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Original Article

Determination of the stature and gender by using hand dimensions

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Abstract

In the field of forensic anthropometry, determining stature and gender is a crucial chapter. The aim of the study was to identify the significant role of all variables on the hand in determining the identity of gender and stature. A total of 568 medical students, who were born and raised in various regions of India and were from the age of 18 to 25 years, were chosen for a descriptive cross-sectional study. The length, maximum and minimum circumferences, thickness, and breadth of both hands were measured using a digital vernier calliper and a cotton thread. The results were predicted using the Statistical Package for the Social Sciences (SPSS 20) computer software. To varying degrees, both hand parameters have a significant relationship with stature and gender. Statistical formulas were used to determine stature and gender. Forensic scientists and crime scene experts will benefit greatly from the results of this investigation.

Keywords: hand dimensions, forensic anthropometry, stature, gender, Indian population

1. Introduction

Identification of mutilated, dismembered, and fragmentary human remains found in mass disasters, criminal mutilation, bomb threats, violent crimes, air plane crashes, road accidents, sexual assaults, and other forensic investigations is crucial and has proven to be a difficult task for forensic experts and physical anthropologists. Gender estimation from body segments and skeletons is an essential element of human identification. It narrows the pool of possibly matching identities from which a proper assessment can be accomplished using DNA or dental data in medico-legal investigations (Gupta *et al.*, 2017).

Metric and morphological methods can be used to estimate gender. The pelvis and skull are the most dimorphic elements of the human skeleton; their absence, as well as the possibility of recovering fragmented limbs in mass disasters, necessitates determining the major indicators of identification from limb fragments (Ahmed, 2016). Somatometry, osteology, and radiology examinations can help to determine main indicators of identity, such as gender, age, and stature, when a human hand is recovered and brought in for investigation. One of the most important factors in determining an individual's identity is determining his or her gender. Forensic scientists can greatly benefit from sex determination using hand dimensions when identifying human remains (Kanchan, Kumar, & Menezes, 2008).

The anatomical approach or the mathematical method are used to calculate stature standards (Ahmed, 2013). The relationship between the measurements of the body's parts allows for the reconstruction of its original stature, which may be calculated successfully using the linear dimensions of the hand. In forensic investigations, the measurements of a person's hand have been used to determine their gender, age, and stature (Ibrahim, Khalifa, Hassan, Tamam, & Hagras, 2018). Due to ethnicity, the impacts of time and geographical contexts, nutrition, physical fitness, and the environment, body proportions in different populations show significant variation (Ahmed, 2013). As a result, biological identity is a population-specific characteristic (Kanchan *et al.*, 2008). Human height is the most essential physical property because its range of variation is large by gender and race, and its traits rarely change (Kim, 2019). Several studies have been published on the correlation between hand measures and stature in order to generate population-specific regression equations (Uhrová *et al.*, 2015).

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In the Indian population, a strong correlation was found between human stature and hand length and breadth. Studies were conducted in various regions of India; to name a few**:** Rajasthan (Jain, & Mathur, 2016; Santosh, Garg, Dagal, & Shekhawat, 2014), Maharashtra (Wakode, Wakode, Ksheersagar, Tajane, & Jachak, 2015), Telangana (Vanishri, & Sheikh, 2019), Uttar Pradesh (Khan, Jahan, & Haque, 2020) and West Bengal (Roy, Ganguly, Mondal, Krishan, & Sen, 2020). A few studies in West Bengal (Gupta *et al.*, 2017) and Uttar Pradesh (Banik, 2016; Sarkar, Chowdhuri, & Bose, 2020) used models to estimate sex using hand length and hand breadth. Other nations have reported using hand measurements to predict stature and gender, including Korea (Jee, Bahn, & Yun, 2015; Jee, & Yun, 2015), Nigeria (Ibeabuchi, Nandi, Olabiyi, & Okubike 2018; Igbigbi, Ominde, & Adibeli, 2018), China (Zhang *et al.*, 2016), Egypt (Ibrahim, Khalifa, Hagras, & Alwakid, 2016) and Australia (Howley, Howley, & Oxenham, 2018), Bangladesh (Asadujjaman, Ali Molla, & Al Noman, 2019) and Kosavo (Arifi, 2020).

Previous research has used hand lengths and breadths as a variable in developing a regression equation for estimating height and gender. Stature and gender estimation by using additional hand parameters that have not previously been used in the Indian population were used in this study. Hand and palm length, as well as maximum and minimum hand circumference, breadth, and thickness, were used to predict gender and stature in the Indian population in this study. A method for determining gender and stature is presented based on statistical methods.

