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Hand Index: An Anthropo-Forensic Tool for Human Identification in India

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Abstract **- The aim of the study was to determine and classify the hand index of 200 individuals selected randomly within age group 18 – 65 years from Udaipur district, Rajasthan, India. The measured parameters are hand length and hand breadth. This study also attempt to compare the hand index obtained from direct as well as indirect (from hand print & hand outline) methods. Data were analyzed using SPSS Statistical software. Results shows that there were statistically significant differences in the hand parameters of male compared to female subjects for all observed parameters. It is interesting that hand index obtained from different methods doesn't indicate variation however there exist statistically significant variation in terms of hand length and hand breadth. Also there is statistically significant difference between the hand dimensions obtained from different methods. Hand classification denoted that population of Rajasthan state belongs to dolichocheir (dch) group of hand for all the direct and indirect methods. The comparison of hand index with populations of 17 different states of India indicates that Indian population belongs to any category of hand index except hyperbrachycheir. Also an attempt has been made to observe the correlative effect of climate divisions of India with the hand categories. Comparison with 25 other foreign countries shows the existence of hyperbrachycheir that is broader large palm but short fingers. This shows that morphological characteristics of hand depend on many factors such as gender, ethnicity, socio-cultural domain, environment & genetic factors and it differs from region to region. Thus, it can be said that Identification of hand parameters is very helpful in concealing identity of mutilated remains in any disastrous act, also in examination of chance evidences in crime scene for criminal proceedings and this comparative data of hand index can also help to determine the resident place of an unknown individual.**
Keywords: **Hand index, Anthropo – Forensic tool, Human identification, Criminal authentication, Hand print, Hand outline, Hand Classification.**

I.INTRODUCTION

The human hand is the chief tactile apparatus and versatile part of the human body. Most of the human interactions in everyday life with the surrounding world are performed by hands. This versatility is possible because of the bony structure of hand which is composed of 27 bones and 15 joints each which contain more measurements information than any of the other body parts.[1] Thus, anthropometry (the systematic scientific study of the measurements of various parts of the human body) to obtain the exact size of the body parts has recently become more and more important in various fields. Many previous studies have focused on the collection of anthropometric dimensions of various body parts [2-12] and several studies has focused peculiarly on hand dimensions.[13-18]

Davies measured 28 hand landmarks on 92 Europeans and made a comparison of hand sizes with different ethnic groups. They found that the hand parts of European females were significantly smaller than those of their West Indian counterparts.[13] Imrhan measured the hand dimensions of Americans of Vietnamese origin,[14] of 40 Bangladeshi males[16] and these dimensions are then compared to the Mexican males.[15] They concluded that hand dimensions of Bangladeshi men were significantly smaller than the Mexican men. Mandahawi[18] conducted a hand anthropometric survey among 235 Jordanian populations and then they compare between Jordanians and other populations (Bangladeshis, Nigerians, Vietnamese Americans, Hong Kong, Chinese, United Kingdom residents, Americans, and Mexicans). The results showed many significant differences between Jordanians and the other populations. Thus anthropometric dimensions vary across gender, race and ethnic groups.[19] The anthropometry also differs within a particular group due to environment, nutrition, physique & nature of work. As a result hand anthropometry has proved to be important parameter in anthropological comparative research.

Anthropometric dimensions of hand are also helpful to investigators in the field of forensic science, forensic anthropology, criminology, biometrics, ergonomics, reconstructive surgeries, mechanical studies, clinical practice etc. Identification of hand parameters helps in concealing identity of mutilated remains in any disastrous act, also in examination of chance evidences in crime scene for criminal proceedings.[20] Hand geometry or shape of the hand[21] is widely used for biometric recognition systems, attendance tracking, physical access, personal identification, verification and recognition. Also the data of various hand dimensions will serve to design many hand held devices which aid in ergonomics. Lewis attempted designing and sizing ergonomic handles for hand tools by using hand anthropometric dimensions.[23]

Anthropological researches witnesses that dimensions of hand i.e. hand length and hand breadth has been extensively used to determine anthropological variables such as stature[24-31] and sex.[32-34] The relative length of digits particularly (2D:4D) digit ratio has been used as a marker for prenatal testosterone exposure relative to prenatal estrogen exposure.[35] 2D:4D digit ratio also acts as a sexually dimorphic phenotypic trait.[36,37] Now a day's various indices are used to determine race and sex of an individual such as cephalic index,[38] facial index,[39] mandibular canine index[40] and hand index.[41,42] Chandra estimated hand index for male industrial workers for the designing of hand tools and equipments.[43]

