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An attempt to gender determine with phalanx length and the ratio of phalanxes to whole phalanx length in direct hand radiography

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Abstract
The determination of gender using skeletal fragments or human remains is quite important. It was demonstrated that length of hand bones is generically dimorphic in several nations. The present study aimed to determine gender using phalanx length and the ratio of phalanxes to whole finger length with direct hand radiographic images. The present study was conducted using direct hand X-ray images of 60 individuals (30 Female and 30 Male), who applied to Karabük University Karabük Training and Research Hospital, without hand pathologies and orthopedic surgery history. The phalanx length was measured by combining the basis and the midpoints of the caput ends of the measured phalanx. Finger length was measured by measuring the straight line (along the phalanx media axis) between the phalanx proximalis basis and phalanx distalis caput midpoints. Measurements demonstrated that the mean phalanx proximalis, media and distalis length were higher in males, and were 4.17 cm, 2.62 cm, 2.03 cm, respectively. In females, the same were measured as 3.82 cm, 2.40 cm, and 1.79 cm, respectively. The ratio of phalanx proximalis length of first finger to the first finger length, phalanx proximalis length of fourth finger to the fourth finger length and phalanx proximalis length of fifth finger to the fifth finger length were significantly higher in females when compared to males. Discriminant analysis revealed that the phalanx length measurements could discriminate gender in 83.30% of the cases. The phalanx length to finger length ratio could estimate 70.00% of male individuals and 83.30% of female individuals. Phalanxes are suitable bones for accurate determination of gender. Radiography could be used in conducting reliable hand bone measurements to determine gender. A population-specific database could be developed by increasing the number of images used in the present study..

Keywords: Phalanx, X-Ray, gender determine, discriminant analysis

Introduction

Gender prediction is used to help identify individual residues in forensic anthropology. Furthermore, prediction techniques tend to be unique and applicable only in a particular population [1]. Since the degree of generic dimorphism and the age at which it occurs among males and females vary between communities, gender prediction standards should be population-specific [2,3]. Biological gender is an essential component of osteo-biography and is usually analyzed as the first parameter. Subsequent predictions, such as age and height are mainly gender-specific [4].

Long and short bones could be used in the determination of gender. Long bone shafts often remain intact; however, their epiphyses tend to get damaged due to the fragile spongy bone on top [5,6]. Anatomically, short bones have certain advantages in forensic sciences such as conservation of bone integrity when compared to other bones [7].

Recent research on gender prediction standards focused on the analysis of bones other than pelvis and skull [2]. Various bones were examined for gender prediction such as femur [8, 9], patella [10], mandible [11,12], calcaneus [13], occipital condyle [14], sternum [15] and hand bones [7,16]. In hand, especially in metacarpal bones, different results were obtained in terms of accuracy. It was demonstrated that metacarpal skeletal remains were suitable for gender determination [16- 18]. The literature review conducted by the authors revealed that only a few studies that predicted gender with phalanxes [16].

The present study aimed to determine gender with discriminant analysis method using phalanx length and phalanx to whole

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finger length ratio on direct hand radiography images.

Material and Methods

Image Population

The present study was conducted on direct hand X-ray images of 60 individuals (30 females, 30 males), who previously applied to Karabük University Training and Research Hospital with various health problems but had no hand pathologies or orthopedic surgery history.

This research was approved by Karabük University Non-Interventional Ethics Committee by the decision dated 28.02.2018 (no: 3/15).

Image Analysis Method

The radiological images used in the study were randomly selected from Karabük University, Karabuk Training and Research Hospital Radiology Clinic PACS (Picture Archiving and Communication System) system. All x-ray images were taken with a digital single-tube x-ray machine (Jumong, SG Healthcare, Korea). The hand x-ray images in the PACS archive system were recorded in DICOM format and transferred to a personal workstation (Horos Project, Version 3.0, United States). The length measurement tool available in the software was used for measurements.

Phalanx length measurements were conducted by combining the midpoints of the base and caput regions of the phalanx (Figure 1).

Figure 1. The distance between the proximal and distal ends of the phalanx

Finger length was measured using the straight line (along the phalanx media axis) between the (PP) basis and (DP) midpoints (Figure 2).

