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Research Paper: Sex Determination Based on Radiographic Examination of Metatarsal Bones in Iranian Population

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ABSTRACT

Background: In forensic medicine, sex can be determined by studying human skeletal remains. This study aimed to evaluate the reliability of metatarsal bones in sex determination in Iranian population.

Methods: A total of 184 healthy individuals (103 males and 81 females) were enrolled in the study. The sample was divided into three age groups: 20-34, 35-49, and ≥50 years. The length, width, length to width ratio (L/W), and length by width (L×W) product of sample's right foot metatarsal bones were measured using their radiographic images.

Results: The differences of length, width, L/W ratio, and L×W between two sexes were significant in all age groups (P<0.001). First metatarsal L×W had sensitivity and specificity of 85.4% and 88.8%, respectively, but the mean total L×W value of metatarsal bones had sensitivity and specificity of 94.2% and 78%, respectively.

Conclusion: The first and the mean L×W values of all metatarsal bones had the highest accuracy for discriminating sexes (86.9% and 85.2%). The first metatarsal width and mean width of all metatarsal bones had an accuracy of 82.6% and 84.2%, respectively. In forensic medicine, these indexes can be used for sex-differentiation.

1. Introduction

Anthropometry is used extensively in sex determination [1]. Accurate determination of gender assists in reaching more precise conclusions about demographic structure in archaeological samples and enhances the probability of body identification in forensic cases [2]. Sex determination is more reliable when a complete skeleton is available; however, this is not usually the case. For example, skull, pelvis,

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and long bones are frequently lost or shattered in mass disasters such as terrorist attacks, mass murders, high power explosions, bomb blasts, air plane crashes, and other high impact transportation mishaps, where the body is so dismembered that conceals the identity of the victim [3-8]. However, other parts of skeleton like feet can be found in these situations. In this regard, the accuracy of sex determination depends on the degree of sexual dimorphism exhibited by the skeleton [2].

Feet bones are frequently used for such studies because of their availability in both forensic and archaeological contexts, small surface area, less exposure to taphonomic elements, and being protected by shoes [5, 6, 9]. The smaller bones of feet, like metatarsal bones, often remain intact due to their resistance to postmortem changes, also their small and stout nature makes them appropriate for such studies [2, 6]. Moreover, their radiographic images can be easily taken. As a result, metatarsal bones could be very helpful to identify the sex. Numerous studies have focused on the forensic significance of different aspects of human foot (anthropometric measurements, bones, impressions and radiographs) [1, 2, 4, 5, 9, 10]. However, few studies have been carried out to evaluate the value of metatarsal bones in sex determination. Since there are many ethnical and regional variations in foot anatomy, specific data about every population are necessary.

In this study, we aimed to determine sex on the basis of osteometric data obtained from radiographs of the metatarsal bones taken from Iranian population. Also we aimed to evaluate the effect of age and height on sex determination. To our knowledge, no study has been conducted so far on Iranian population in this field.

2. Materials and Methods

A total of 184 people (103 males and 81 females) aged between 20 and 80 years [mean(SD)=37.8(15)], referred to the hospital with any trauma (car accident, falls, …), were enrolled in the study after obtaining their informed consent forms. Anteroposterior radiograph images of the right foot were taken from all participants. Exclusion criterion was the presence of any fracture or pathologic finding in the feet.

The study sample was divided into three age groups: 20-34, 35-49, and ≥50 years. The radiographic images were obtained using the standard radiographic technique and a film-focus distance of 100 cm, and then were digitally saved. Next, the metatarsal measurements were carried out through using digital forms. The length of each metatarsal bone was measured from the highest point to the lowest point (maximum metatarsal length). The mid-shaft diameter (width) was measured from the middle of each metatarsal bone (using 50% of biomechanical length) [11]. Ratio of Length to Width (L/W) and Length by Width (L×W) were calculated using the data obtained from foot radiographs (Figure 1).

The obtained data were analyzed using SPSS 16 for Windows (SPSS Inc., Chicago, Illinois). Numeric variables were presented as mean and standard deviation. Independent t test was used to compare the mean of variables between two groups. The Pearson correlation coefficient was used for evaluating the correlation between the two quantitative variables. Diagnostic value of parameters was evaluated using the area under Receiver Operating Characteristics (ROC) curve, and subsequently the Area Under Curve (AUC). Sensitivity, specificity, and accuracy were estimated based on the best cut point. Best cut point was determined using Youden's index. Logistic regression was used to design models to predict sex. P-value less than 0.05 was considered statistically significant.

3. Results

A total of 103(56%) males and 81(44%) females were studied. More than half of our participants (102 persons) were younger than 35 years.

Metatarsal length

The longest metatarsal bones belonged to the youngest age group. Table 1 compares metatarsal lengths. The difference in lengths between two sexes was significant in all age groups (P<0.001). The highest level of accuracy in sex determination on the basis of metatarsal length belonged to the mean total metatarsal length (81%). Accuracy of first metatarsal length was 80.5%. The best cut point was calculated as 7.082 cm. Sensitivity and specificity were 72.8% and 91.4%, respectively. Figure 2 depicts the ROC curve.

