400)
LIFL – Left index finger length, LRFL – Left ring finger length, – Right index finger length, RRFL – Right ring finger length,

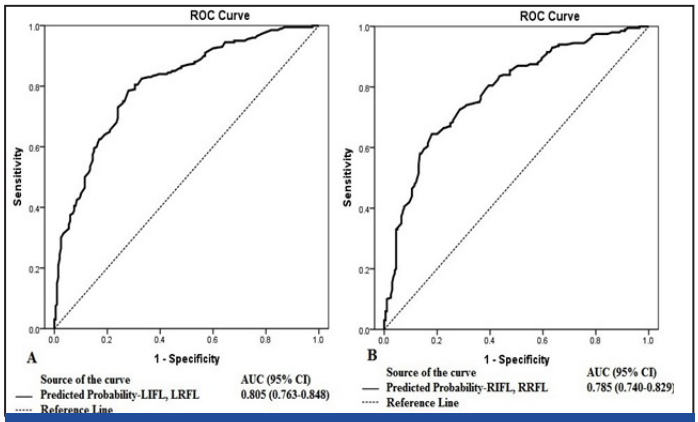
Measurements	Hold-out group- Rajbanshi population (Males:50; Females:50)			Test Group- Karbi population (Males:100; Females:100)		
	Male Cpp	Female Cpp	Mean Cpp	Male Cpp	Female Cpp	Mean CpP
LIFL (mm)	90.0	60.0	75.0	49.0	73.0	61.0
LRFL (mm)	86.0	56.0	71.0	51.0	81.0	66.0
RIFL (mm)	90.0	60.0	75.0	51.0	72.0	61.5
RRFL (mm)	82.0	64.0	73.0	52.0	71.0	61.5
LIFL, LRFL (mm)	80.0	60.0	70.0	50.0	78.0	64.0
RIFL, RRFL (mm)	86.0	64.0	75.0	56.0	74.0	65.0

[Table/Fig-7]: Correct prediction percentage (CPP) in estimation of sex from IFL and RFL based on sectioning point (0.5) in binary logistic regression (BLR) analysis
LIFL – Left index finger length, LRFL – Left ring finger length, – Right index finger length, RRFL – Right ring finger length

0.5 for the derived value of function (y) were classified as female, and scores below 0.5 as males. The correct prediction percentage was thus, obtained on the hold out sample and the other unrelated test sample. Besides, drawing prediction percentage based on BLR



[Table/Fig-8]: ROC analysis indicating the predictive probability from IFL (A) and RFL (B) on both sides for estimation of sex



[Table/Fig-9]: ROC analysis indicating the predictive probability from combined IFL and RFL of Left (A) and Right (B) sides for estimation of sex

analysis, Receiver Operating Curve (ROC) analysis was performed on the predicting probabilities obtained from BLR analysis. Area Under the Curve (AUC) was considered as the predictive accuracy of IFL and RFL in sex estimation.

RESULTS

The descriptive statistics of IFL and RFL among male and female individuals in the present study are depicted in [Table/Fig-3]. The IFL and RFL lengths were observed to be significantly longer (p<0.001) among males than females in both right and left hands. The sex differences in finger length were observed to be statistically significant (p<0.001). Differences in lengths of LIFL and LRFL were observed to be higher than RIFL and RRFL. The ring finger was observed to be longer than index finger among both sexes [Table/Fig-3]. Statistically significant side differences were not observed between right and left hands for IFL among both sexes and RFL in females (p<0.05) [Table/Fig-4]. The descriptive statistics of IFL and RFL ratio among males and females in the present study are shown in [Table/Fig-5]. The mean values of IFL and RFL ratio were identical in left and right hands among both sexes. The sex differences in IFL and RFL ratio were not observed to be statistically significant (p>0.05) on right and left sides [Table/Fig-5].

A significant correlation was observed between sex and the different variables analysed. Predicting models derived for estimation of sex from IFL and RFL using BLR analysis are shown in [Table/Fig-6]. It is

evident that the univariate and bivariate models derived for IFL and RFL estimate sex with mean correct prediction percentage ranging between 70.0% and 75.0% in the hold-out group and between 61.0% and 66.0% in the test group. Mean Correct Prediction Percentage (CPP) was thus, higher for the hold out group belonging to the same population from which the regression models were derived than the test group that constituted of a different population group from the region. CPP in the hold-out group was higher for IFL than the RFL in both hands [Table/Fig-7]. Based on the Receiver Operating Curve (ROC) analysis [Table/Fig-8], LIFL (79.5%) and LRFL (79.6%) shows greater potential for discriminating sex over RIFL (77.1%) and RRFL (78.1%). The IFL and RFL together [Table/Fig-9] have an increased potential of discriminating sex in the left (80.5%) and right hands (78.5%).