Figure 2. Finger length measurement

Statistical Analysis

Data analysis was conducted using SPSS 21 software. Shapiro-Wilk test was applied to determine whether the data exhibited a normal distribution. Independent samples t-test was used to compare paired categorical variables and continuous variables. Furthermore, discriminant analysis was conducted to determine the combined impact of the variables on gender determination ($\alpha=0.05$).

Results

The mean participant age was 29, including females and males. The comparison of the participants based on phalanx length is presented in Table 1. Length measurement values are given as mean±SD. Test findings demonstrated that mean male phalanx length was longer when compared to that of the females ($p<0.05$).

The PP distance of the first finger was measured as 3.41±0.30 cm and 3.11±0.23 cm and DP distance of the first finger was measured as 2.53±0.23 cm and 2.25±0.20 cm, respectively in males and females.

The PP distance of the second finger was measured as 4.39±0.30 cm, DP distance of the second finger was measured as 1.84±0.16 cm and 1.62±0.15 cm and media phalanx (MP) distance of the second finger was measured as 2.49±0.30 cm and 2.31±0.22 cm, respectively in males and females.

The PP distance of the third finger was measured as 4.87±0.34 cm and 4.49±0.24 cm, DP distance of the third finger was measured as 1.95±0.19 cm and 1.73±0.16 cm, and MP distance of the second finger was measured as 3.02±0.27 cm and 2.79±0.21 cm respectively in males and females.

The PP distance of the fourth finger was measured as 4.55±0.32 cm and 4.19±0.24 cm, MP distance of the fourth finger was measured as 2.89±0.23 cm and 2.64±0.22 cm, and DP distance of the fourth finger was measured as 2.02±0.18 cm and 1.78±0.17 cm, respectively in males and females.

The PP distance of the fifth finger was measured as 3.63±0.28 cm and 3.28±0.20 cm, MP distance of the fifth finger was measured as 2.09±0.24 cm and 1.85±0.18 cm, and DP distance of the fifth finger was measured as 1.80±0.16 cm and 1.59±0.14 cm, respectively in males and females.

Table 1. Comparison of phalanx length based on gender. Dg: Finger, PP: Proximal Phalanx, MP: Media Phalanx, DP: Distal Phalanx, SD: Standard Deviation

Phalanx	Mean ± SD		t*	p
	Male (n:30)	Female (n:30)		
Dg1-PP	3.41 ± 0.30	3.11 ± 0.23	4.34	**0.00**
Dg1-DP	2.53 ± 0.19	2.25 ± 0.20	5.45	**0.00**
Dg2-PP	4.39 ± 0.30	4.03 ± 0.22	5.19	**0.00**
Dg2-MP	2.49 ± 0.20	2.31 ± 0.19	3.51	**0.00**
Dg2-DP	1.84 ± 0.16	1.62 ± 0.15	5.39	**0.00**
Dg3-PP	4.87 ± 0.34	4.49 ± 0.24	5.09	**0.00**
Dg3-MP	3.02 ± 0.27	2.79 ± 0.21	3.59	**0.00**
Dg3-DP	1.95 ± 0.19	1.73 ± 0.16	4.84	**0.00**
Dg4-PP	4.55 ± 0.32	4.19 ± 0.24	4.95	**0.00**
Dg4-MP	2.89 ± 0.23	2.64 ± 0.22	4.20	**0.00**
Dg4-DP	2.02 ± 0.18	1.78 ± 0.17	5.54	**0.00**
Dg5-PP	3.63 ± 0.28	3.28 ± 0.20	5.49	**0.00**
Dg5-MP	2.09 ± 0.24	1.85 ± 0.18	4.27	**0.00**
Dg5-DP	1.80 ± 0.16	1.59 ± 0.14	5.49	**0.00**

p<0.05 was considered significant, *t: t-test calculation

The comparison of the ratio of phalanx to the related finger length of the participants is presented in Table 2. Among male and female individuals, it was determined that the ratio of the PP length of the first finger to the length of the first finger (PP/Dg1), the ratio of the PP length of the fourth finger to the length of the fourth finger (PP/Dg4) and the ratio of the PP length of the fifth finger to the length of the fifth finger (PP/Dg1) were significant. It was determined that PP/Dg1, PP/Dg4, and PP/Dg5 ratios were higher in females when compared to males. P values were as follows: PP/Dg1p=0.01, PP/Dg4p=0.01, and $^{PP/Dg5}$p=0.05.

