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Sex Determination from Hand Dimensions of North and South Indians

ABSTRACT: When dismembered human remains are encountered, the decedent's sex may not be obvious. For these scenarios, techniques for sex determination may play a vital part of the medicolegal investigation. Five hundred hands (230 males, 270 females) from North and South Indian region were studied to investigate sexual dimorphism in hand dimensions (hand length, hand breadth, and palm length). The hand index (hand breadth/hand length \times 100) and the palm index (hand breadth/palm length \times 100) were derived. The hand dimensions show a higher accuracy in sex determination when compared to indices. Of all hand dimensions, hand breadth has the highest accuracy of sex determination in the study group. The sex differences were found to be statistically significant only for the hand index on the left side. The morphometric parameters of the hand show considerable sexual dimorphism in the Indian population while the hand and palm index remain poor sex indicators. The study thus has medicolegal implications when a dismembered hand is brought for examination.

KEYWORDS: forensic science, forensic anthropology, identification, sex determination, hand dimensions, hand index, palm index

Identification of human remains is a prime issue in cases of mass disasters, explosions, and assault cases where the body is dismembered to conceal the identity of the victim. The estimation of sex is important in the forensic identification of human remains. Accurate sexing of the remains primarily narrows down the pool of possible victim matches. Besides, it is also important owing to the difference in age of epiphyseal fusion, and different formulae for stature estimation in males and females. An individual hand when recovered and brought for examination, can provide valuable information about the stature, sex, and age of the person. The stature has been estimated from different hand dimensions, and small bones of the hand using statistical equations and formulae (1–7).

Although researchers have attempted sex determination from small bones of the hand (8–12), the information on the determination of sex from soft tissue measurements of the hand is presently inconclusive. The fact that foot measurements, foot index, and foot print ratio are often suggested as a sex discriminator in different population groups (13–16) prompted us to evaluate the usefulness of hand dimensions, hand index, and palm index in discriminating sex of the Indian population. To the best of our knowledge no systematic studies are available on the determination of sex from hand measurements. In the present investigation, an attempt has been made to find the sexual dimorphism of the hand dimensions including hand and palm indices, among North and South Indians using statistical considerations.

Material and Methods

The study was conducted on 500 right-handed medical students, aged between 20–30 years, at Manipal, India. Study was carried out on North Indians (males-120, females-100) and South Indians

(males-110, females-170) separately in order to test for regional bias. The subjects were classified into North and South Indians based on their region of origin considering the zonal divisions of India (17). North and South Indians are said to differ in body constitution primarily owing to the climatic variations in the two regions. The students with any disease, deformity, injury, fracture, amputation, or history of any surgical procedures of either hand, and poorly defined flexion creases were excluded from the study. Effect of hand dominance on measurements has been suggested (18); hence, left-handed students were excluded.

Three morphometric parameters (Fig. 1) were recorded for each hand in cm to the nearest mm using vernier calipers (UNA and Co., New Delhi, India) as described previously in literature (1,19).

1. Length of the hand (HL): The distance between the mid-point of the inter-styloid line (line joining the most distal point on the styloid processes of radius and ulna) to the most anterior projection of the middle finger (A to B).
2. Length of the palm (PL): The distance between the mid-point of the distal transverse crease of wrist (extending from ulnar to radial side) to the most proximal flexion crease of the middle finger (C to D).
3. Breadth of the hand/ palm (HB): The distance between the radial side of the second metacarpophalangeal joint and the ulnar side of the fifth metacarpophalangeal joint (E to F).

The subjects were asked to place their hands supine on a flat hard horizontal surface with fingers extended and adducted, following which the hand and palm length was measured. Then the subjects were asked to place their hands prone on a flat hard horizontal surface, with thumb in abducted and other fingers extended and adducted, and the hand breadth was measured. All the measurements were taken by one observer (PR) in order to avoid inter-observer bias. Care was taken to see that there was no abduction or adduction at the wrist joint, i.e. the forearm was directly in line with the middle finger.