DISCUSSION

The morphological sex difference in the absolute length of the finger has been reported along with the fact that male fingers were significantly longer as compared to female fingers [19,24,25,31,32]. In the present study, RFL was observed to be longer than IFL among both hands of males and females. Besides, IFL and RFL of both hands of males were significantly longer than those of female individuals ($p<0.05$). Several researchers have reported the existence of significant sex differences in RFL and IFL in different ethnic populations [18,19,24,25,33]. Differences in finger length dimensions (e.g., IFL and RFL) seem to be indicative of a size-based difference along with a shape-based difference between sexes [19,33]. The distribution of finger length measurements showed the extent and range of overlapping in male and female values for IFL and RFL on right and left side among the Rajbanshi individuals. The present study has observed statistically insignificant bilateral variations in RFL and IFL among them. Bilateral differences in the IFL and RFL could influence the standards derived in the present study and the findings obtained from one side thus, may not be applicable to the other owing to side differences in both sexes among the study population. A number of studies have reported bilateral variations in IFL and RFL among individuals belonging to different Indian ethnic populations [18-20,24,25].

The index and ring finger ratio was observed to be similar among both sexes for right and left hands ($p>0.05$). Considerable overlapping in the frequency distributions of index and ring finger ratios were observed among both sexes in the study population. Finger ratio is generally considered to be a sexually dimorphic trait that is independent of body size and the ratio is not significantly related to height and age of the either sexes [19,25,33]. Studies have observed IFL and RFL ratio as a sexually dimorphic trait that has been established early in life and remains fairly stable postnatal and remained consistent with age and growth in a population [22,23,34]. The sexual dimorphism in IFL and RFL ratio develops between the 13th and 14th week of gestation [35,36] under the influence of parental androgens and estrogens [37,38]. In general, a lower IFL and RFL ratio has been reported among females [19,33,39,40]. Manning reported that IFL was generally about 96.0% of RFL [40]. So the average IFL and RFL ratio for males would be 0.96. Hence, index and ring finger ratio may serve as an important index for estimation of sex of an individual. Studies among different ethnic populations have observed that index and ring finger ratio can be used for sex estimation [18,19,24,25]. Its utility however, is shown to be limited in forensic case work and is shown to vary between different populations. In the present study, no statistically significant sex differences were observed in index and ring finger ratio which can be attributed to population variations.

A number of previous studies have utilized sectioning point analysis to determine sex of individuals. Sectioning points utilized in these studies however, was derived from mean male and female values. The present study uses a more robust BLR analysis in sexing and the sectioning point in logistic regression analysis are taken as 0.50. Accordingly, the results of the present study indicate LIFL, RIFL, LRFL and RRIL as sex discriminating variables among adult Rajbanshi and Karbi individuals. Here estimation of sex was performed using independent linear anthropometric measurements of hand dimension. The index and ring finger ratios were not taken into consideration in BLR models due to their derived and dependency in nature showed insignificant sex differences. Recent studies on sexing in anthropological casework have utilized ROC analysis to predict the accuracy of variables in sexing based on AUC [19,41-43]. Our observations based on AUC curve indicate that predictive probability increases when IFL and RFL are taken together when compared to IFL and RFL taken individually. Predicted probabilities are observed to be higher on left than on right side, and LIFL and LRFL appear to be better predictors of sex than RIFL and RRFL in estimation of sex of the adult Rajbanshi individuals. Our observations with regard to predictive probabilities of IFL and RFL together are similar to that reported from a North Indian population [19]. It is evident that the BLR models derived in the present study on the Rajbanshi population show a higher prediction percentage when applied on the similar adult Rajbanshi population in the hold out group than on the test group of different population comprising of tribal Karbi individuals. This emphasizes the fact that regression models derived in a population group should ideally be applied to the same population.