Hand index is found to be an important tool in determination of nature, personality, predisposition to certain diseases and many other unique points about an individual. It is also reported that hand index have direct correlation with psychiatric illness.[44] Based on hand index, shape of the hand can be determined as Hyperdolichocheir, Dolichocheir, Mesocheir, Brachycheir, Hyperbrachycheir using the scale of Martin and Saller (1957)[45] which can then be compared between groups to investigate ethnic and regional variations.

The present investigation is an attempt to:

a. To find hand index from measured hand dimensions in the studied population.
b. To compare hand index calculated from direct as well as indirect methods from hand print and hand outline.
c. To compare hand index with existing standard hand anthropometric data of other states of India and of other countries across the globe in terms of classification of hand index, which may help to differentiate between populations and ethnic groups.

This research study will have a lot of significance in anthropology to evaluate ethnic and environmental differences in population groups; in forensic domain for identification purposes, for sexual discrimination, for criminal investigation; in biometric applications; in reconstructive surgeries as well as in ergonomics.

II.MATERIALS AND METHODS

A. Subjects

In the study 200 individuals (90 males and 110 females) have been selected randomly as subjects, within age group 18 – 60 years from Udaipur district, Rajasthan, India. Subjects with any kind of deformity in hand were excluded from the study. All the subjects were informed about the study design, measurements and privacy of data collected. Consent was taken from each subject before obtaining measurements. All of the data were analyzed using SPSS 22. Descriptive statistics (including the mean and standard deviation) for the value of each hand dimensions were calculated and depicted in tables. 't'-test was used to compare the difference in measurements between males and females. Paired-samples t-test was used to compare the variability among the different methods employed for calculating hand index.

B. Anthropometric measurements

- Hand length (HL) = It is measured as straight distance from interstylion (isty) to dactylion (daIII) of the middle finger.

- Hand breadth (HB) = It is measured as straight distance from metacarpal radialis (mr) to metacarpal ulnare (mu) as depicted in figure 1.

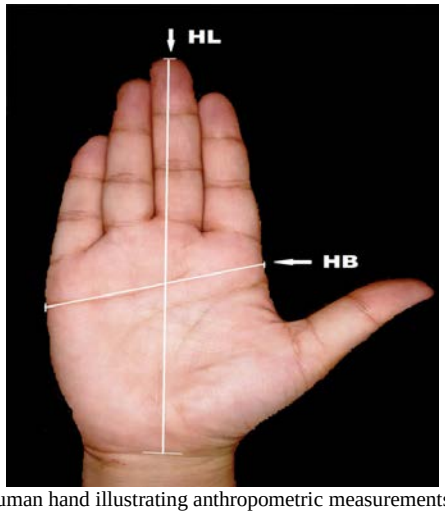

Fig.1Human hand illustrating anthropometric measurements; Hand Length (HL) and Hand Breadth (HB).

C.Techniques for obtaining measurements

Standard anthropometric technique and landmark given by Vallois and Martin & Saller[45,46] was followed for obtaining measurements. Sliding caliper was used to obtain anthropometric measurements.

1.Techniques for direct measurement:

Subjects were asked to wash their hands with soap & water, and made to sit in a relaxed state. They were asked to place their hand straight on a flat surface. Measurements were taken i.e. hand length and hand breadth from both right and left hand with the help of sliding caliper. All the measurements were repeated three times and mean value was taken for statistical analysis. All the measurements were performed during the time period 9.00 – 12.00 to eliminate diurnal variations and uniformly by one observer in the same way and under the same conditions to avoid inter-observers error.