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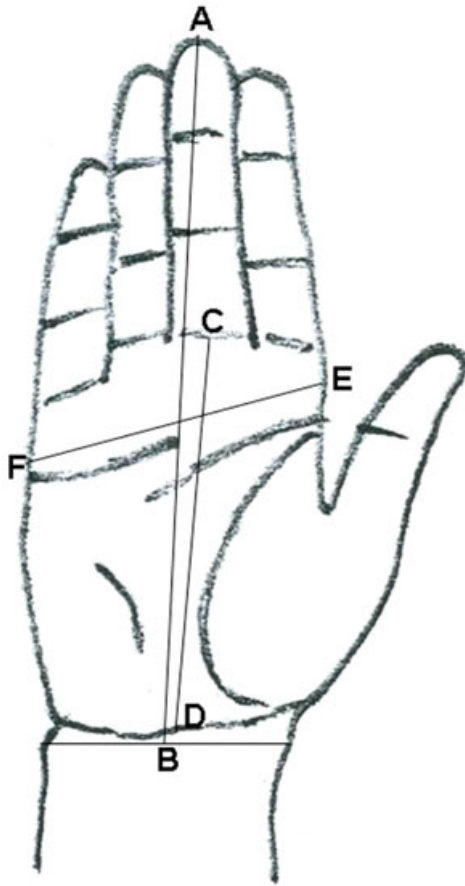


FIG. 1—Human hand illustrating the landmarks: hand length (HL: A to B), palm length (PL: C to D), hand breadth (HB: E to F).

The hand index is calculated individually for both hands in males and females by using the formula: hand index = (hand breadth/hand length) × 100, while the palm index is calculated

individually for both hands in males and females by using the formula: palm index = (hand breadth/palm length) × 100.

For all hand dimensions and indices, average of mean values in males and females was taken as cut off value for sex determination and termed as the “sectioning point” (20).

$$\text{Sectioning point} = \frac{\text{Mean male value} + \text{Mean female value}}{2}$$

The data obtained were computed and analyzed with SPSS (version 11.0) computer software and results drawn. The significance of results was tested using student’s *t*-test. A *p*-value of less than 0.05 was considered as significant.

Results and Discussion

Descriptive statistics for hand dimensions among North and South Indians for right and left hand are shown in Tables 1 and 2 respectively. In both North and South Indian groups, mean values of hand dimensions are significantly larger in males when compared with females in both hands (*p* < 0.001). Male and female differences in hand dimensions seen in this study are, however, larger when compared with an earlier study by Agnihotri et al. (21). In the study group (*n* = 500), the hand dimensions were found to be significantly higher on the right side (HL: *t* = 3.431, *p* = 0.001; PL: *t* = 2.496, *p* = 0.013; HB: *t* = 18.350, *p* ≤ 0.001). This right-sided dominance has been attributed to handedness of the students.

Descriptive statistics for hand and palm index for males and females in both hands in the two regional groups are presented in Tables 3 and 4. Statistically significant differences were observed in the derived indices between right and left sides. Indices on the dominant (right) side were larger (*p* < 0.001) in both regional groups. The hand index is found to be higher in males in both regional groups, similar to the only other available study by Agnihotri et al. (21) on Mauritius students. However, the hand index on the left side only, shows statistically significant sex differences in North Indians (*p* < 0.05) and South Indians (*p* ≤ 0.001). Other

TABLE 1—Descriptive statistics: hand length, palm length and hand breadth (cm) in the right hand.

Group	North Indian						South Indian					
	Male (n = 120)			Female (n = 100)			Male (n = 110)			Female (n = 170)		
Sex	HL	PL	HB	HL	PL	HB	HL	PL	HB	HL	PL	HB
Min.	18.0	9.6	7.2	15.8	8.0	6.4	18.0	9.6	7.3	16.0	8.4	6.4
Max.	21.9	12.9	8.9	20.4	11.0	7.9	22.8	12.1	9.6	20.4	10.8	8.2
Mean	19.9*	10.9*	8.0*	17.9*	9.7*	7.2*	19.9*	10.8*	8.1*	17.9*	9.7*	7.2*
SD	0.9	0.6	0.4	0.9	0.6	0.3	0.9	0.5	0.4	0.9	0.6	0.4

Min., minimum; Max., maximum; SD, standard deviation; HL, hand length; PL, palm length; HB, hand breadth; **p* < 0.001.