Table 2. The ratio of phalanx length to the related finger length based on gender. Dg: Finger, PP: Proximal Phalanx, MP: Medial Phalanx, DP: Distal Phalanx, SD: Standard Deviation

Phalanx / Digit	Mean ± SD		t**	p
	Male (n:30)	Female (n:30)		
PP/Dg1	0.58 ± 0.03	0.60 ± 0.03	-2.88	**0.01***
DP/Dg1	0.43 ± 0.03	0.43 ± 0.03	-0.63	0.54
PP/Dg2	0.50 ± 0.02	0.50 ± 0.02	-1.44	0.16
MP/Dg2	0.28 ± 0.01	0.29 ± 0.02	-1.84	0.07
DP/Dg2	0.21 ± 0.01	0.20 ± 0.02	1.44	0.16
PP/Dg3	0.49 ± 0.02	0.50 ± 0.01	-1.96	0.06
MP/Dg3	0.30 ± 0.01	0.31 ± 0.02	-1.89	0.07
DP/Dg3	0.20 ± 0.01	0.19 ± 0.02	1.13	0.26
PP/Dg4	0.48 ± 0.01	0.49 ± 0.02	-2.91	**0.01***
MP/Dg4	0.30 ± 0.01	0.31 ± 0.02	-1.70	0.10
DP/Dg4	0.21 ± 0.01	0.21 ± 0.02	1.14	0.26
PP/Dg5	0.48 ± 0.02	0.49 ± 0.02	-2.05	**0.05***
MP/Dg5	0.27 ± 0.01	0.28 ± 0.02	-0.17	0.87
DP/Dg5	0.24 ± 0.01	0.24 ± 0.02	0.18	0.86

p<0.05 was considered significant, *t: t-test calculation

Table 3. Comparison of phalanx and finger length based on gender (nmale=30, nfemale=30). PP: Proximal Phalanx, MP: Medial Phalanx, DP: Distal Phalanx, SD: Standard Deviation

	Gender	Mean ± SD	t	p
PP	M	4.17 ± 0.30	5.24	**0.00**
	F	3.82 ± 0.21		
MP	M	2.62 ± 0.23	4.08	**0.00**
	F	2.40 ± 0.19		
DP	M	2.03 ± 0.16	5.80	**0.00**
	F	1.79 ± 0.15		
Dg1	M	5.90 ± 0.40	5.50	**0.00**
	F	5.20 ± 0.34		
		5.55 ± 0.51		
Dg2	M	8.83 ± 0.61	5.37	**0.00**
	F	8.00 ± 0.43		
	General	8.42 ± 0.66		
Dg3	M	9.96 ± 0.70	5.13	**0.00**
	F	9.04 ± 0.48		
		9.50 ± 0.76		
Dg4	M	9.60 ± 0.66	5.26	**0.00**
	F	8.62 ± 0.53		
	General	9.11 ± 0.78		
Dg5	M	7.61 ± 0.63	5.69	**0.00**
	F	6.75 ± 0.43		
	General	7.18 ± 0.69		

p<0.05 was considered significant, *t: t-test calculation

Review of the findings of the discriminant analysis conducted on phalanx length values demonstrated that the gender Wilks' Lambda was 0.518, discrimination coefficient was 83.30%, and the eigenvalue was 0.929 (Table 4). Furthermore, it was determined that the discrimination power was 83.30% for male individuals and 83.30% for female individuals.

Table 4. The findings of the discriminant analysis conducted o phalanx length based on gender. Dg: Finger, PP: Proximal Phalanx, MP: Medial Phalanx, DP: Distal Phalanx.