The purpose of this study is to improve prediction performance by expanding earlier studies in the Indian population. Anthropometric hand measures have been used to estimate gender or stature in limited research throughout the world. The present study aims to fill the gap by generating models that may be used to estimate the gender and stature of living human beings in the current Indian population. The findings of our study are applicable in the fields of forensic science, sports medicine, and clinical anthropology.

2. Materials and Methods

2.1 Materials

A descriptive cross-sectional study of 274 female and 294 male medical students who were born and raised in various regions of India irrespective of their caste, religion, dietary habits, and socio-economic status and were aged 18-25 years in the Department of Anatomy, KIMS Karad, was undertaken between the years 2019 and 2020.

The study was approved by the ethics committee, and the relevant permissions were obtained. The students were informed about the study's aims and objectives, and their informed consent was documented on the pro-forma sheet. Individuals with obvious deformities, injuries, fractures, amputations, or history of any surgical procedure on hand or previous history of trauma to their hands, feet, spine, and limbs were excluded from the study.

2.2 Stature measurement

The stature was measured using a stadiometer. (Saka, Alamu, Olayode, Akinjisola, & Ogundipe 2016*).* Body height and spinal stability change substantially throughout the day. Changes in posture from supine to upright affect body height. The diurnal variations appear to be caused by changes in the cervical, thoracic, and lumbar spine regions. Adolescents and young adults see the greatest change in vertebral column length. Within 3 hours of rising in the morning, the height reduction begins, with a total loss of roughly 15 millimeters (mm) (Standring, 2016). To avoid errors, each individual's stature was measured from 2 to 5 p.m.

The length, width, thickness, and circumference of both hands were measured using anthropometric methods. The hand was placed on a flat surface with the palmer aspect facing upwards and the thumb adducted, measurements were taken with the use of a digital vernier calliper (300 mm length, accuracy 0.1 mm). A cotton thread was used to measure the maximum and minimum hand circumferences, the length of the cotton thread was measured with a digital vernier calliper.

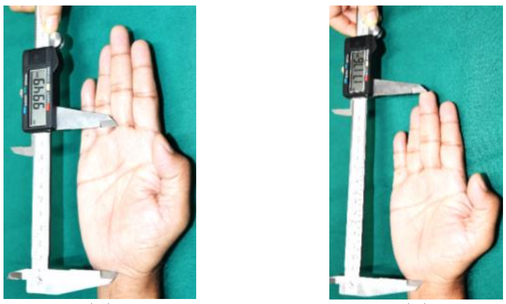
(A) (B)

Figure 1. Landmarks and technique of the measurement of Stature (A) Front view, (B) Side view

2.3 Hand measurements

Hand length-The distance from the middle of inter-stylion to the tip of middle finger.

Palmar length-The distance from the middle of the inter stylion to the proximal flexion crease of the middle finger.



(A) (B)

Figure 2. Landmarks and technique of the measurement of (A) hand and (B) palmar length

Minimum hand breadth-The distance between the most laterally positioned point on the 2nd metacarpal bone's head and the most medially placed point on the 5th metacarpal bone's head.

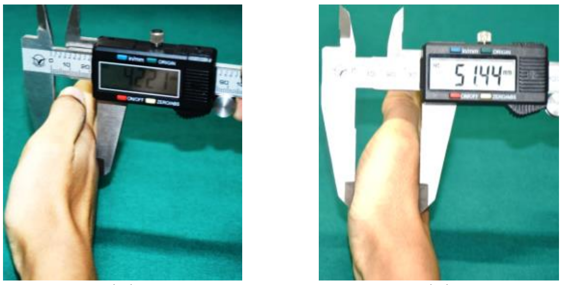
Maximum hand breadth-The distance between the most lateral point on the 1st metacarpal's head and the most medial point on the 5th metacarpal's head with closed fingers.

(A) (B)

Figure 3. Landmarks and technique of the measurement of (A) minimum and (B) maximum hand breadth

Minimum hand thickness -The distance between the dorsal and palmar aspects of the head of 3rd metacarpalwith adducted fingers.

Maximum hand thickness-The maximum distance from the back of the hand to the most projected point of the thenar eminence (Jee, Bahn, & Yun, 2015).