TABLE 2—Descriptive statistics: hand length, palm length and hand breadth (cm) in the left hand.

Group	North Indian						South Indian					
	Male (n = 120)			Female (n = 100)			Male (n = 110)			Female (n = 170)		
Sex	HL	PL	HB	HL	PL	HB	HL	PL	HB	HL	PL	HB
Min.	18.0	9.5	7.0	15.8	8.2	6.2	17.9	9.7	7.2	15.4	8.2	6.2
Max.	21.7	12.0	8.9	20.7	11.1	7.8	22.6	12.2	9.6	20.3	10.9	8.0
Mean	19.9*	10.9*	7.9*	17.9*	9.6*	7.1*	19.9*	10.8*	8.0*	17.9*	9.7**	7.1**
SD	0.9	0.5	0.4	0.9	0.6	0.3	0.9	0.6	0.4	0.8	0.5	0.3

Min., minimum; Max., maximum; SD, standard deviation; HL, hand length; PL, palm length; HB, hand breadth; **p* < 0.001

TABLE 3—Descriptive statistics: hand index and palm index in North Indians.

Group	Right Hand				Left Hand			
	Male		Female		Male		Female	
	HI	PI	HI	PI	HI	PI	HI	PI
Minimum	37.1	64.3	36.3	65.1	37.0	64.8	34.9	65.4
Maximum	44.1	83.8	44.6	85.5	43.6	83.8	45.4	86.2
Mean	40.4	73.9	40.1	74.4	40.0*	73.1	39.5*	73.4
SD	1.3	3.1	1.8	4.1	1.5	3.3	1.9	4.1

SD, standard deviation; HI, hand index; PI, palm index; * $p < 0.05$.

TABLE 4—Descriptive statistics: hand index and palm index in South Indians.

Group	Right Hand				Left Hand			
	Male		Female		Male		Female	
	HI	PI	HI	PI	HI	PI	HI	PI
Minimum	35.9	65.8	36.1	64.1	36.9	67.3	35.5	64.1
Maximum	46.7	82.6	45.1	88.1	45.8	82.8	43.9	85.7
Mean	40.7	74.9	40.5	74.9	40.5*	74.3	39.7*	73.6
SD	1.6	3.3	1.7	3.7	1.6	3.4	1.7	3.7

SD, standard deviation; HI, hand index; PI, palm index; * $p < 0.001$.

indices did not show any statistically significant differences between males and females. Agnihotri et al. (21) concluded that hand index is a reliable sex discriminator for both hands in Mauritius students. They have, however, neither presented the statistical analyses of the data nor do they mention about the sectioning point, statistical significance, and reliability of the hand index in sex determination. Their observations were based solely on the mean values of hand index in different age groups from which a deviation point was determined for sex differentiation. Deviation point mentioned in the article also has not been elaborated on. Hence the findings of our study cannot be compared with their findings. It is shown in earlier studies that various hand measurements tend to differ in various ethnic groups (19,22). Population differences between the two studies may in addition be the probable reason for difference in findings. To the best of our knowledge, no studies have ever examined the palm dimensions and index as a sex determinant; hence findings could not be compared.

Population differences in anthropological studies have been noted and it is well realized that they need to be studied separately (23). In our study, the hand dimensions did not show any significant difference between the North and South Indians. Hence, the sectioning point was derived as a cut off to discriminate male and female hands for the pooled North and South Indian data in the study group (Table 5). The results of the study thus, can be successfully applied irrespective of the zonal residence that is difficult to determine when analyzing dismembered parts such as a hand. The gender wise frequency distribution of the entire study group (North and South Indians combined) for the different hand dimensions is hence presented in Figs. 2, 3, and 4 to illustrate the dimorphism present between males and females. The mean values of derived hand and palm indices are larger in South Indian males and females. However, significant differences are observed only in right palm index, left palm index, and left hand index between North and South Indian males. No such statistically significant differences were observed in North and South Indian females.

