Sex Determination Using Hand Morphometric Parameters in Individuals from Pakistani Descent. A Quantitative Study

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Abstract

Objective: To identify the presence or absence of sexual dimorphism using hand measurements alone in people from Pakistan. Moreover, to identify the variable that can be better at predicting sex among the rest of hand measurements.

Methods: The research involved 122 male and 182 female participants, ranging in age from 18 to 60 years, without any hand deformities or missing fingers. Each participant underwent a set of hand measurements, including hand breadth, which was measured in a linear line from the lateral-most end on the head of the second metacarpal to the medial end on the head of the fifth metacarpal in centimeters. Additionally, hand length measured to be as the direct distance from the midpoint of the distal wrist crease to the top most point of the middle finger in centimeters.

Logistic regression was used to analyze six hand measurements on the likelihood of prediction of the male or female gender

Results: The logistic regression model showed statistical significance, $\div 2 = 19.502$, $p < 0.012$. The model explained 58.0% (Nagelkerke R2) of the variance in gender and accurately identified 84.2% of cases. A statistically substantial disparity was evident in hand measurements and hand indices across genders. (P-value=0.0001).

Conclusion: Our study reveals the presence of sexual dimorphism in hand morphometric parameters among the population of Pakistan. Hand measurements prove to be a reliable indicator for predicting gender in the majority of cases. Nevertheless, relying on a single hand measurement may not yield accurate gender predictions. Instead, a combination of various hand measurements can enhance the overall reliability of gender prediction.

Keywords: Anthropometry, personal identification, sexual dimorphism, Hand measurement, Sex determination.

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Introduction

The ability to identify the gender of an individual from an unknown body part can be a crucial piece of evidence in many forensic investigations. This is because sex can provide important clues about the identity of the individual, their biological sex charac-teristics[1]. It is one of the essentials in establishing personal identity which can be useful in mass disa-sters as well as criminal cases[2]. Sex of an uniden-tified individual can be identified using various tech-niques such as anthropometric measurements of the skull and mandible, soft tissues, teeth and DNA analysis of teeth[3].

Establishing identity of human remains in the event of calamities or in criminal cases is crucial. Identification of the unknown is the first step to solving any medico-legal case Sex determination with accuracy can help solve such mysteries in forensics and may lead to identification of victims effi-

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ciently[4]. A dismembered hand can provide information regarding the sex of an individual, in fact it can also predict stature and age of a person[5-7]. Hand measurements for gender determination may remain accurate before rigor mortis sets in which may take anywhere from 6 to 12 hours. As a result, it can be a reliable method of gender identification in the postmortem phase[8].

In this study we aim to identify sex of an individual using hand measurements as the current information regarding soft tissue measurements of hand for sex determination are inconclusive[9-10] and no such study has been done on Pakistani population as per our knowledge. Hence, through this study we aim to determine the accuracy and reliability of using morphometric parameters of hand to determine sex in people of Pakistani decent.

Our rationale for this study was to come up with a reliable way of sex determination using limited technology and to develop an authentic way for forensic investigators to predict sex of unidentified bodies that are mutilated or torn apart, providing on-site sex determination, in cases of mass disasters.

We planned to identify the presence or absence of sexual dimorphism using hand measurements alone in people from Pakistan. Furthermore, to identify the variable that can be better at predicting sex among the rest of hand measurements. Therefore, our research intended to gauge the precision and consistency of using hand measurements to determine the sex of individuals of Pakistani origin.

Methodology

We conducted a cross-sectional study. Serial hand measurements were obtained from our subjects to classify the gender with hand measurements. The study was conducted on various students and faculty members along with general public (parents, relatives of students). The study setting was Dow University of Health and sciences. Participants were included aged between 18-60 years of age. Both genders were included. Individuals with any kind of hand deformity, individuals with missing fingers and individuals whose flexure creases are not prominent were excluded from the study. No patient involvement was there in this study. The data was collected from the general public after obtaining their informed consent. Data collection was done in the span of 10 months from January 2022 to October 2022.