2.Techniques for indirect measurement from hand print:

A hand print was obtained as suggested by Cummins & Mildo (1926)[47] and Kapoor (1987).[48] Before taking hand prints, hand was first cleaned with soap and subsequently dried. A small amount of printing ink was taken on a glass slab and is spread over the glass slab using the cotton pad till a thin film is obtained. By using this cotton pad, ink was distributed through the palm and finger in equal proportion. The following areas are given special attention: the zone of flexion crease at the wrist, the ulnar margin, the metacarpo phalangeal crease and the central hollow portion of the palm. The sheet of paper is kept over the palmer pad and the proximal part of the palm is brought in contact with the paper first, followed by the distal part. In order to ensure printing of the hollow of the palm and distal borders, pressure is everted particularly over the central region of the hands over the knuckles and the pressure was applied on the bracelet line also. Then the palm is slowly lifted radio – ulnar wards carefully to avoid any smudging. Prints were taken with only thumb in abducted position as shown in figure 2(a). After taking the hand print from both the right and left hand, measuring scale was used to measure hand length & hand breadth from both right and left hand prints.

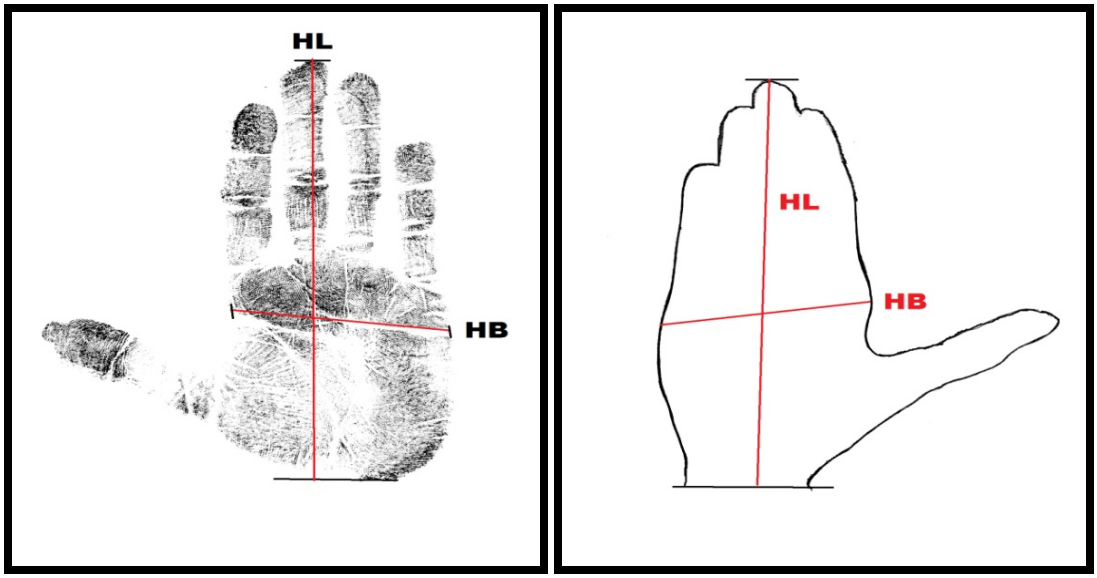

Fig.2 (a) Hand Print (b) Hand outline, depicting the position of hand with thumb in abducted position and rest of the fingers in adducted position.

3.Techniques for indirect measurement from hand outline:

Method for obtaining hand outline was followed as described in Dey & Kapoor (2015c).[49] A Hand outline was obtained in A4 size paper which was placed on the palmer pad. Then with the help of sharp pencil an outline of the hand was drawn carefully taking into consideration the line of bracelet crease. Hand outline was also taken in the same position as hand prints as shown in figure 2(b). Once hand outline was obtained, measuring scale was used to measure hand length & hand breadth from both right and left hand outline.

D.***Hand Index***

Hand index is the percentage variation between the hand breadth to the hand length. It can also be defined as a measure to describe the shape of the hand. Types of hand as determined by hand length & hand breadth measurements are – Hyperdolichocheir (hdch) hands with very long fingers and narrow smaller palm, dolichocheir (dch) hands have long fingers and narrow small palm, mesocheir (mch) hands have long fingers but short small palm, brachycheri (bch) hands with short fingers and long large palm whereas hyperbrachycheir (hbch) hands have short fingers with broader large palm respectively (Martin and Saller, 1957). Hand index was calculated from hand dimensions of both direct as well as indirect methods using the formulae:

$$\text{Hand index} = \frac{\textit{Hand breadth (mr–mu)}}{\textit{Hand length (sty–da)}} \times 100$$

The values of hand index were used to determine hand types. Based on the hand index, the hand phenotype was classified as shown in Table I.

