ARAŞTIRMA / RESEARCH

Hand Anatomy, Gender Differences, ROC Curve Values and Regression Formulas in Young Adults

Genç Erişkinlerde El Anatomisi, Cinsiyet Farklılıkları, ROC Eğrisi Değerleri ve Regresyon Formülleri

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Abstract

Objective: In this study, our aim was to obtain the cut-off values with the "Receiver Operator Characteristic (ROC)" for estimating gender from the hand sizes of young adult female and male individuals, and also to create logistic regression equations.

Material and Method: This study was carried out on 64 healthy young adult volunteers (29 males, 35 females) aged 18-22 years. Hand photos of the volunteers were taken using the Canon 800D camera. Hand length and hand breadth were measured with the "Image J" program. A total of 256 measurements were carried out.

Results: Right hand mean length (in cm) was 17.70 for women and 20.01 for men; The mean breadth of the right hand was found to be 8.10 in women and 9.34 in men. The difference between the right and left sides in terms of hand length in men and both hand length and hand breadth in women was statistically significant $p<0.005$. The difference between the genders in terms of hand length and breadth values was also statistically significant, $p<0.005$. Cut-off values (in cm); 18.97 for right hand length, 8.874 for right hand breadth, 19,015 for left hand length, and 8.883 for left hand breadth. Regression equations for estimating gender were obtained from hand length and hand breadth. Among the equations created based on hand length and hand breadth, the equation with the highest probability of correct prediction was the equation based on left hand breadth (R square=0.824, overall true predicted ratio =93.8%).

Conclusion: We believe that the regression formulas obtained from hand morphometric values will be useful for anatomists, forensic medicine specialists and forensic anthropologists.

Keywords: Gender differences, hand dimensions, regression formulas, ROC values.

Öz

Amaç: Çalışmamızda genç erişkin kadın ve erkek bireylerin el boyutlarından cinsiyet tahminine yönelik "Receiver Operator Characteristic" analizi ile cut-off değerlerinin (kesme-değerlerinin) elde edilmesi ve logistic regresyon denklemlerinin oluşturulması amaçlanmıştır.

Gereç ve Yöntem: Çalışma, sağlıklı 18-22 yaş aralığında, 64 genç erişkin gönüllü üzerinde (29 erkek, 35 kadın) gerçekleştirildi. Gönüllülerin el fotoğrafları Canon 800D fotoğraf makinesi kullanılarak çekildi. Standardizasyon için fotoğraflamadan önce milimetrik cetvel kullanıldı. El uzunluğu ve el genişliği "Image J" programı ile ölçüldü. Toplamda 128 elde ölçüm yapıldı.

Bulgular: Sağ el ortalama uzunluğu (cm) kadınlarda 17,70, erkeklerde 20,01; sağ el ortalama genişliği kadınlarda 8,10, erkeklerde 9,34 olarak bulundu. Her iki cinsiyette de el uzunluğu değerleri ile el genişliği değerleri arasında orta düzeyde pozitif korelasyon tespit edildi. Erkeklerde el uzunluğu, kadınlarda hem el uzunluğu hem de el genişliği bakımından sağ ve sol taraflar arasındaki fark, istatistiksel olarak anlamlıydı $p<0,005$. El uzunluk ve genişlik değerleri açısından cinsiyetler arasındaki fark istatistiksel olarak anlamlıydı $p<0,005$. Kesme-değerleri (cm); sağ el uzunluğu için 18,977, sağ el genişliği için 8,874, sol el uzunluğu için 19,015 sol el genişliği için 8,883 olarak saptandı. El uzunluğu ve el genişliğine bağlı oluşturulan denklemler içerisinde doğru tahmin ihtimali en yüksek olan denklem sol el genişliğine bağlı oluşturulan denklemdi (R^2=0,824, Genel doğru tahmin oranı %93,8).

Sonuç: El morfometrik değerlerinden elde edilen regresyon formüllerinin anatomistler, adli tıp uzmanları ve adli antropologlar açısından faydalı olacağı kanaatindeyiz.

Anahtar Kelimeler: Cinsiyet farklılıkları, el boyutları, regresyon denklemleri, ROC değerleri.