(A) (B)

Figure 4. Landmarks and technique of the measurement of (A) minimum and (B) maximum hand thickness

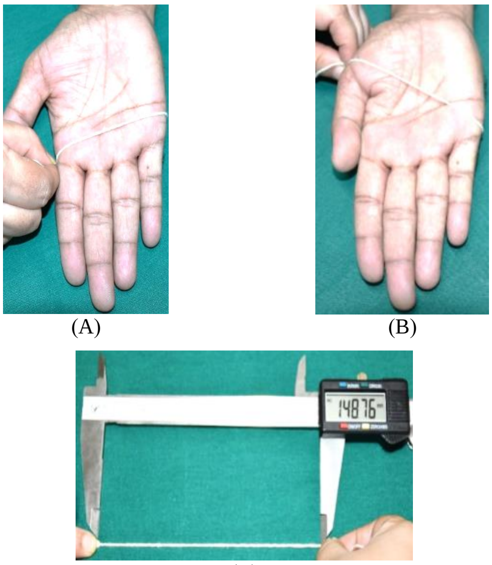
Minimum hand circumference-The superficial distance around the edge of the head of 2nd and 5th metacarpalswith adducted fingers.

Maximum hand circumference-The superficial distance around the edge of the head of 1stand 5th metacarpals with adducted fingers.

Except for stature, which was measured in centimetres, all measurements were taken in millimeters. The measurements were taken three times, with the average being calculated. To avoid inter-observer bias, all of the measurements were taken by the same observer.

2.4 Statistical analysis

Data was collected on a Microsoft excel spreadsheet, and descriptive statistics were used to evaluate and assess the parameters in both males and females. The mean and standard deviation of stature were calculated, as well as hand indices and their correlation coefficient with stature. To calculate stature, a regression model was developed. The strength of the association between the variables was evaluated using Pearson's correlation analysis. The significance of the body proportions assessed in both males and females was determined using students t-test. When the P-value was less than 0.05 ($P < 0.05$), differences were declared significant, and when $P < 0.001$ was present, correlation was indicated. The efficacy of hand measurements in stature estimation was investigated using linear and multiple linear regression analysis. The precision of gender determination was calculated using receiver operating characteristic curve analysis. The genders were categorized based on the cut off points. If the gender probability value is less than 0.5, the hand dimensions are female; otherwise, they are male. The collected data was statistically calculated using the Statistical Package for the Social Sciences (SPSS 20) software to derive linear regression equations.



(A) (B) (C)

Figure 5. Landmarks and technique of the measurement of (A) minimum and (B) maximum hand circumference, (C) technique of the measurement of the length of the cotton thread

3. Results and Discussion

In males, there is a significant correlation between stature and maximum and minimum breadths, maximum and minimum circumferences, palm and hand length on both sides, as shown in Table 1. On both sides, there is a significant correlation between stature and maximum and minimum breadths, maximum and minimum thicknesses, maximum and minimum circumferences, palm and hand length in females.

As seen in Table 2, in all dimensions, there are higher values for males than for females. Males have considerably higher right and left hand lengths, maximum and minimum breadths, maximum and minimum thicknesses, maximum and minimum circumferences, and palm lengths than females.

Table 1. Coefficient of correlation (r) between gender-based stature and hand-indices

Hand indices	Female		Male	
	r	*P*	*r*	*P*
HLRT	.529**	.000	.596**	.000
HLLT	.532**	.000	.601**	.000
HBMAXRT	.388**	.000	303**	.000
HBMAXLT	.388**	.000	.303**	.000
HBMINRT	.383**	.000	.232**	.000
HBMINLT	.384**	.000	.233**	.000
HTMAXRT	.194**	.001	-.040	.490
HTMAXLT	.196**	.001	-.039	.502
HTMINRT	.242**	.000	.008	.891
HTMINLT	.241**	.000	.007	.902
HCMAXRT	.277**	.000	.256**	.000
HCMAXLT	.274**	.000	.260**	.000
HCMINRT	.373**	.000	.317**	.000
HCMINLT	.371**	.000	.320**	.000
PLRT	.362**	.000	.472**	.000
PLLT	.365**	.000	.466**	.000