TABLE I HAND CLASSIFICATION BASED UPON THE VALUE OF HAND INDEX ACCORDING TO MARTIN & SALLER (1957).

S.No.	Hand Index	Hand Classification
1.	≤ 40.9	Hyperdolichocheir (hdch)
2.	41.0 – 43.9	Dolichocheir (dch)
3.	44.0 – 46.9	Mesocheir (mch)
4.	47.0 – 49.9	Brachycheir (bch)
5.	≥ 50.0	Hyperbrachycheir (hbch)

III.RESULTS AND DISCUSSION

The conducted research provides important new information concerning the hand index, hand shape and hand phenotype in the population of Rajasthan, India. All the measurements were expressed in centimeters. The data depicted in Table II represents the mean and standard deviation of the actual values of hand length and hand breadth obtained directly as well as indirectly from hand prints and hand outlines of all the subjects. It has been shown there was significant difference between males and females and males have significantly higher values of hand dimensions compared to the females ($P<0.001$) for all the methods. However the difference in terms of right and left was statistically non-significant.

TABLE II SUMMARY OF HAND ANTHROPOMETRIC MEASUREMENTS (MEAN ± STD. DEV)

Hand Dimension	Male (N=110)	Female (N=90)	Total (N=200)
Direct Measurements			
RHL	19.3±1.11	17.5±1.08	18.5±1.42
RHB	8.3±0.39	7.6±0.39	8.0±0.51
LHL	19.2±1.11	17.3±1.05	18.4±1.44
LHB	8.2±0.38	7.5±0.39	7.9±0.51
Indirect Measurements from Hand Prints			
RHL	18.8±0.96	17.1±0.86	18.0±1.24
RHB	7.7±0.43	7.1±0.43	7.4±0.53
LHL	18.8±0.85	17.1±0.81	18.0±1.18
LHB	7.7±0.46	7.1±0.41	7.4±0.55
Indirect Measurements from Hand Outlines			
RHL	19.4±1.05	17.7±0.93	18.6±1.30
RHB	8.1±0.47	7.5±0.45	7.8±0.56
LHL	19.2±0.99	17.6±0.87	18.5±1.22
LHB	7.7±0.59	7.8±0.57	7.8±0.58

RHL = Right Hand Length, RHB = Right Hand Breadth, LHL = Left Hand Length, LHB = Left Hand Breadth

Also there is statistically significant difference between the hand dimensions obtained from different methods (Table III). In the present study, measurements obtained from hand print seem to show significant differences with the direct measurements both for right and left hand dimensions. However measurements obtained from hand outlines show non-significant values for the left hand dimensions whereas the right hand dimensions are statistically significant with the direct measurements. Differences with respect to hand print and hand outline are statistically significant. Thus, it is important to obtain the print or hand impression of the suspected individual as in crime scenes, evidences are recovered in the form print or impression and not the direct measurements of the hand.

TABLE III COMPARISON OF HAND DIMENSIONS OBTAINED FROM DIRECT AS WELL AS INDIRECT (FROM HAND PRINT AND HAND OUTLINE) METHODS.

S.No.	Groups	t - value	Significant level
1	DRHL – IPRHL	10.134	.000
2	DRHL – IORHL	-3.369	.001
3	IPRHL – IORHL	-14.133	.000
4	DRHB – IPRHB	22.077	.000
5	DRHB – IORHB	6.384	.000
6	IPRHB – IORHB	-13.075	.000
7	DLHL – IPLHL	8.194	.000
8	DLHL – IOLHL	-1.554	.122
9	IPLHL – IOLHL	-11.026	.000
10	DLHB – IPLHB	19.608	.000
11	DLHB – IOLHB	1.587	.114
12	IPLHB – IOLHB	-5.770	.000

DRHL = Direct Right Hand Length, DRHB = Direct Right Hand Breadth, DLHL = Direct Left Hand Length, DLHB = Direct Left Hand Breadth, IPRHL = Indirect from prints Right Hand Length, IPRHB = Indirect from prints Right Hand Breadth, IPLHL = Indirect from prints Left Hand Length, IPLHB = Indirect from prints Left Hand Breadth, IORHL = Indirect from outlines Right Hand Length, IORHB = Indirect from outlines Right Hand Breadth, IOLHL = Indirect from outlines Left Hand Length, IOLHB = Indirect from outlines Left Hand Breadth

The hand index for right hand in the studied population was 43.1±2.49 for direct method, 41.3±2.27 for indirect hand print method and 42.0±2.43 for indirect hand outline method. Likewise for left hand, the hand index was 42.8±2.51 for direct method, 41.3±2.15 for indirect hand print method and 42.1±2.37 for indirect hand outline method (Table IV). It is interesting that hand index obtained from different methods doesn't indicate variation however there exist variation in terms of hand length and hand breadth. Hand classification denoted that population of Rajasthan state belongs to dolichocheir (dch) group of hand for all the direct and indirect methods.