Metatarsal width

Table 1 compares metatarsal widths in male and female age groups. The differences in metatarsal widths between the age groups was significant only for the first metatarsal bone. The difference in metatarsal width between two sexes was significant in most age groups (P<0.001). The mean total metatarsal width had the highest reliability for sex differentiation (84.2%). Sensitivity and specificity were calculated as 81.6% and 88.8%, respectively. Accuracy of the first metatarsal width in sex differentiation was 82.6%.

Metatarsal Length/Width

There was no statistically significant difference in metatarsal L/W ratio between different age groups but the difference between males and females among some age groups were significant. Metatarsal L/W ratio had no significant accuracy for differentiating sexes (Table 1). AUC was close to 0.5 indicating inefficiency of metatarsal L/W index to discriminate sex (Figure 2).

Metatarsal Length×Width

Metatarsal L×W was different among all age groups (Table 1). Also, two sexes were different in terms of the metatarsal L×W in all age groups (P<0.001). The highest accuracy for determining sex was observed in the first metatarsal L×W and then in the mean of total metatarsal L×W value (86.9% and 85.2%). The best cut point was 6.301 cm; the sensitivity and specificity of this cut point were 94.2% and 78%, respectively. Figure 2 shows the related ROC curve.

4. Discussion

The equations, cut off points, and the specific values obtained from measurements are population-specific and cannot be generalized to other populations. This limitation highlights using local biometric parameters instead of the ones presented in other populations for sex differentiation. Some studies have been conducted to evaluate the relation between sex and bone index. Some have assessed foot length [1, 4, 5, 10, 12-14] and others have studied the metatarsal bone measurements [2, 9, 15-18] or other modalities such as radiographs [6]. Because metatarsals bones were longer in men than women [2, 6, 15], they can be used for sex determination.

According to our study, mean length, width, and L×W indexes in men were larger than those in women. The best metatarsal index to differentiate males from females were the first metatarsal L×W value and then mean of total metatarsal L×W. In contrast, the accuracy of L/W ratio was low. The best accuracy was observed in the first metatarsal L×W (86.9%) and then in the mean total metatarsal L×W values (85.2%). Sensitivity and specificity varied depending on the metatarsal bones.

Figure 1. Length to Width (L/W) and Length by Width (L×W)

Table 1. Metatarsal L/W ratio had no significant accuracy for differentiating sexes

Metatarsal L/W Ratio	AUC	SE	P*	95% Confidence Interval	
				Lower Bound	Upper Bound
First	0.664	0.040	0.001	0.586	0.741
Second	0.581	0.043	0.061	0.497	0.664
Third	0.633	0.041	0.002	0.552	0.714
Fourth	0.625	0.042	0.004	0.543	0.707
Fifth	0.530	0.043	0.481	0.446	0.615