**Correlation is significant at the 0.01 level (2-tailed).
Abbreviation: HLRT, HLLT = Hand length right and left; HBMINRT,HBMINLT = Minimum hand breadth right and left; HBMAXRT, HBMAXLT = Maximum hand breadth right and left; HTMINRT, HTMINLT = Minimum hand thickness right and left; HTMAXRT, HTMAXLT = Maximum hand thickness right and left; HCMINRT, HCMINLT = Minimum hand circumference right and left; HCMAXRT, HCMAXLT = Maximum hand circumference right and left; PLRT, PLLT= Palm length right and left

Table 2. Gender-specific mean and standard deviation of the hand indices

Hand indices	Female		Male		Unpaired 't' test value	P value
	Mean	SD	Mean	SD		
HLRT	17.24	0.92	19.04	1.01	22.151	<0.001
HLLT	17.24	0.91	19.02	1.02	21.833	<0.001
HBMAXRT	8.63	0.57	10.10	0.75	26.065	<0.001
HBMAXLT	8.63	0.57	10.10	0.76	26.009	<0.001
HBMINRT	6.68	0.59	7.93	0.63	24.443	<0.001
HBMINLT	6.68	0.59	7.93	0.63	24.437	<0.001
HTMAXRT	2.54	0.39	3.16	0.92	10.346	<0.001
HTMAXLT	2.54	0.39	3.16	0.92	10.336	<0.001
HTMINRT	2.16	0.32	2.61	0.55	11.940	<0.001
HTMINLT	2.16	0.32	2.61	0.55	11.876	<0.001
HCMAXRT	20.47	1.38	23.77	1.70	25.340	<0.001
HCMAXLT	20.46	1.39	23.73	1.69	25.082	<0.001
HCMINRT	17.04	1.09	19.86	1.39	26.773	<0.001
HCMINLT	17.03	1.09	19.81	1.39	26.380	<0.001
PLRT	9.91	0.51	11.00	0.60	23.234	<0.001
PLLT	9.91	0.50	10.97	0.61	22.526	<0.001

A backward linear regression model was used to determine female and male stature using left and right hand indices. For all regression models, the ANOVA F values show thatusing right and left hand indices to determine the predictor variables "Stature" is statistically significant ($p < 0.05$) for both genders, implying that it is significantly more accurate. Regression model equations can be used to determine the stature of various hand measurements as shown Table 3.

Table 4 shows the Receiver Operating Characteristic (ROC) Curve analysis used to evaluate the cut-off values for left and right hand measurements to predict gender. These are the specificity and sensitivity values that show good predictive value and specificity. A logistic regression equation with categorized hand indices as independent variables was used to determine gender.

Model 1. Right hand indices are used to determine gender.

Gender = 2.033 × HBMAXRT + 2.104 × HBMINRT - 1.779 × HTMAXRT + 1.907 × HTMINRT + 0.985 × HCMAXRT + 1.418 × HCMINRT + 1.684 × PLRT - 4.200

In Model 1, gender has been found to be significantly related to the right hand's maximum and minimum breadth, maximum and minimum thickness, and maximum and minimum circumference. The gender analysis based on right hand indices was quite close to the actual gender values, as shown in the model. The overall accuracy of this model was 93.5%, with 93.8% of females and 93.2% of males correctly classified.

Model 2. Left hand indices are used to determine gender.

Gender = .931 × HLLT + 1.857 × HBMAXLT + 2.161 × HBMINLT - 1.820 × HTMAXLT + 1.960 × HTMINLT + 1.428 × HCMAXLT + 1.141 × HCMINLT + .854 × PLLT - 4.151

Gender was discovered to be significantly related to left hand length, maximum and minimum breadth, maximum and minimum thickness, maximum and minimum circumference, and palm length in Model 2. The gender analysis based on left hand indices was quite close to the actual gender values, as shown in the model. The overall accuracy of this model was 91.7%, with 91.6% of females and 91.8% of males correctly classified.

Model 3. Right and left hand indices are used to determine gender.

Gender = -1.970 × HTMAXRT + 1.463 × HCMINRT + 1.227 × PLRT + .890 × HLLT + 1.938× HBMAXLT + 2.102 × HBMINLT + 2.141 × HTMINLT + 1.053 × HCMAXLT - 4.443

Gender has been found to be significantly related to the maximum thickness, minimum circumference, and palm length of the right hand, as well as the maximum and minimum breadth, minimum thickness, and maximum circumference of the left hand in Model 3. The gender analysis based on left and right hand indices was quite close to the real gender values, as shown in the model. The overall accuracy of this modelwas93.0%, with 93.5% of males and 92.3% of females correctly classified.