1. Introduction

When there are natural disasters such as earthquakes, floods and unexpected situations such as plane crashes, and mass deaths such as war and terrorist incidents, human body integrity is often completely destroyed. In identification, answers to four important questions are sought. These questions are the gender, height, age and race of the individual. Fingerprint and DNA examinations are the best methods for positive identification. In cases where these two methods cannot be used for many reasons, such as burns, gender estimations are made according to the morphologic characteristics of anatomical structures. In human remains, the skull and pelvis can be studied morphologically, which gives successful results in sex prediction (1). In cases where the skull and pelvis are not intact, gender can be estimated from other bones. It is possible to predict gender with an accuracy value of approximately 75% by examining the shape features of the distal end of the humerus (2). In addition, teeth are also used for gender estimation due to differences in shape and structural features (3). Apart from the morphological features of anatomical structures, gender estimation can be made with a certain percentage accuracy using statistical calculation methods from numerical data obtained with metric measurement techniques. In the literature, it is possible to find studies on gender prediction from many different anatomical structures such as hand index, 2D_4D ratio, clavicula, and foramen magnum dimensions (4-7). In addition, it is possible to come across studies on sex determination from the scapula and cranial measurements using 3D-CT images (8,9). Estimates based on the calculations used in these studies may vary due to racial and ethnic differences. For this reason, there is a need for many studies that take into account not only racial but also ethnic and regional differences. In our study, it was aimed to use different statistical methods and to obtain regression equations for estimating gender from hand sizes in a narrow age range in a young adult population.

2. Material and Method

The approval of the ethics committee of the study was given by the "Non-Invasive Clinical Research Ethics Committee of İzmir Katip Çelebi University Faculty of Medicine" with the decision numbered 24.02.2022-0045. Informed consent was obtained from the participants for the study.

The study was carried out on hand-held photographs obtained from young volunteers (29 males, 35 females) aged 18-22 years and is a cross-sectional study. Participants in the study were university students. They did not engage in any active sports that could affect hand development. Those who have bone and joint disorders and those who do active sports were not included in the study.

The photos were taken by the same researcher with a Canon 800D camera from a distance of 50 cm at an angle of 90 degrees. A portable lamp was used to illuminate the environment adequately. For standardization, a millimetric ruler was placed in the area to be photographed. Before the photographs were taken, the volunteers were asked to place their hands on the table with their palms facing up. Hand measurements were made using the "Image J" program. Hand length was measured as the distance from the middle of the wrist line to the tip of the middle finger. Hand breadth was measured as the distance from the lateral of the second metacarpal to the medial of the fifth metacarpal (4).

Statistical Analysis

IBM SPSS 26 program was used for statistical analysis. Descriptive statistical values (median, minimum, maximum, standard deviation) were determined. The distribution of the obtained data was evaluated with the Shapiro–Wilk test. The difference between the right and left sides was made with the paired t-test. Independent t-test was used to evaluate the difference between genders. The correlation between hand length and hand breadth was checked. Cut-off values for hand length and hand breadth were obtained by ROC analysis. Equations for gender estimation were created with logistic regression analysis (10).

3. Results

The mean age and standard deviation values of the volunteers participating in the study were 19.64±1.07. The mean length of the right hand (in cm) was 17.70 for women and 20.01 for men; The mean breadth of the right hand was found to be 8.10 in women and 9.34 in men. The mean left hand length was 17.81 for women and 20.13 for men; The mean left hand breadth was found to be 8.05 in women and 9.40 in men (Figure 1).

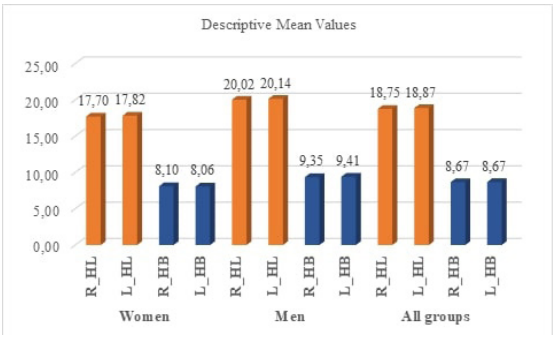

Figure 1: Mean Values of Hand Measurements

R_HL: Right Hand Length, R_HB: Right Hand Breadth, L_HL:Left Hand Length, L_HB:Left Hand Breadth

Minimum and maximum values were obtained for right and left hand dimensions of both genders (Table 1).