LIMITATIONS

Limitations of the study are related to the fact that the study was conducted on live adult population. The findings of the present study thus, should not be applied on children, adolescents or elderly individuals. The dimensions of finger lengths are likely to alter after death with rigor setting in or with putrefactive changes occurring later. Thus, the observations of the present study can be applied only in cases of dismemberment in which the human remains are relatively fresh and do not exhibit postmortem changes that can alter finger lengths. The findings may not be applicable for desiccated, decomposed, and bloated bodies that affect hand dimensions.

CONCLUSION

Estimation of sex from the IFL and RFL measurements is a supplementary approach when extremities or other body parts are not available for examination. The present study has highlighted the application of IFL and RFL to determine sex among individuals belonging to the Rajbanshi population of North Bengal, India. It is suggested that finger lengths are relatively useful predictors of sex and both IFL and RFL could be utilized to estimate sex of the individuals when more reliable means of sex estimation are not available during medico-legal investigations. This study further observes that the models derived for a population group have better applicability when applied on the same population. Studies on estimation of sex from finger lengths in different age groups and among different populations need to be encouraged.

REFERENCES

[1] Cattaneo C. Forensic Anthropology: An Introduction. In: Siegel JA, Saukko PJ, editors. Encyclopedia of forensic sciences (second edition). London, U.K.: Academic Press, Elsevier, 2013;9–11.
[2] Indian Genome Variation Consortium. Genetic landscape of the people of India: A canvas for disease gene exploration. *J Genet*. 2008;87:3–20.
[3] Bhatnagar DP, Thapar SP, Batish MK. Identification of personal height from the somatometry of the hand in Punjabi males. *Forensic Sci Int*. 1984;24:137-41.
[4] Risley HH. Tribes and castes of Bengal. Calcutta: The Bengal Secretariat Press, 1891.
[5] Majumder PP. People of India: biological diversity and affinities. *Evol Anthropol.* 1998;6:100–10.
[6] Kalla AK. The ethnology of India: antecedents and ethnic affinities of peoples of India. New Delhi: Munshiram Manoharlal Publishers, 1994.
[7] Singh KS. People of India: introduction national series. New Delhi: Anthropological Survey of India- Oxford University Press, 2002.