The independent variables, i.e. hand indices, should be included in the model in accordance with the instructions in Table 4. If the gender probability value is less than 0.5, the hand dimensions are female; otherwise, they are male. The gender estimate was more than 93% accurate using all three logistic regression models generated.

In the current study, we took samples from the age group of 18 to 25 year, in which we got stature in the range of 171.29 cm to 174.87 cm for adult males with a mean stature that was 172.4 cm and an SD of 7.0 cm. The female stature was in the range of 157.66 cm to 161.08 cm with a mean stature that was 159.8cm and an SD of 7.1 cm. The mean of

Table 3. Regression model equations to determine the stature for male, female and irrespective of gender

Gender	Using side of hand measurements	Regression model equations	ANOVA F	P value	Adjusted R^2
Male	Right	84.679 + 4.063×HLRT + 2.274×HBMINRT – 2.416×HTMAXRT	67.435	p<0.001	0.405
	Left	84.579 + 4.108×HLLT + 2.181×HBMINLT – 2.390×HTMAXLT	68.628	p<0.001	0.409
	Right and Left	84.269 + 1.432×HBMINRT + 0.991×HCMINRT – 3.601×PLRT + 4.915×HLLT	42.046	p<0.001	0.412
Female	Right	85.249 + 4.995×HLRT + 1.462×HBMINRT + 0.970×HCMINRT – 3.820×PLRT	35.425	p<0.001	0.335
	Left	82.974 + 4.819×HLLT + 2.181×HTMINLT + 1.214×HCMINLT – 3.195×PLLT	35.072	p<0.001	0.333
	Right and Left	84.269 + 1.432×HBMINRT + 0.991×HCMINRT – 3.601×PLRT + 4.915×HLLT	35.704	p<0.001	0.337
Irrespective of gender	Right	67.394 + 4.666×HLRT + 2.311×HBMINRT – 3.413×HTMAXRT + 2.695×HTMINRT + 0.921×HCMINRT – 1.574×PLRT	164.723	p<0.001	0.634
	Left	65.561 + 3.941×HLLT + 2.270×HBMINLT – 3.465×HTMAXLT + 2.592×HTMINLT + 0.882×HCMINLT; ANOVA F = 196.010	196.010	p<0.001	0.632
	Right and Left	66.630 + 2.302×HBMINRT – 3.350×HTMAXRT + 2.522× HTMINRT + 0.939×HCMINRT – 1.410×PLRT + 4.614×HLLT	165.138	p<0.001	0.635

Table 4. Number of observed genders predicated on hand indices cut-off values and cut-off values to use in calculating g(x)

Hand indices	Cut-off as per ROC Curve	Observed gender		Total	Value to be entered in calculation of g(x)
		Female n=274	Male n=294		
HLRT	<18.15	225	48	273	0
	>=18.15	49	246	295	1
HBMAXRT	<9.30	246	32	278	0
	>=9.30	28	262	290	1
HBMINRT	<7.30	242	34	276	0
	>=7.30	32	260	292	1
HTMAXRT	<2.73	187	91	278	0
	>=2.73	87	203	290	1
HTMINRT	<2.35	195	84	279	0
	>=2.35	79	210	289	1
HCMAXRT	<22.05	242	41	283	0
	>=22.05	32	253	285	1
HCMINRT	<18.15	231	31	262	0
	>=18.15	43	263	306	1
PLRT	<10.45	231	42	273	0
	>=10.45	43	252	295	1
HLLT	<18.15	230	52	282	0
	>=18.15	44	242	286	1
HBMAXLT	<9.30	247	32	279	0
	>=9.30	27	262	289	1
HBMINLT	<7.30	243	34	277	0
	>=7.30	31	260	291	1
HTMAXLT	<2.73	187	88	275	0
	>=2.73	87	206	293	1
HTMINLT	<2.35	194	83	277	0
	>=2.35	80	211	291	1
HCMAXLT	<21.95	237	38	275	0
	>=21.95	37	256	293	1
HCMINLT	<18.15	234	34	268	0
	>=18.15	40	260	300	1
PLLT	<10.45	227	48	275	0
	>=10.45	47	246	293	1

the stature and hand indices of all studies are varied, which proves the well-known fact that different populations show a variation in stature as well as in body proportions. In the current study, the mean of stature and hand indices in males was found to be significantly higher than in females. These results were also observed in many populations (Table 5). The current study revealed that regression models may predict stature and gender based on hand dimensions. Hand indices were found to be statistically significant for both stature and gender. Using the three logistic regression models created, the gender estimate was more than 93% reliable. The aim of this study is to discover stature and reliable gender discriminators