Table 1. Descriptive Statistics

		N	Min	Max	Mean	STD
Women	Right Hand Lenght	35	14.97	22.17	17.7034	1.20084
	Left Hand Lenght	35	15.31	22.42	17.8159	1.20715
	Right Hand Breadth	35	6.76	9.57	8.1012	0.54705
	Left Hand Breadth	35	6.74	9.58	8.0582	0.53577
Men	Right Hand Lenght	29	18.83	21.79	20.0160	0.79155
	Left Hand Lenght	29	18.63	22.26	20.1362	0.84938
	Right Hand Breadth	29	8.57	10.09	9.3477	0.33480
	Left Hand Breadth	29	8.56	10.22	9.4075	0.39165
Total	Right Hand Lenght	64	14.97	22.17	18.7513	1.55014
	Left Hand Lenght	64	15.31	22.42	18.8673	1.56920
	Right Hand Breadth	64	6.76	10.09	8.6660	0.77617
	Left Hand Breadth	64	6.74	10.22	8.6696	0.82546

A moderate positive correlation was found between hand length values and hand breadth values in both genders (Table 2).

Table 2. Correlation Analyses

		Men					Women			
		Right Hand Lenght	**Right Hand Breadth**	**Left Hand Lenght**	**Left Hand Breadth**		**Right Hand Lenght**	**Right Hand Breadth**	**Left Hand Lenght**	**Left Hand Breadth**
Right Hand Lenght	r	1	0.530**	0.940**	0.344		1.000	0.595**	0.965**	0.491**
	p		0.003	0.001	0.068			0.001	0.001	0.003
Right Hand Breadth	r	0.530**	1	0.554**	0.900**		0.595**	1.000	0.562**	0.913**
	p	0.003		0.002	0.001		0.001		0.001	0.001
Left Hand Lenght	r	0.940**	0.554**	1	0.396*		0.965**	0.562**	1.000	0.471**
	p	0.000	0.002		0.033		0.001	0.001		0.004
Left Hand Breadth	r	0.344	0.900**	0.396*	1		0.491**	0.913**	0.471**	1.000
	p	0.068	0.000	0.033			0.003	0.000	0.004	

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

The difference between the right and left sides in terms of hand length in men and both hand length and hand breadth in women was statistically significant p<0.005 (Table 3).

Table 3. Difference Between Right and Left Side

		Mean	**STD**	**SEM**	**95% Confidence Interval of the Difference**				
					Lower	Upper	t	df	p
Men	R_HL vs L_HL	-0.12024	0.28926	0.05371	-0.23027	-0.01021	-2.239	28	0.033
	R_HB vs L_HB	-0.05983	0.17131	0.03181	-0.12499	0.00534	-1.881	28	0.070
Women	R_HL vs L_HL	-0.11246	0.18522	0.03131	-0.17608	-0.04883	-3.592	34	0.001
	R_HB vs L_HB	0.04300	0.12131	0.02050	0.00133	0.08467	2.097	34	0.043

Paired t test, p<0.005
R_HL: Right Hand Length, R_HB: Right Hand Breadth, L_HL:Left Hand Length, L_HB:Left Hand Breadth

The difference between the genders in terms of hand length and hand breadth values was also statistically significant, p<0.005. Cut-off values obtained with ROC curve; 18.977 for right-hand length, 8.874 for right-hand breadth, 19,015 for left-hand length, and 8.883 for left-hand breadth (Table 4).

Table 4. ROC Curve Parameters of Hand Measurements

Hand Measurements	**AUC(95%)CI**	**p**	**Cut-off values**	**Sensitivity(%)**	**Specificity(%)**
Right Hand Lenght	0.945 (0.882-1.000)	<0.001	18.977	89.7	88.6
Right Hand Breadth	0.959 (0.907-1.000)	<0.001	8.874	93.1	91.4
Left Hand Lenght	0.947 (0.885-1.000)	<0.001	19.015	89.7	88.6
Left Hand Breadth	0.962 (0.912-1.000)	<0.001	8.883	93.1	94.3

Regression equations for estimating gender were obtained from hand length and hand breadth (Table 5). Among the obtained regression equations, the equation with the highest probability of correct prediction was the equation based on left hand breadth (R square=0.824, overall true positive rate=93.8%).

Table 5. Logistic Regression Formulas for Gender Estimation

Hand Parameters	**Logistic regression formulas**	**R Square**	**Predicted percentage correct (%)**		
			Men	**Women**	**Overall**
Right Hand Lenght	37.891 + (-1.998* R-HL)	0.71	93.1	88.6	90.6
Right Hand Breadth	45.302 + (-5.116*R-HB)	0.804	93.1	91.4	92.2
Left Hand Lenght	35.096 + (-1.840*L-HL)	0.692	79.3	88.6	84.4
Left Hand Breadth	44.161 + (-4.999*L-HB)	0.824	93.1	94.3	93.8

R_HL: Right Hand Length, R_HB: Right Hand Breadth, L_HL:Left Hand Length, L_HB:Left Hand Breadth

4. Discussion

It is possible to use the structures of many anatomical parts of the human body for sex determination. A certain percentage of correct predictions can be obtained with morphological and anthropometric evaluations. The results obtained from the studies in the literature may be specific to the people of the region where the studies were carried out. Therefore, it is necessary to compare the results obtained from different races, ethnicities, and geographical regions.