[8] Kanchan T, Krishan K, Sharma A, Menezes RG. A study of correlation of hand and foot dimensions for personal identification in mass disasters. *Forensic Sci Int*. 2010;199:112.e1-6.
[9] Kanchan T, Krishan T. Anthropometry of hand in sex determination of dismembered remains-A review of literature. *J Forensic Leg Med*. 2011;18:14-17.
[10] Sen J, Kanchan T, Ghosh S. Sex estimation from foot dimensions in an indigenous Indian population. *J Forensic Sci*. 2011;56:S148-53.
[11] Krishan K, Kanchan T, Sharma A. Multiplication factor versus regression analysis in stature estimation from hand and foot dimensions. *J Forensic Leg Med*. 2012;19:211-14.
[12] Rastogi P, Kanchan T, Menezes RG, Yoganarasimha K. Middle finger length--a predictor of stature in the Indian population. *Med Sci Law*. 2009;49:123-26.
[13] Rastogi P, Kanchan T, Menezes RG, Yoganarasimha K. Middle finger length--a predictor of stature in the Indian population. *Med Sci Law*. 2009;49:123-26.
[14] Sen J, Ghosh S. Estimation of stature from foot length and foot breadth among the Rajbanshi: an indigenous population of North Bengal. F*orensic Sci Int*. 2008;181:55.e1-6.
[15] Kanchan T, Rastogi P. Sex determination from hand dimensions of North and South Indians. *J Forensic Sci*. 2009;54:546–50.
[16] Krishan K, Kanchan T, Sharma A. Sex determination from hand and foot dimensions in a North Indian population. *J Forensic Sci.* 2011;56:453-59.
[17] McIntyre MH, Cohn BA, Ellison PT. Sex dimorphism in digital formulae of children. *Am J PhysAnthropol*. 2006;129:143–50.
[18] Kanchan T, Kumar GP. Index and ring finger ratio- a morphologic sex determinant in South-Indian children. *Forensic Sci Med Pathol*. 2010;6:255-60.
[19] Krishan K, Kanchan T, Asha N, Kaur S, Chatterjee PM, Singh B. Estimation of sex from index and ring finger in a North Indian population. *J Forensic Leg Med*. 2013;20:471-79
[20] Sen J, Kanchan T, Ghosh A, Mondal N, Krishan K. Estimation of stature from lengths of index and ring fingers in a North-Eastern Indian population. *J Forensic Leg Med*. 2014;22:10-15.
[21] Kyriakidis I, Papaioannidou P. Epidemiologic study of the sexually dimorphic second to fourth digit ratio (2D:4D) and other finger ratios in Greek population. *Coll Antropol.* 2008;32:1093–98.
[22] Manning JT. Digit ratio: a pointer to fertility, behaviour, and health. New Brunswick: Rutgers University Press; 2002.
[23] Voracek M. Comparative study of digit ratios (2D:4D and other) and novel measures of relative finger length: testing magnitude and consistency of sex differences across samples. *Percept Mot Skills*. 2009;108:83–93.
[24] Kanchan T, Kumar GP, Menezes RG. Index and ring finger ratio: a new sex determinant in South-Indian population. *Forensic SciInt*. 2008;181:53.e1–4.
[25] Kanchan T, Kumar GP, Menezes RG, Rastogi P, Rao PPJ, Menon A, et al. Sexual dimorphism of index to ring finger ratio in south Indian adolescents. *J Forensic Leg Med.* 2010;17:243–46.
[26] Touitou Y, Portaluppi F, Smolensky MH, Rensing L. Ethical principles and standards for the conduct of human and animal biological rhythm research. *Chronobiol Int.*2004;21:161–70.
[27] Singh IP, Bhasin MK. Anthropometry. Delhi: Kamla-Raj Enterprises, 1989.
[28] Goto R. Mascie-Taylor CGN. Precision of measurement as a component of human variation. *J Physiol Anthropol*. 2007;26:253–56.
[29] Ulijaszek SA, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. *Br J Nutr*. 1999;82:165–77.
[30] Harris EF, Smith RN. Accounting for measurement error: a critical but often overlooked process. *Arch Oral Biol*. 2009;54:S107-17.
[31] Lippa RA. Are 2D: 4D finger-length ratios related to sexual orientation? yes for men, no for women. *J PersSoc Psychol*. 2003;85:179–88.
[32] Williams TJ, Pepitone ME, Christensen SE, Cooke BM, Huberman AD, Breedlove NJ, et al. Finger-length ratios and sexual orientation. *Nature*. 2000;404:455–56.
[33] Lippa RA. Are 2D:4D finger-length ratios related to sexual orientation? yes for men, no for women. *J PersSoc Psychol.* 2003;85:179–88.
[34] Voracek M, Dressler SG, Loibl LM. The contributions of Hans-Dieter Ro¨sler: pioneer of digit ratio (2D:4D) research. *Psychol Rep*. 2008;103:899–916.
[35] Garn SM, Burdi AR, Babler WJ, Stinson S. Early prenatal attainment of adult metacarpal-phalangeal rankings and proportions. *Am J Phys Anthropol*. 1975;43:327–32.
[36] Van Anders SM, Hampson E. Testing the prenatal androgen hypothesis: measuring digit ratios, sexual orientation, and spatial abilities in adults. *Horm Behav*.2005;47:92–98.
[37] Lutchmaya S, Baron-Cohen S, Raggatt P, Knicmeyer R, Manning JT. 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Hum Dev*. 2004;77:23–28.
[38] Putz DA, Gaulin SJC, Sporter RJ, McBurney DH. Sex hormones and finger length: what does 2D:4D indicate? *Evol Hum Behav*. 2004;25:182–99.
[39] McFadden D. Masculinization effects in the auditory system. *Archives of Sexual Behavior.* 2002;31:99–111.
[40] Manning JT, Callow M, Bundred PE. Finger and toe ratios in humans and mice: implications for the aetiology of diseases influenced by HOX genes. *Med Hypotheses*. 2003;60:340e-43.
[41] Kanchan T, Gupta A, Krishan K. Estimation of sex from mastoid triangle - a craniometric analysis. *J Forensic Leg Med*. 2013;20:855–60.
[42] Raghavendra Babu YP, Kanchan T, Attiku Y, Dixit PN, Kotian MS. Sex estimation from foramen magnum dimensions in an Indian population. *J Forensic Leg Med*. 2012;19:162–67.
[43] Krishan K, Kanchan T, Sharma R, Pathania A. Variability of palmprint ridge density in a North Indian population and its use in inference of sex in forensic examinations. *HOMO* 2014;65(6):476-88.

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