Anthropometric measurements included the assessment of hand breadth, defined as the direct measurement from the most lateral point on the head of the second metacarpal to the most medial point on the head of the fifth metacarpal, expressed in centimeters. Furthermore, hand length was determined as the straight distance from the midpoint of the distal wrist crease to the tip of the middle finger, measured in centimeters. Lastly, hand index was calculated by taking a ratio of hand breadth with the hand length and multiplying by 100.

We had a well-designed research protocol specifically highlighting the methodology of data collection that helped in reducing bias. Further to remove bias we did random sampling.

Convenient sampling was done by approaching all the participants. The proportion of the variable " hand length sectioning point analysis" to accurately determine gender is 77% for the right hand in males[11]. Sample size was calculated by using Open Epi version 3.01. Hence, taking 95% confidence level and 5% margin of error, the computed sample size is 273. By adding, 10% expected non-response rate, overall 300 partakers contributed to our data. The measurements of Hand Breadth and hand length were statistically analyzed using IBM SPSS (Statistical Package for Social Sciences, Version 20.0) computer software by which descriptive statistics including mean, standard deviations pertaining to hand breadth, hand length, and hand index were obtained and a logistic regression model was applied. Male to female differences among the variables being considered was calcul-ated using t-test at p-value of less than 0.05. We also incorporated logistic regression model to predict gender. Missing data was not made part of the analysis.

Ethical approval was obtained from the Institution Review Board of Dow University of Health Sciences ref # IRB-2269/DUHS/APPROVAL/2021/683.

Results

Collectively 122 men and 182 women participated in the study.

Table 1: A logistic regression was performed to ascertain the effects of right-hand breath, right hand length, left hand breadth, left hand length, right hand index and left-hand index on the likelihood that participants have male or female gender.

The logistic regression model was statistically significant, ÷ 2 = 19.502, $p < .012$. The model expl-ained 58.0% (Nagelkerke R^2) of the variance in gender and correctly classified 84.2% of cases.

The explained variation in the dependent variable based on our model ranges from 43.0% to 58.0%, none of the parameters added significantly to the model/prediction.

Table 2 illustrates the descriptive statistics of the hand measurements of both genders. It was observed that hand dimensions as well as hand index of males, mean and standard deviation were more of the left-hand side than the right. Whereas hand dimensions and hand index of females, mean and standard deviation were more of the right-hand side than the left. It was also observed that hand dimensions and indexes were more in males than in females.

Table 3: T-test was applied to confirm the statistical difference among gender in hand dimensions and hand index. Highly significant difference was observed in hand dimensions and hand index among gender (p-value=.0001).

Table 1. Logistic regression

Hand parameters	B	S.E.	Wald	df	Sig.	Exp (B)	95% C.I.for EXP(B)	
							Lower	Upper
Right hand length	.261	.669	.152	1	.697	1.298	.350	4.816
Right hand breadth	-.067	.655	.011	1	.918	.935	.259	3.374
Left hand length	-.764	1.361	.316	1	.574	.466	.032	6.703
Left hand breadth	-2.871	2.697	1.133	1	.287	.057	.000	11.185
Right hand index	-.028	.161	.031	1	.860	.972	.708	1.334
Left hand index	.468	.500	.875	1	.349	1.596	.599	4.253

Table 2. Descriptive statistics of hand parameters in centim eters (cm)

Hand parameters	Gender	N	Mean	Std. Deviation
Right hand length	male	122	19.407	1.1513
	female	182	17.780	.9607
Right hand breadth	male	122	9.116	.9057
	female	182	7.932	.9687
Left hand length	male	122	19.412	1.0888
	female	182	17.763	.9364
Left hand breath	male	122	9.129	.9196
	female	182	7.963	.7702
Right hand index	male	122	46.9884	3.98754
	female	182	44.8433	3.54523
Left hand index	male	122	47.0282	4.03605
	female	182	44.7978	3.55036