The mean values of hand length and hand breadth of men and women reported by Verma et al. (10) in their study on the young population in Northern India were smaller than the mean values obtained in our study (hand length 19.39 in men, 17.70 in women, hand breadth 8.35 in men and 7.39 in women). In the logistic regression equations obtained by Verma et al. (10) they found the true positive rate of 80.9 in men and 80.7 in women for hand length, 85.5 in men, and 89.4 in women for hand breadth. In our study, however, these rates for the right hand are higher than in the study of Verma et al. (10). In our study, the true positive rate for right hand length was 93.1 in men and 88.6 in women; for right hand breadth, it was found to be 93.1 in males and 91.4 in females. However, the success rate of the equations obtained for the left hand length in our study is slightly lower. The true positive rate was found to be 79.3 in men and 88.6 in women. Verma et al. (10) reported that the largest AUC value in the ROC curve was dependent on hand breadth. Similarly, in our study, the largest AUC value (0.962) belonged to the breadth of the left hand.

Ahmet Abdalla's (11) study (120 males and 120 females in the age range of 25-30 years) in Sudanese society used a different statistical method than our study. In addition, only left hand measurements were made in their studies. The mean values of hand length and hand breadth of the volunteers participating in the study are smaller than the values in our study. In their evaluation with the discriminant function analysis method, the success rate of hand length in estimating gender was 78% in men and 83% in women; They found the success rate of hand breadth to be 78% for men and 93% for women. When we compare our results obtained with logistic regression analysis, the correct predictive value for left hand length was found to be 79% in men, 88.6% in women, and found 93.1% in men, and 94.3% in women for left hand breadth. In our study, the percentage of gender prediction was found to be quite high, especially according to hand breadth. These percentage differences may be due to the differences in the hand and finger types of the societies, as well as the advantages and disadvantages of the statistical methods used against each other. In addition, Ahmet Abdalla (11) did not evaluate the right hand in his study. In our study, there is a significant difference between the percentages of gender prediction from the right and the left hand breadths. In addition, higher gender prediction values were obtained for right hand length in males (Table 5) (8).

In the study carried out by Shoo-Chan et al. (12) in Korea, the variables they examined included hand length, hand breadth, hand thickness, and hand circumference. When they evaluated the data obtained by the discriminative function analysis method, they found that the highest percentage of accuracy in estimating gender was related to hand circumference. They found the correct prediction rate for gender to be 88.6% for males and 89.6% for females. We did not examine hand thickness in our study. However, our percentage of correctly estimating the gender we obtained from hand breadth with logistic regression analysis is higher than the percentage values obtained by Shoo Chan et al. (12). We think that this may be due to racial morphological differences or statistical method differences.

In the study of Kanchan et al., (13) in which 500 hands were measured; hand length, hand breadth, palm length, hand index, and palmar index were evaluated for sexual dimorphism. They reported that hand sizes (especially hand breadth) gave better results in estimating gender than indexes (13). In our study, hand index calculations were not performed. However, in our study, results related to hand breadth were more successful than hand length.

Ishak et al. demonstrated significant sexual dimorphism in the measurements of hands in a Western Australian Population. The study was carried out on 91 male and 110 female individuals, and they considered that cross-validated sex classification accuracy range between 82.6 and 96.5% with a sex bias of ≤5% (14). These results of the mentioned study are in agreement with ours.

5. Conclusion and Recommendations

We think that the logistic regression equations and cut-off values of hand sizes obtained from our study for gender estimation will be useful for law enforcement officers, forensic medicine physicians, anthropologists, and macroscopic anatomists in cases where fingerprints and DNA cannot be reached.

6. Contribution to the Field

This study enabled the obtaining of logistic regression equations for gender estimation and determination of cut-off values.

Limitation of this study

The number of people who wanted to participate in the study voluntarily was less than expected due to Covid-19.

The Ethical Aspect of Research

The approval of the ethics committee of the study was given by the "Non-Invasive Clinical Research Ethics Committee of İzmir Katip Çelebi University Faculty of Medicine" with the decision numbered 24.02.2022-0045. Informed consent was obtained from the participants for the study.

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