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Research Article

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Gender Determination Using Anthropometric Parameters of Metacarpals and Phalanges on Hand Radiographs

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ABSTRACT

Gender determination in a living human being based on the skeleton system remains a challenge obviously because a human skeletal does not show a consistent or gradual growth rate. The purpose of this study was to assess the accuracy of gender determination from the linear measurments of metacarpals and phalanges using hand radiographs. A retrospective, quantitative study was conducted and computed and digital hand posterior-anterior radiographs were taken using the standardized imaging protocol (total=80, male=40, female=40). The linear measurements of metacarpals and the proximal, middle and distal phalanges were obtained. The results showed that males having significantly larger metacarpals and phalanges than females (p< 0.05). The Standardized Canonical Discriminant Function Coefficients were reported as M4=.659, MP3 = .394, DP3 = .328, M1 = .267, PP3 = .258, DP4 = .176, M3 = .105, PP1 = .103, PP4 = .089, DP2 = .077, M2 = .054, and MP1 = .045. It can be concluded that linear measurements of each metacarpal and the proximal, middle and distal phalanges of the right hand can be used to distinguish the gender of individuals of the Sri Lankan population. Further, linear measurments of the 4th metacarpal from hand PA radiographs can be highly contributed to predicting the gender while MP3 and DP3 follow the significant contribution. Further studies are recommended with a larger sample to confirm the results.

Key words: *Radiographs, Gender, Metacarpals, Phalanges, Linear measurements*

INTRODUCTION

Determining gender, age, and stature of living or dead human beings are currently a mandatory element in many aspects. Mostly in forensic medicine, it has been given much information regarding the determination of gender and age by using several methods and based on many sources [1]. But it is also crucial to make attention to living human beings by stressing many aspects as well. Especially gender and age estimation in a living human being based on the skeleton system remains a challenge obviously because a human being's skeletal does not show a consistent or gradual growth rate. Many studies have been done related to gender and age estimation in selected skeletal human beings by using x-ray images [2].

The skeletal system can be well diagnosed by using x-ray imaging modalities such as conventional radiography, computed radiography (CR), digital radiography (DR), and Computed Tomography. Since plain radiography was involved as the primary imaging diagnostic modality, hand posterior-anterior (PA) x-ray radiographs have been frequently studied projection which leads to diagnosing many diseases such as injuries, rheumatoid arthritis, infections, and tendons ligament damage. Each hand consists of mainly three categories of bones (phalanges, metacarpals, and carpals) that all together give support and flexibility to soft tissue to make movements of the hand. Phalanges are the bones that make up the fingers of the hand and toes of the foot as well. Each hand consists

of 14 phalanges; hence all are 56 phalanges in the human body. Even though each finger builds up with three phalanges, the thumb has only two phalanges That metacarpus is classified as a type of long bone even though they seem small because; each metacarpal bone consists of a distal head, shaft, and proximal base. Proximally each bone articulates with carpal bones while distally, it articulates with proximal relevant phalange [3].

The human hand shows differences in proportion between males and females due to hormonal changes. Several studies have measured the phalanges and the metacarpal's lengths to determine or estimate any differences based on different variables [2, 4-11]. Some studies have concluded that the lengths of phalanges and metacarpals can be used as a tool for gender determination. Alcioglue *et al*. observed that a better gender determination could be found through the use of the length of the phalanges for the Turkish population [7]. In a gender determination study done by Kondo *et al*. in the modern Japanese population, it was found that males had longer 4th fingers but shorter 2nd fingers than females [10].

Both CR and DR show higher image quality and many post-processing techniques, giving better diagnostic power than conventional plain radiography imaging [12]. One of the main advantages of CR and DR imaging modalities over conventional radiography is that both CR and DR x-ray radiographs can be archived by using Digital Image Communication in Medicine (DICOM). It is a standard procedure for communicating and managing medical imaging information and data related to medical images in many healthcare facilities [13]. DICOM was developed by the American college of radiology (ACR) AND the National Electrical Manufacturers Association (NEMA) [13, 14]. DICOM standard is mainly used to produce, store, share, display, send, query, process, retrieve, and print medical images. Picture Archiving and communication system (PACS) is a medical imaging technology that uses DICOM to store and transmit medical images. PACS eliminates problems related to manual storage and file sharing. Many other advantages come with post-processing techniques in CR and DR imaging modalities that can be facilitated to diagnose even subtle changes on radiographs [14].

Many countries have successfully evaluated the length of metacarpals and phalanges variation according to age as well as gender. However there is no evidence of gender determinations using the metacarpals and phalanges of hand based on the Sri Lankan population. Therefore, this study would be the first step in assessing the gender based on the linear measurments of metacarpals and phalanges by using hand radiographs in a cohort of Sri Lankan population.