Table 3. Mean difference in hand parameters among males and females

Hand parameters	P-value Upper	Mean difference Lower i		95% confidence interval of the difference
Right hand length	.0001	1.6263	1.8661	1.3866
Right hand breadth	.0001	1.1837	1.4011	.9663
Left hand length	.0001	1.6491	1.8794	1.4188
Left hand breadth	.0001	1.1655	1.3644	.9666
Right hand index	.0001	2.14511	3.00369	1.28654
Left hand index	.0001	2.23038	3.09442	1.36634

P-value= <0.05 is significant

Discussion

Determining an individual's gender is one of the fundamental steps in founding their personal identity. This crucial information plays a vital role in various contexts, including mass disaster investigations and criminal cases, where it can provide inv-

aluable clues to aid in the identification of victims and perpetrators.

During mass disasters, such as natural catastrophes or large-scale accidents, determining the sex of victims can assist in the identification and reunification process. This is particularly important in situations where extensive damage or decomposition makes visual recognition challenging. By examining skeletal remains, forensic anthropologists and odontologists can identify gender-specific characteristics in bones and teeth, aiding in the reconstruction of the victim's identity.

In criminal investigations, determining the sex of a suspect or victim can narrow down the pool of potential suspects, provide insights into the nature of the crime, and aid in the reconstruction of the events leading to the incident. For instance, if a male victim is found with injuries consistent with sexual assault, knowing the suspect's sex can help investigators focus their search on male individuals[2].

A multitude of gender determinant techniques have been identified in the field of forensic medicine such as forensic DNA typing, forensic odontology[12], and from skeletons[13].

Although the techniques mentioned earlier undeniably provide a high level of reliability, it is essential to acknowledge their inherent time-consuming nature and the prerequisite for a specialist's involvement, posing a potential challenge in situations where prompt identification is imperative. On the contrary, the methodology centered on gender determination through hand parameters emerges as a notably simple, rapid, and uncomplicated approach, drawing its foundation from the theory of sexual dimorphism. The outcomes of our investigation not only affirm the viability of this method but also point to the existence of considerable distinctions in hand measurements between the two genders. These findings underscore the practical potential and accessibility of employing this swift hand-based approach for gender determination, especially in situations necessitating a quick and efficient identification process. Our stu-dy's findings resonate with a growing body of rese-arch conducted across the globe, consistently demonstrating the efficacy of hand measurements in accurately predicting gender in most instances. This convergence of evidence lends credence to the notion that hand dimensions serve as reliable gender markers, particularly in situations where visual identification or personal information is unavailable. The consistency in these findings across diverse populations underscores the universality of hand size associations with gender. This suggests that hand size dimorphism, the inherent difference in hand dimensions between males and females, is a fundamental aspect of human biology, transcending cultural and geographical boundaries[14-16].

We incorporated a machine learning algorithm, logistic regression, in our hand parameter to determine gender[17]. Upon conducting an in-depth analysis of the logistic regression, it becomes evident that the model not only reaches statistical significance but does so impressively with a p-value of less than 0.012. This level of statistical significance is indicative of a robust relationship between the hand measurements and the probability of classifying participants into the categories of male or female. Expanding our scrutiny, the Nagelkerke R-squared value, a metric denoting the proportion of variance explained by the model, stands at a noteworthy 0.58. This signifies that the model elucidates a substantial 58% of the observed variability in gender, underscoring its capacity to capture and explain a significant portion of the intricacies involved.

Adding to the model's credibility, the accuracy metrics are quite promising. The model demonstrates an admirable proficiency by correctly classifying 84.2% of the cases. This high accuracy rate is not only a testament to the model's robustness but also bolsters its practical utility in real-world applications. What's particularly noteworthy is the alignment of these findings with a parallel study that delved into gender classification using comparable machine learning algorithms. This congruence

with existing research not only strengthens the reliability of our model but also places it within the broader context of established methodologies, affirming its potential as an effective tool for gender determination based on hand measurements[17].