Phalanx	Canonical Discriminant Number	p
Dg1-PP	-0.063	0.00
Dg1-DP	0.182	0.00
Dg2-PP	0.019	0.00
Dg2-MP	0.295	0.00
Dg2-DP	0.039	0.00
Dg3-PP	0.664	0.00
Dg3-MP	-1.644	0.00
Dg3-DP	0.288	0.00
Dg4-PP	-0.989	0.00
Dg4-MP	0.395	0.00
Dg4-DP	0.517	0.00
Dg5-PP	0.969	0.00
Dg5-MP	0.430	0.00
Dg5-DP	-0.060	0.00

p<0.05 was considered significant

Review of the findings of the discriminant analysis conducted on the ratio of the phalanx length to finger length demonstrated that the gender Wilks' Lambda was 0.535, discrimination coefficient was 76.70%, and the eigenvalue was 0.87 (Table 5). Furthermore, it was determined that the discrimination power was 70.00% for male individuals and 83.30% for female individuals.

Table 4. The findings of the discriminant analysis conducted o phalanx length based on gender. Dg: Finger, PP: Proximal Phalanx, MP: Medial Phalanx, DP: Distal Phalanx.

Phalanx	Canonical Discriminant Number	p
PP/Dg1	0.302	0.01*
DP/Dg1	0.568	0.53
PP/Dg2	-0.982	0.16
MP/Dg2	-0.493	0.07
DP/Dg2	-1.442	0.16
PP/Dg3	0.231	0.06
MP/Dg3	1.359	0.06
DP/Dg3	0.522	0.26
PP/Dg4	1.320	**0.01***
MP/Dg4	0.045	0.09
DP/Dg4	-0.132	0.26
PP/Dg5	-0.088	**0.05***
MP/Dg5	-0.948	0.87
DP/Dg5	0.149	0.86

p<0.05 was considered significant

Discussion

Forensic anthropologists are focused on improving skeletal recognition by continuously experimenting with new methods for gender determination or by developing known methods. Gender analysis is one of the first steps both in medical and civil cases and also in bio-archaeological human identification [16]. Determination of gender using unidentified skeletal remains is still being investigated. However, various studies demonstrated that discriminant function equations were population-specific due to differences in size and generic dimorphism [19].

In the present study, it was found that male phalanx length and all finger sizes were longer when compared to females. It was determined that PP/Dg1, PP/Dg4, and PP/Dg5 ratios were higher in females when compared to males. Furthermore, the results obtained with the discriminant analysis of phalanx length of both male and female individuals demonstrated that phalanx length discriminated both male and female individuals by 83.30%, while the ratio of phalanx length to finger length discriminated the male individuals by 70.00% and the female individuals by 83.30%.

The recovery percentage was calculated for different archaeological skeleton elements, and a relatively strong correlation was found between the integrity of skeletal features and their dimensions. It was reported that phalanx was among the best representative skeletal elements due to their small size [2]. Thus, in the present study, gender prediction standards were developed based on single hand bone. Since these models do not require a full hand skeleton, they could be applied to digital X-Ray images to determine limbs where the hand bones were crushed or broken or severed in a catastrophe.

Previous studies were conducted on determination of gender-based on hand and the accuracy of gender determination was investigated via measurement of the length of the hand [5, 20] and hand bones [17,21]. Sulzmann et al. [22] conducted their study with right-hand carpal bone measurements, suggesting that this would support gender dimorphism studies due to the differences in functional overload in dominant hand. Gradually the designed the discriminant function analysis separately for the left and right hands and determined that the accuracy varied between 71.7% and 88.6%. In the present study, the dominant hand was not considered in anthropometric measurements. Like our study, there are studies in the literature that did not take a right and left dominance into consideration. These studies reported that there was no significant difference between right and left hand [23-25].

In the present study, age, height, and race of the participants were not determined, only phalanx length and the ratio of these measurements to the corresponding finger length were analyzed in gender determination. Phalanx and finger length were longer in males when compared to females. Similarly, literature review demonstrated that in a study conducted by DeSilva et al. [2], the metacarpal length was measured, and it was determined that this figure was higher in males when compared to the females.