TABLE IV HAND INDEX OBTAINED FROM DIRECT AS WELL AS INDIRECT METHODS (MEAN ± STD. DEV)

Hand Index	Male (N=110)	Female (N=90)	Total (N=200)	Hand Classification
Direct Measurements				
RHI	42.9±2.35	43.5±2.64	43.1±2.49	Dolichocheir
LHI	42.5±2.35	43.2±2.64	42.8±2.51	Dolichocheir
Indirect measurements from Hand Prints				
RHI	41.1±2.09	41.5±2.46	41.3±2.27	Dolichocheir
LHI	41.2±2.15	41.4±2.15	41.3±2.15	Dolichocheir
Indirect measurements from Hand outlines				
RHI	41.8±2.25	42.2±2.62	42.0±2.43	Dolichocheir
LHI	42.0±2.40	42.2±2.35	42.1±2.37	Dolichocheir

RHI = Right Hand Index, LHI = Left Hand Index

The comparison of hand index with populations of 17 different states of India indicates that Indian population belongs to any category of hand index except hyperbrachycheir as shown in Table V. Male population of 2 states (Karnataka & Maharashtra) belongs to hyperdolichocheir hand classification, 4 states (Rajasthan, Arunachal Pradesh, Mizoram & West Bengal) belongs to dolichocheir, 9 states (Assam, Haryana, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Manipur, Meghalaya, Tripura & Uttarakhand) and 3 states (Gujarat, Nagaland & Odisha) belongs to brachycheir hand classification. On the basis of availability of literature on female hand anthropometric variables, only 12 states can be studied. Female population of India from 4 states belongs to hyperdolichocheir, 4 belong to dolichocheir and 4 belong to mesocheir category of hands. There are sexual differences in terms of hand category.

TABLE V COMPARISON OF HAND INDEX WITHIN DIFFERENT STATES OF INDIA.

S. No.	States	Hand Index		Classification	
		M	F	M	F
1.	Rajasthan (Present study)	42.90	43.50	dch	dch
2.	Arunachal Pradesh [12]	41.81	39.16	dch	hdch
3.	Assam [6]	46.60	-	mch	-
4.	Gujarat [3]	48.92	44.44	bch	mch
5.	Haryana [23]	45.19	-	mch	-
6.	Himachal Pradesh [29]	44.51	43.45	mch	dch
7.	Jammu & Kashmir [42]	45.65	44.38	mch	mch
8.	Karnataka [34]	40.70	40.50	hdch	hdch
9.	Madhya Pradesh [3]	44.62	43.60	mch	dch
10.	Maharashtra [24]	39.78	39.78	hdch	hdch
11.	Manipur [6]	46.38	-	mch	-
12.	Meghalaya [3]	46.15	45.96	mch	mch
13.	Mizoram [12]	43.60	39.88	dch	hdch
14.	Nagaland [6]	49.73	-	bch	-
15.	Odisha [3]	49.69	-	bch	-
16.	Tripura [6]	45.26	-	mch	-
17.	Uttarakhand [44]	44.23	44.23	mch	mch
18.	West Bengal [58]	43.75	42.59	dch	dch

M = Male, F = Female, hdch = Hyperdolichocheir, dch = Dolichocheir, mch = Mesocheir, bch = Brachycheir