MATERIALS AND METHODS

This was designed as a retrospective, quantitative study based CR and DR hand PA radiographs which were performed from 1st February 2021 to 1st November 2021.

After receiving ethical clearance from the Faculty of Allied Health Sciences (reference number: AHS/ERC/2021/050) all radiographs were obtained from the Department of Radiology, Teaching Hospital, Peradeniya. Eighty hand radiographs (encompassing 40 women and men) that were obtained by using CR and DR imaging acquisition modalities were included as the study population. All the radiographs were taken using the standardized imaging protocol (Focus Receptor Distance =100cmwith the vertical central X-ray beam perpendicular to the receptor). The radiographs that show little or lack of skeletal trauma and/or abnormalities in the phalanges and metacarpals were encompassed in the study. To ensure normal bone study, history of bone tumors or arthritis, significant fractures, pathological lesions such as congenital and development dysplasia, metabolic bone illnesses, connective tissue diseases, and earlier orthopedic surgery were excluded from the study. Further, radiographs with unidentified age and gender details and repeat examinations were excluded from the study.

Linear measurements of the metacarpals (M), proximal phalanges(PP), middle phalanges(MP), and distal phalanges(DP) of the right hand were obtained using MicroDicom Viewer (Version 3.1.4), from the CR and DR DICOM radiographs under the same light condition. All selected radiographs were classified into two groups according to gender.

All radiographs were displayed 100% and, the edges of bones were confirmed by zooming further. The gender of the patients was identified from the DICOM tags. Then the following measurements were made on all five metacarpals and phalanges separately: the length 1) from the mid-point of the base to the mid-point of the head of the metacarpals; 2) from the mid-point of their bases to the mid-point of their apices of proximal, middle, distal phalanges.

The data were analyzed using SPSS (version 27.0). Before subjecting the data to statistical analyses, descriptive statistics (mean and standard deviation) were calculated and assessed for the normality. The data was not normally

distributed. Therefore, Mann-Whitney Test was applied to compare the length differences between the male and female groups. The confidence level was set at 95% and a p-value less than 0.05 was taken to be substantial. Direct discriminant function analysis was conducted to identify the gender discriminatory capabilities of the linear measurements obtained (**Figure 1**).

Figure 1. Measuring parameters on hand radiographs.
Detailed information is discussed in table 1.

Table 1. Measuring parameters.

M1: 1st Metacarpal	PP1:1st Proximal phalange	MP1:1st Middle phalange	DP1:1st Distal phalange
M2: 2nd Metacarpal	PP2:2nd Proximal phalange	MP2:2nd Middle phalange	DP2:2nd Distal phalange
M3: 3rd Metacarpal	PP3:3rd proximal phalange	MP3:3rd Middle phalange	DP3:3rd Distal phalange
M4: 4th Metacarpal	PP4:4th Proximal phalange	MP4:4th Middle phalange	DP4:4th Distal phalange
M5: 5th Metacarpal	PP5:5th Proximal phalange	MP5:5th Middle phalange	

RESULTS AND DISCUSSION

The descriptive statistics of linear measurements of Ms, PPs, MPs, and DPs for both male and female groups are presented in **Table 2.** The Wilk's Lambda (λ) test of mean difference is displayed in **Table 2**.
The results showed that all the metacarpals (M1 [λ= .606, P=.000], M2 [λ=.564, P=.000], M3[λ=.51, P=.000], M4[λ=.521, P=.000], M5[λ=.874, P=.001]), proximal phalanges (PP1[λ=.734, P=.000], PP2[λ=.866, P=.001], PP3[λ=.705, P=.000], PP4[λ=.699, P=.000], PP5[λ=.882, P=.002]), middle phalanges (MP1[λ=.808, P=.000], MP2[λ=.903, P=.005], MP3[λ=.831, P=.000], MP4[λ.843, P=.000], MP5[λ=.936, P=.024]) and distal phalanges (DP1[λ=.888, P=.002], DP2[λ=.830, P=.000], DP3[λ=.821, P=.000], DP4[λ=.875, P=.001]) were significantly larger ($p < 0.05$) in males than females.

Table 2. Mean linear dimension of phalanges based on gender

Descriptive	Gender (Male:40, Female:40)	Mean(mm)	SD
M1	Male	46.721	2.778
	Female	42.776	2.129
M2	Male	69.591	4.216
	Female	63.481	2.636