TABLE 5—Percentage accuracy of sex determination based on SP analysis in entire study population ($n = 500$).

Dimension	Right Hand			Left Hand		
	SP	Male	Female	SP	Male	Female
HL	18.9	83.0	88.5	18.9	82.6	88.9
PL	10.3	85.7	89.6	10.3	81.7	91.9
HB	7.6	87.0	91.1	7.5	88.7	91.5
HI	40.5	—*	—*	39.9	53.9	55.9
PI	74.6	—*	—*	73.6	—*	—*

SP, sectioning point; HL, hand length; PL, palm length; HB, hand breadth; HI, hand index; PI, palm index; *Male–female differences were not significant ($p > 0.05$).

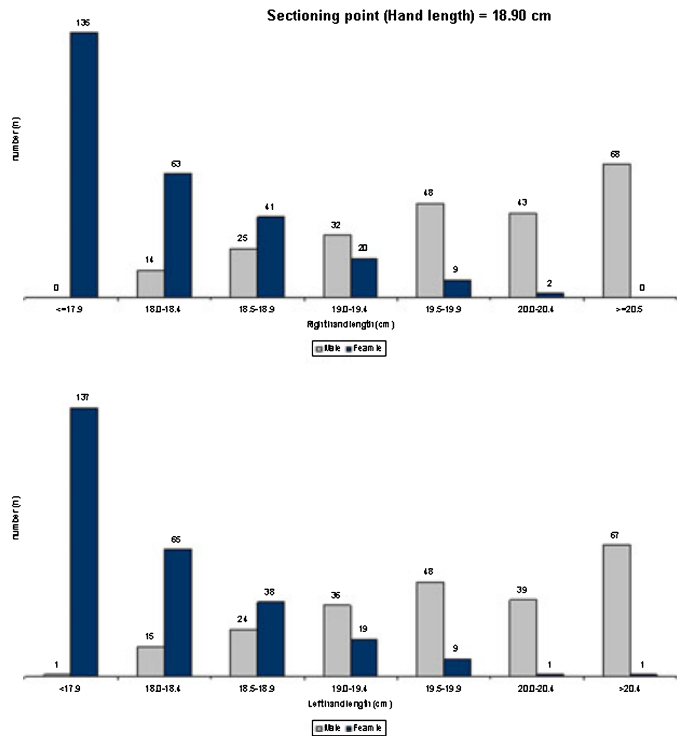


FIG. 2—Hand length (cm): distribution of males and females in the entire study group.

The accuracy of the sectioning point derived from the study is tested on the same sample from which it is derived. Percentage accuracies of sex determination of the hand dimensions and indices are shown in Table 5. It is apparent that hand dimensions show a higher accuracy of sex determination. The left hand index remained a poor indicator of sex. Recognizing the fact that sex can be estimated by pure chance with 50% accuracy, the derived indices do not demonstrate any diagnostic value. Most of the indices and ratios derived to accurately determine sex of human remains incorporate a parameter expected to have a larger value in males and another parameter that is expected to be relatively or absolutely greater in females (20,24). Indices basically remove the effect of size from the data and show the hand proportions. Hand and palm indices in our study show that males and females have similar hand proportions.

For the pooled data, based on sectioning point analysis hand length identifies c. 83% males and 89% females in both hands, palm length identifies 86% males and 90% females in the right hand and 82% males and 92% females in the left hand, and the