If we look at the map of India, it can be said that the northern states predominated by mesocheir group of hands whereas southern states shows hyperdolichocheir category. Eastern and western states show a mix combination of dolichocheir & mesocheir and dolichocheir & brachycheir respectively (Figure 3). Also an attempt has been made to observe the correlative effect of climate divisions of India with the hand categories. It has been observed that the different types of hand categories when superimposed on the climatic divisions of India as depicted by Bhasin & Bhasin (2002)[50] shows that the hyperdolichocheir hand category coincides with cold humid winter type (with shorter summers), Monsoon type (with dry winters), Monsoon type (with short dry season), Tropical savannah type and Semi-Arid steppe type; dolichocheir category correlates with Hot dessert type, Semi-Arid steppe type, Monsoon type (with dry winters) and Tropical savannah type; mesocheir correlates with Polar type, Monsoon type (with dry winters), Tropical savannah type and Semi-Arid steppe type; and similarly brachycheir coincides with the Monsoon type (with dry winters) and Tropical savannah type. It can be said that cold climate generally favors mesocheir hand classification where as hot climatic is direct correlate of dolichocheir hand. Thus, it can be deduced that along with environmental and climatic condition, many factors such as food habits, culture, occupation and lifestyle do play a role in the morphological dimensions of hand. It is suggested that more studies are needed to throw light on the hand categories with the climatic patterns which will help in identify the adaptive identification of the population.

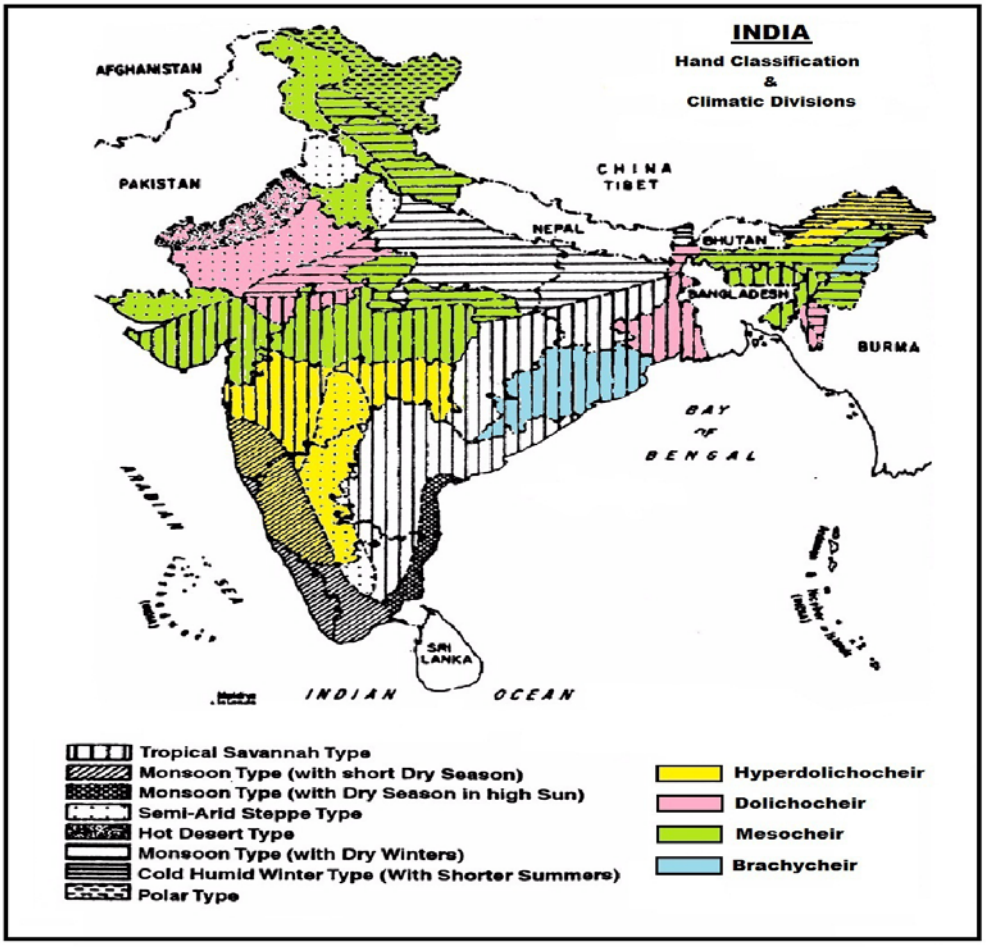

Fig.3 Map showing State Wise Hand classification and climatic divisions of India.