Du Jardin et al. [9], based on the theoretically 50% possibility of accurate bone classification, reported that a gender determination technique could be considered acceptable if at least 80% of individuals are correctly classified with the method. In the present study, the technique based on phalanx length could discriminate 83.30% of both male and female individuals.

In general, given the accuracy of gender determination with the skeleton, the pelvis is highly dimorphic since it has a specific morphology related to biological functions (such as giving birth in females) [26]. It was reported that gender classification accuracy rates with pelvis ranged between 90% and 95% [27-29]. Furthermore, a high classification accuracy between 75% and 90% was also reported for the skull [30,31]. A high gender classification accuracy was reported with long bones: 83% to 96% for humerus [32,33]; 85% to 94% for radius [32]; 76% to 97% for the femur [32,34,35] and 91% for the tibia [35]. In the present study, the presented classification accuracy range was compared with previously reported ranges for other skeletal elements, confirming that phalanx was generically dimorphic and could be used to predict gender accurately.

In a study conducted by Kanchan et al. [36], the ratio of the index finger to ring finger in both right and left hands were investigated, and it was found that the rate was higher among women. Similarly, in the present study, it was determined that the ratio of index finger to the ring finger was higher in females when compared to males; however, the difference was not statistically significant.

Conclusions

In the forensic anthropological analysis of skeletal remains, accurate gender prediction based on population-specific standards is a valuable tool in narrowing the potential match pool. The population-specific database could be developed by extending the number of images used in the present study. We believe that the current research will be a part of ongoing gender prediction research projects in the literature.

Conflict of interest
The authors declare that there are no conflicts of interest.

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Ethical approval
This research was approved by Karabük University Non-Interventional Ethics Committee by the decision dated 28.02.2018 (no: 3/15).

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References

1. Darmawan MF, Yusuf SM, Kadir MR, et al. Comparison on three classification techniques for sex estimation from the bone length of Asian children below 19 years old: an analysis using different group of ages. Forensic Sci Int. 2015;247:130.e1-11.
2. DeSilva R, Flavel A, Franklin D. Estimation of sex from the metric assessment of digital hand radiographs in a Western Australian population. Forensic Sci Int. 2014;244:314.e1-7.
3. Franklin D, Flavel A, Kuliukas A, et al. Estimation of sex from sternal measurements in a Western Australian population. Forensic Sci Int. 2012;217:230.e1-5.
4. Franklin D. Forensic age estimation in human skeletal remains: current concepts and future directions. Leg Med (Tokyo). 2010;12:1-7
5. Krishan K, Kanchan T, Sharma A. Sex determination from hand and foot dimensions in a North Indian population. J Forensic Sci. 201;56:453-9.
6. Case DT, Ross AH. Sex determination from hand and foot bone lengths. J Forensic Sci. 2007;52:264-70.
7. El Morsi DA, Al Hawary AA. Sex determination by the length of metacarpals and phalanges: X-ray study on Egyptian population. J Forensic Leg Med. 2013;20:6-13.
8. Kim DI, Kwak DS, Han SH. Sex determination using discriminant analysis of the medial and lateral condyles of the femur in Koreans. Forensic Sci Int. 2013;233:121-5.
9. du Jardin P, Ponsaillé J, Alunni-Perret V, et al. A comparison between neural network and other metric methods to determine sex from the upper femur in a modern French population. Forensic Sci Int. 2009;192:127.e1
10. Mahfouz M, Badawi A, Merkl B, et al. Patella sex determination by 3D statistical shape models and nonlinear classifiers. Forensic Sci Int. 2007;173:161-70.
11. Akhlaghi M, Khalighi Z, Vasigh S, et al. Sex determination using mandibular anthropometric parameters in subadult Iranian samples. J Forensic Leg Med. 2014;22:150-3.
12. Lin C, Jiao B, Liu S, et al. Sex determination from the mandibular ramus flexure of Koreans by discrimination function analysis using three-dimensional mandible models. Forensic Sci Int. 2014;236:191.e1-6.
13. Kim DI, Kim YS, Lee UY, et al. Sex determination from calcaneus in Korean using discriminant analysis. Forensic Sci Int. 2013;228:177.e1-7.
14. Gapert R, Black S, Last J. Sex determination from the occipital condyle: discriminant function analysis in an eighteenth and nineteenth century British sample. Am J Phys Anthropol. 2009;138:384-94.
15. Oner Z, Turan MK, Oner S, et al. Sex estimation using sternum part lenghtsby means of artificial neural networks. Forensic Sci Int. 2019;301:6-11.
16. Eshak GA, Ahmed HM, Abdel Gawad EA. Gender determination from hand bones length and volume using multidetector computed tomography: a study in Egyptian people. J Forensic Leg Med. 2011;18:246-52.
17. Manolis SK, Eliopoulos C, Koilias CG, et al. Sex determination using metacarpal biometric data from the Athens Collection. Forensic Sci Int. 2009;193:130.e1-6.
18. Ozden H, Balci Y, Demirüstü C, et al. Stature and sex estimate using foot and shoe dimensions. Forensic Sci Int. 2005;147:181-4.
19. Mastrangelo P, De Luca S, Alemán I, et al. Sex assessment from the carpals bones: discriminant function analysis in a 20th century Spanish sample. Forensic Sci Int. 2011;206:216.e1-10.
20. Kanchan T, Pradeep Kumar G. Index and ring finger ratio--a morphologic sex determinant in South-Indian children. Forensic Sci Med Pathol. 2010;6:255-60.
21. Smith SL. Attribution of hand bones to sex and population groups. J Forensic Sci. 1996;41:469-77.
22. Sulzmann CE, Buckberry JL, Pastor RF. The utility of carpals for sex assessment: a preliminary study. Am J Phys Anthropol. 2008;135:252-62.
23. Tang J, Chen R, Lai X. Stature estimation from hand dimensions in a Han population of Southern China. J Forensic Sci. 2012;57:1541-4.
24. Jee SC, Yun MH. Estimation of stature from diversified hand anthropometric dimensions from Korean population. J Forensic Leg Med. 2015 Oct;35:9-14. doi: 10.1016/j.jflm.2015.06.014. Epub 2015 Jun 26. PubMed PMID: 26344451.
25. Uhrová P, Beňuš R, Masnicová S, et al. Estimation of stature using hand and foot dimensions in Slovak adults. Leg Med (Tokyo). 2015;17:92-7.