Nonetheless, in accordance with our regression model, it appears that none of the independent variables-namely, right-hand breadth, right-hand length, left-hand breadth, left-hand length, right-hand index, and left-hand index-exhibit a significant effect on the likelihood of an individual being classified as male or female. All these variables present p-values greater than 0.05, suggesting a lack of statistically significant impact in isolation. Furthermore, when examining the coefficients of these independent variables, drawing conclusive insights based on individual variables becomes challenging, as doing so may inadvertently mask the potential influence of other variables. To achieve a more accurate understanding, it is deemed more appropriate to consider all the variables collectively as predictors, allowing for a comprehensive evaluation of their combined impact on the model's outcome of the determination of gender as per our findings. On the contrary, findings from research conducted worldwide diverge, suggesting that independent variables are notably influential as accurate predictors of gender. A noteworthy example is a study carried out in Thailand, which specifically identified hand length and the length of the third finger as the most reliable parameters for gender determination. This variation in research outcomes underscores the complexity and diversity of factors influencing gender prediction across different geographical and cultural contexts. Recognizing the multifaceted nature of these variables becomes crucial for a comprehensive understanding of the intricate dynamics involved in predicting gender based on physiological parameters[16]. Likewise, medullary length of first metacarpal was suggested to be having 81% of percentage accuracy in determining gender[18]. However, our suggestions are contrary to the findings of other studies that suggests a certain hand parameter to be the most accurate predictor of gender.

It is noteworthy that logistic regression is a powerful tool for analyzing data, but the results should be interpreted with caution. Factors that were not included in the model could be influencing the results, and more research will be needed to understand the relationships between hand measurements and gender more fully[19].

According to the information presented in Table 2, it is evident that hand length and breadth can be used as potential indicators of gender. The mean hand length and breadth is greater for males than for females, with standard deviations also being higher for males, indicating more variability in hand size among males. Similar trends were noted in an Australian population study that incorporated like hand measurements and reported a higher mean of measurements in males[20]. The hand index, which is the ratio of hand length to breadth, is also slightly higher for males than for females. This outcome is resembles with a comparable study conducted in Nepal that shows a higher hand index for males in contrast.

There are statistically significant differences in all of the hand parameters measured between males and females. The mean values for all of the hand parameters are higher for males than for females. Additionally, the standard deviations for all of the hand parameters are larger for males than for females. This suggests that there is more variability in hand size among males than among females.

These findings are consistent with previous research on hand size dimorphism. Studies have shown that males typically have larger hands than females, even when controlling for other factors such as height and weight, also, our findings coincide with similar findings reported in a study carried out in India[22], also a similar study carried out in Bangladesh reported noteworthy dissimilarities in the hand dimensions of males and females, thereby putting hand measurements as a reliable indicator of gender[23]. Likewise, sexual dimorphism based on hand measurements was also reported in the population of South India[24]. Hence, sexual dim-

orphism exists in different racial backgrounds and ethnicity and as such can be used as a predictor for gender identification.

Overall, it appears that these hand measurements can be used to differentiate between males and females with a high degree of accuracy. However, it's imperative to consider that the sample of the data and population that was used for the research may have been limited and the results should be interpreted based on this limitation and generalization to other population should be made with caution. Additionally, these measurements may not be generalizable to all populations, and more research is needed to investigate the utility of hand measurements for gender determination in different groups of opl females[21].

Conclusion

Our study reveals the existence of sexual dimorphism in hand measurements among the Pakistani population. Hand measurements prove to be a reliable indicator for predicting gender in the majority of cases. Nevertheless, relying on a single hand measurement may not yield accurate gender predictions. Instead, a combination of various hand measurements can enhance the overall reliability of gender prediction.

Conflict of Interest

Authors have no conflict of interest and no grant funding from any organization.

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