Table 5. Comparison with prior studies

Sr.no	Author	Study region / Country	Sample size		Parameters studied	Results
			Male	Female		
1	Uhrová *et al.*, (2015)	Slovak Republic	120	130	HL,HB	Hand dimensions found a positive correlation with stature in both sexes.)p < 0.01(
2	Jee *et al.*, (2015)	Korea	167	154	HL,MnHB, MxHB,MnHT, MxHT, MnHC, MxHC, PL	Sex estimation was done accurately by MHC for 88.6% of males and 89.6% of females.
3	Jee, & Yun, (2015)	Korea	167	154	HL,MnHB, MxHB,MnHT, MxHT, MnHC, MxHC, PL	Hand length found the highest correlation with stature in both males (r = 0.628) and females (r = 0.534).
4	Zhang X *et al.*, (2017)	China	13,221	13,706	HL, HB Both side	The right hand lengths and foot lengths were the best predictors of stature.
5	Ibrahim *et al.*, (2016)	Egypt	250	250	HL, HB, PL Both side	The highest correlation with stature was observed with hand and palm length.
6	Banik, (2016)	West Bengal, India	158	110	HL, HB Both side	Sex estimation was done accurately by HL (left 79.10%), HB (right 77.61%), HL (right) and HB (left) (75.37%),
7	Howley, *et al.*, (2018)	Australia	35	61	HL,HB,PL	Sex estimation was done accurately by using left HB with 96.7% for females and right PL was achieved with 85.7% for males. Stature can be estimated with a high degree of expected accuracy in the Australian population using isolated body parts such as the forearm, hand, lower leg, and foot.
8	Uzun, *et al.*, (2018)	Ortahisar, Turkey	112	288	HL, HB, PL Both side	Sex estimates based on measurements of the right upper extremity obtained in model 1 were correct in 94.8% of women and 83.0% of men (p = 0.608).and with 95.1% accuracy from measurements of the left upper extremity in women and 83.9% in men (p = 0.597).
9	Ibeabuchi, *et al.*, (2018)	Lagos, Nigeria	100	130	HL, HB Both side	A stronger correlation was recorded between stature and hand length, while hand breadth and stature showed a weak association.
10	Atirah, & M, (2018)	Malaysia	200	200	HL, HB, PL Both side	Hand length and handprint length have the strongest correlation with stature for male and female subjects.
11	Arifi, (2020)	Kosovo	830	793	HL Both side	The length of the hand can be used to determine body height, and it is a good predictor of body height for both males and females.
12	Roy, *et al.*, (2020)	West Bengal, India	200	200	HL, HB Both side	The linear and stepwise multiple equation regression equations showed a significant relationship between stature and both HL and HB.
13	Present study, (2021)	Maharashtra India	294	274	HL, PL, MnHB, MxHB, MnHT, MxHT, MnHC, MxHC, PL Both side	The relationship between stature and the right-hand and left-hand indices is significant for both males and females. The sex estimate from hand indices was more than 93% accurate using all three logistic regression models generated.

HL-hand length, PL –palm length, HB-hand breadth, MnHB - minimum hand breadth, MxHB -maximum hand breadth, MnHT - minimum hand thickness, MxHT - maximum hand thickness, MnHC - minimum hand circumference, MxHC - maximum hand circumference

using different hand indices. While the problem of gender determination has been significantly simplified by DNA technologies, the method has restrictions on skilled manpower, time and financial concerns, particularly in underdeveloped nations and in situations where DNA analysis cannot be conducted.

3.1 Limitations of the study

The limitation of this study was that it was limited to a specific age range (18–25 years). As a result, the opinions acquired may differ from those of the target group. Bodyweight data can be used in future studies. The use of the models for determining sex and stature from dry bone measurements was not tested in this study.

4. Conclusions

According to this study conducted on Indian participants, the length, breadth, thickness, and circumference of the hand can be used to determine gender and stature with high accuracy. Circumference and thickness can be employed as reliable gender discriminators in addition to length and breadth, which have mostly been studied in earlier studies.

The findings of this study revealed that using Indian individuals' hand dimensions for gender and stature determination could be a valuable reference for future forensic research based on hand dimensions. These data could be useful in forensic, epidemiological, and anthropometric research.

Acknowledgements

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