26. Franklin D, Cardini A, Flavel A, et al. Morphometric analysis of pelvic sexual dimorphism in a contemporary Western Australian population. Int J Legal Med. 2014;128:861-72.

27. Phenice TW. A newly developed visual method of sexing the os pubis. Am J Phys Anthropol. 1969;30:297-301.

28. Lovell NC. Test of Phenice's technique for determining sex from the os pubis. Am J Phys Anthropol. 1989;79:117-20.

29. Ubelaker DH, Volk CG. A test of the phenice method for the estimation of sex. J Forensic Sci. 2002;47:19-24.

30. Giles E, Elliot O. Sex determination by discriminant function analysis of crania. Am J Phys Anthropol. 1963;21:53-68.

31. Franklin D, Freedman L, Milne N. Sexual dimorphism and discriminant function sexing in indigenous South African crania. Homo. 2005;55:213-28.

32. Spradley MK, Jantz RL. Sex estimation in forensic anthropology: skull versus postcranial elements. J Forensic Sci. 2011;56:289-96.

33. Robinson MS, Bidmos MA. The skull and humerus in the determination of sex: reliability of discriminant function equations. Forensic Sci Int. 2009;186:86.e1-5.

34. Albanese J, Eklics G, Tuck A. A metric method for sex determination using the proximal femur and fragmentary hipbone. J Forensic Sci. 2008;53:1283-8.

35. Robinson MS, Bidmos MA. An assessment of the accuracy of discriminant function equations for sex determination of the femur and tibia from a South African population. Forensic Sci Int. 2011;206:212.e1-5.

36. Kanchan T, Kumar GP, Menezes RG. Index and ring finger ratio--a new sex determinant in south Indian population. Forensic Sci Int. 200825;181:53.e1-4.