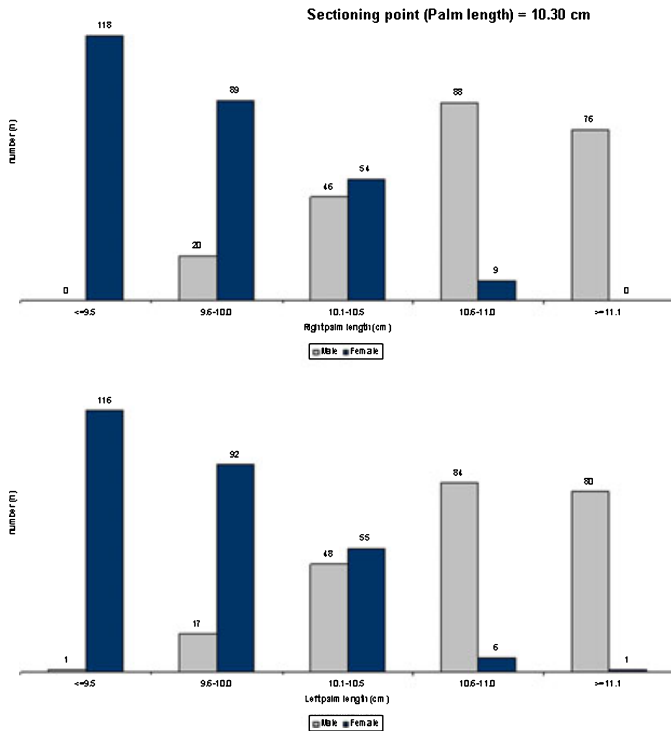


FIG. 3—Palm length (cm): distribution of males and females in the entire study group.

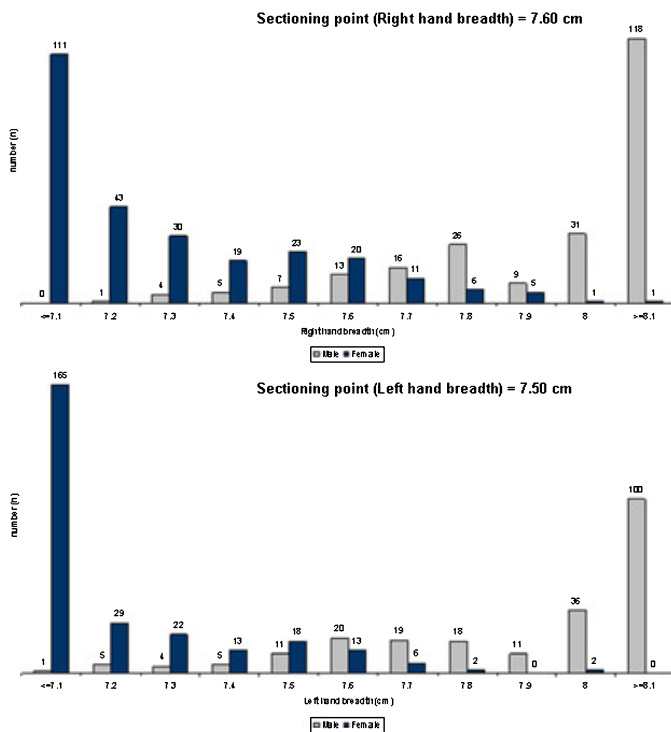


FIG. 4—Hand breadth (cm): distribution of males and females in the entire study group.

hand breadth identifies 87% males and 91% females in the right hand and 89% males and 92% females in the left hand. Thus hand dimensions can identify sex with reasonable accuracy in the study group and hand breadth appears to be the most reliable sex discriminator.

Conclusion

The study did not find any significant differences in hand measurements among North and South Indians. The study reveals that the morphometric parameters of the hand show considerable sexual dimorphism in the North and South Indian population and hand breadth appears to be the most reliable sex discriminator in the study group. Among the derived indices, sex differences are found to be statistically significant only for the hand index on the left side. Recognizing the fact that sex can be estimated by pure chance with 50% accuracy, these indices demonstrate no diagnostic value. Hand index and palm index hence are poor indicators of sex.

This study can be useful to determine the sex of a dismembered hand when it is subjected for medicolegal examination. The study has medicolegal implications even when part of the hand is recovered and brought for examination. Although this preliminary study includes subjects with similar age, profession, handedness, environment and socio-economic background in two regions of India, similar studies of different ethnic groups and regions are recommended to test the findings of our study.

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