Further comparison of hand index of male population of Rajasthan was performed with male populations of 25 other countries across the globe as depicted in Table VI. It indicates that male population of 25 other countries do not have hand index category of hyperdolichocheir and dolichocheir. However Rajasthan state as representative of India exhibit dolichocheir category of hands that is long fingers with narrow and small palm. However, most other countries across the world generally have mesocheir group of hand. As compare to Indian population, foreign countries show the existence of hyperbrachycheir that is broader large palm but short fingers. There is significant variation in hand shape in various geographical zones. This shows that morphological characteristics of hand depend on many factors such as gender, ethnicity, socio-cultural domain, environment & genetic factors. We believe that hereditary factors primarily affect the hand shape and then environment plays a secondary role. This comparative data of hand index can help to determine the resident place of an unknown individual.

TABLE VI COMPARISON OF HAND INDEX AMONG COUNTRIES OF THE WORLD.

S.No.	Countries	Hand Index (Male)	Hand Classification
1.	India (present study)	42.90	dch
2.	Algeria[10]	52.06	hbch
3.	Australia [27]	46.57	mch
4.	Bangladesh [16]	46.03	mch
5.	China [8]	46.93	mch
6.	Egypt [30]	45.65	mch
7.	France [51]	45.75	mch
8.	Iran [11]	56.04	hbch
9.	Jordan [18]	45.87	mch
10.	Korea [28]	46.90	mch
11.	Mauriatus [32]	44.44	mch
12.	Mexico [15]	45.98	mch
13.	Malaysia [52]	51.71	hbch
14.	Netherland [53]	45.11	mch
15.	Nigeria [54]	43.68	mch
16.	Norway [4]	44.10	mch
17.	Philippine [5]	49.62	bch
18.	Saudi Arabia [2]	56.04	hbch
19.	Sri Lanka [55]	55.47	hbch
20.	Slovakia [31]	45.35	mch
21.	Sweden [7]	45.34	mch
22.	Thailand [9]	46.50	mch
23.	Turkey [56]	45.95	mch
24.	USA [57]	47.45	bch
25.	Vietnam [14]	44.75	mch
26.	West Indies [22]	44.56	mch

dch = Dolichocheir, mch = Mesocheir, bch = Brachycheir, hbch = Hyperbrachycheir

IV.CONCLUSION

This study provides a comparative hand (length, breadth, and index) anthropometric data for Indians. It is well established that body size has an effect on individual parameters like the linear dimensions of the body; they are not always reliable or accurate predictor of identification however ratios of these linear dimensions are not significantly related to height and age thus are independent of body size and thus provide better results. Hand index obtained in the research study can be used in the discrimination of sex. It can be used in anthropological research. It has great application in forensic cases for criminal identification. DNA technology to a greater extent resolved the problem of identification by evaluating the genetic information from the unknown individual's cell and it give most reliable results. But DNA technology has its limitations with respect to cost - effectiveness, skilled workers and availability of required machine in laboratories. Hence, this study has succeeded in establishing standard values of hand index which will serve as a useful tool in forensic domain. The data can also be utilized in ergonomics to design products and interfaces or hand tools that will increase user satisfaction and comfort which eventually results in increase in productivity.

Further, this research also provided standard values of hand index obtained from hand print and hand outline as there is statistically significant difference between the hand dimensions obtained from different methods. And it is very likely to encounter hand print and hand impression in crime scene which will serve as an evidence to conceal the identity of the intruder and thus narrowing the investigation procedure.

The comparison of hand index with populations of 17 different states of India indicates that Indian population belongs to any category of hand index except hyperbrachycheir. Also the northern states are predominated by mesocheir group of hands whereas southern states shows hyperdolichocheir category. Eastern and western states show a mix combination of dolichocheir & mesocheir and dolichocheir & brachycheir respectively. Correlation of hand categories with the climatic divisions of India revealed that cold climate generally favors mesocheir hand classification where as hot climatic is direct correlate of dolichocheir hand. However more studies are needed in this direction to validate its implication and applicability. Comparison of hand index with male populations of 25 other countries across the globe indicates that they do not have hand index category of hyperdolichocheir and dolichocheir. As compare to Indian population, foreign countries show the existence of hyperbrachycheir that is broader large palm but short fingers. Thus, there is significant variation in hand shape in various geographical zones. However, the cause for these differences has not been thoroughly investigated. The authors suggest further study with larger sample size and with increased number of

hand variables for better accuracy and reliability keeping in mind the future dynamics of research.

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