M3	Male	66.495	3.925
	Female	60.037	2.738
M4	Male	58.32	3.458
	Female	47.046	1.980
M5	Male	52.033	7.428
	Female	47.046	5.805
PP1	Male	30.313	2.263
	Female	28.087	1.3763
PP2	Male	39.770	5.3437
	Female	36.644	1.9402
PP3	Male	43.904	2.7134
	Female	40.993	1.7354
PP4	Male	40.995	2.3991
	Female	37.870	2.4249
PP5	Male	32.323	3.3049
	Female	30.087	2.872
MP1	Male	22.687	2.3783
	Female	20.533	2.0948
MP2	Male	22.311	1.8526
	Female	21.119	1.8202
MP3	Male	26.879	1.7898
	Female	25.342	1.6622
MP4	Male	25.638	1.8243
	Female	24.182	1.5867
MP5	Male	17.854	1.6600
	Female	17.106	1.2069
DP1	Male	16.336	1.448
	Female	15.331	1.4138
DP2	Male	17.447	1.2989
	Female	16.272	1.3318
DP3	Male	17.792	1.3758
	Female	16.604	1.1913
DP4	Male	15.917	1.3566
	Female	14.865	1.4558

Wilk's Lambda tests in this studyassess the ability of the variables (M, PP, MP, and DP) included in the model to make substantial estimates about thegender. The Canonical Correlation reflects the relationship between Discriminant Function and gender and in this study it is 0.763 **(Table 4)**. As demomstrated in **Table 4**, in the test of function, the value of the significance test associated with the Canonical Correlation is $p < 0.05$. Therefore in this study, the Discriminant Function plays a significant role in terms of accounting for differences between gender groups.

Table 3. Wilk's Lambda test of mean differences

	Wilks' Lambda	**F**	**Sig.**
M1	.606	50.808	.000
M2	.564	60.375	.000

M3	.517	72.842	.000
M4	.521	71.626	.000
M5	.874	11.194	.001
PP1	.734	28.277	.000
PP2	.866	12.092	.001
PP3	.705	32.663	.000
PP4	.699	33.590	.000
PP5	.882	10.434	.002
MP1	.808	18.485	.000
MP2	.903	8.425	.005
MP3	.831	15.821	.000
MP4	.843	14.515	.000
MP5	.936	5.310	.024
DP1	.888	9.874	.002
DP2	.830	15.957	.000
DP3	.821	17.001	.000
DP4	.875	11.179	.001

Table 5 presents Standardized Canonical Discriminant Function Coefficients. These coefficients reflect the relative contributions of the variables (linear measurments of M, PP, MP, and DP) to the Discriminant Function. All variables that reported Standardized Canonical Discriminant Function Coefficients greater than the value of 0.3 are considered to contribute substantially to the Discriminant Function. As demonstrated in **Table 5**, the lengths of M4=.659, MP3 = .394 and DP3 = .328 contribute substantially to the Discriminant Function. Further, it can be observed that the length of M4 contributes to group separation more than other variables in this study, as it reported a higher Standardized Canonical Discriminant Function Coefficient of 0.659. MP5 demonstrated the least contribution to group separation giving a Standardized Canonical Discriminant Function Coefficient of 0.042.

Table 4. Summary of Canonical Correlation Discriminant Function

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.390[a]	100.0	100.0	.763
Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.418	59.670	19	.000

Table 5. Standardized Canonical Discriminant Function Coefficients

	Function
	1
M1	.267
M2	.054
M3	.105
M4	.659
M5	-.179
PP1	.103
PP2	-.050
PP3	.258
PP4	.089

PP5	-.052
MP1	.045
MP2	-.275
MP3	.394
MP4	-.587
MP5	-.042
DP1	-.279
DP2	.077
DP3	.328
DP4	.176

Since the determination of gender assists in concluding the identity of an individual, it has remained an essential fact. Anthropometric measurements of the hand are beneficial factors in gender identification as shown in this research.

In this study the second metacarpal (index finger) bones of the right hand showed a higher mean value in both genders. Further, males have substantially longer metacarpals and distal, middle and proximal phalanges than females. These results are similar with the study done by Kondo *et al*. on a Japanese population [10] DP4). A study done on "Nigerian population" found that all the metacarpals and three proximal phalanges of the right hand provided dimensional differences in sex, which is slightly different from what was observed in this study [2]. The study done on on Egyptian population discovered that the measurements of the metacarpals and phalanges can be used in gender determination [1]. From these results, it is clear that the ability to discriminate between sexes based on hand measurements varied between populations and it is population specific. According to the present study linear measurements of the 4th metacarpal from hand PA radiographs can be highly contributed to predicting the gender while MP4, MP3 and DP3, follow the considerable contribution for Sri Lankan population.

CONCLUSION

This study showed that males have greater metacarpals and phalanges lengths than females. Further, it also indicates that the linear measurements for each metacarpal and proximal, middle and distal phalanges of the right hand can be used for discriminating the gender of the individuals. The linear measurments of the 4th metacarpal from hand PA radiographs can be highly contributed to predicting the gender while MP3 and DP3 follow the significant contribution. To beast of our knowledge, this is the first study determining gender by linear measurments of metacarpals and phalanges on hand radiographs in Sri Lankan population. Further studies are recommended with a larger sample to confirm the results.

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