* P<0.05 have statistically significant

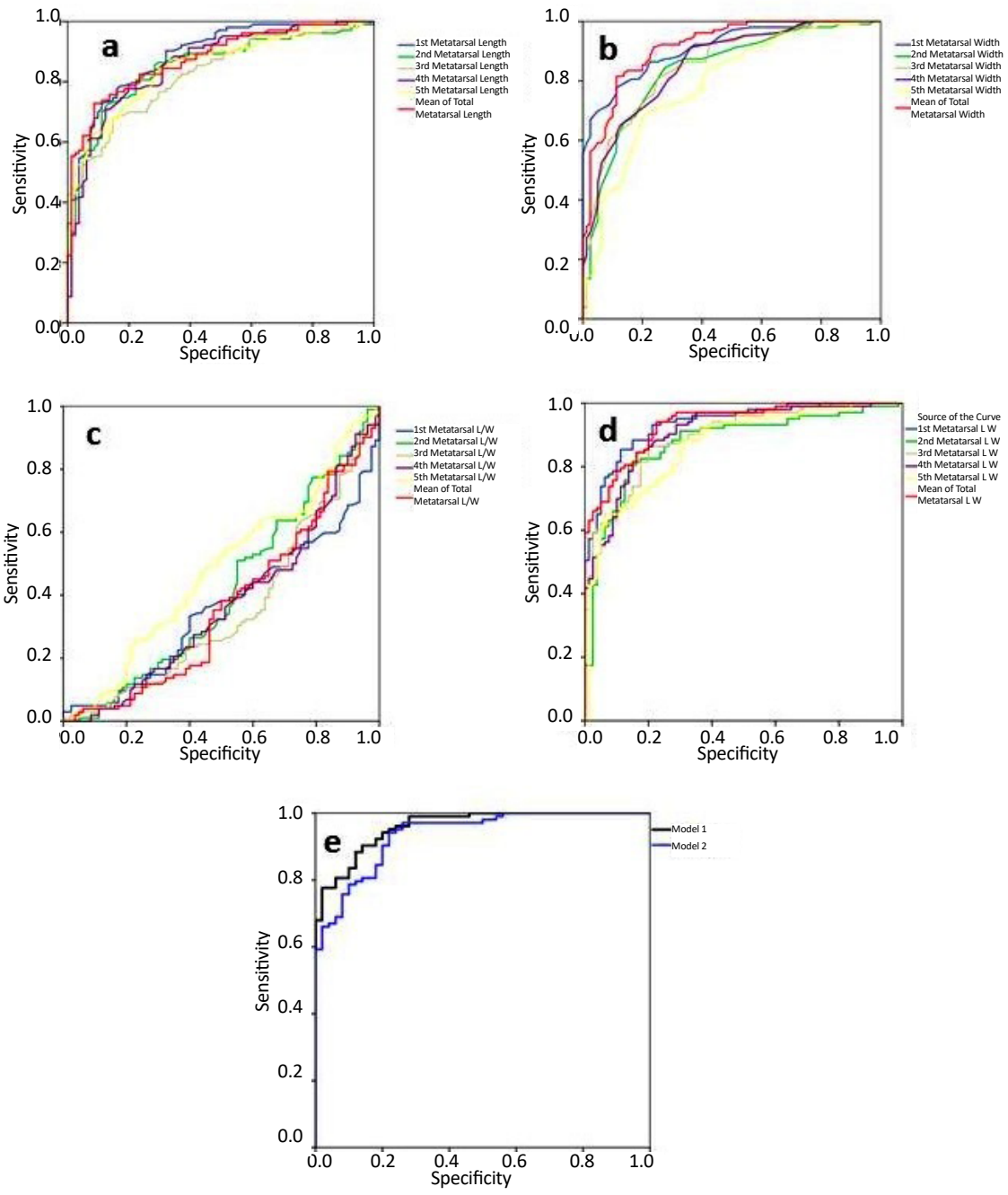

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Figure 2. Inefficiency of metatarsal L/W index to discriminate sex

In Robling et al., study [2], the accuracy of estimating sex using metatarsal parameters was 92%-96%, however, the accuracy reached 100% by using all measurements of the first metatarsal bone. Wilbur [19] reported that in some studies the diagnostic accuracy for determining sex using second metatarsal length was 63.6% to 88% which had the highest level of accuracy. In Troy Case et al. study [20], the length of all metatarsal bones had an accuracy of 74% for discriminating sexes. In Abdel Moneim et al. study [6], the accuracy of correct estimation of sex was 85.5% for the first metatarsal and 100% for the second and third metatarsal midshaft diameters. Moreover, in their study the accuracy of correct estimation of sex was 96.4% for the fourth metatarsal and 100% for the first, third, and fifth metatarsal length. However, the accuracy of this index was about 5% lower in prac-

tice. In another study, the accuracy was 85.2% to 89.3% for right metatarsal length [21]. In our study the order of metatarsal length accuracy in determining sex ranged from the highest, i.e. mean total metatarsal length to the first metatarsal bone and then the second, fourth, fifth, and finally the lowest one i.e. the third metatarsal bone.

In Mountrakis et al. study, the following metatarsal bone indices of both feet were measured in Athens collection: maximum length, dorsoplantar and mediolateral width of the head, midshaft and base of each metatarsal bone. They found that the accuracy of study for sex determination was about 81%-90%. They indicated that the width of metatarsal bone was more reliable than the length in determining the gender [9]. This finding was similar to our result.

The differences between the results of our study and other studies could be attributed to racial differences, variations in sample's ages and lifetimes [19], differences in sample sizes, homogeneity of participants, and different study methods (studies directly conducted on bone as opposed to radiography). Degenerative skeletal change in aged individuals is a reason for the difference in metatarsal length in the older groups. However, the effect of age on metatarsal length is little [15]. Taller height is correlated with the larger bone length [22, 23]. In this regard, we presented two models using logistic regression to compare the predictable accuracy of sex by metatarsal bone alone in the first model and to include age and height in the second model. We found that using metatarsal bone alone had a good accuracy in the absence of age and height.

In this study, the data obtained from each metatarsal bone both separately and in combination with all metatarsal lengths and widths were used. Although, the use of concurrent data of five metatarsal bones could increase the diagnostic efficacy, this improvement was not significant. One important point in our study was using radiographic data, thus the values are not true biometric dimensions of bones, because the radiographic beam is divergent and the bones are not in immediate contact with the radiography table or film. This can cause the measured values to become slightly greater than the true values. Although, this does not affect the ROC curve behavior and its efficacy, the calculated cut off points are applicable to radiographs.

Our study had some limitations, too. Our participants belonged to a heterogeneous population from different Iranian ethnicities. Since our study was conducted on right foot radiographs of Iranian population, the results might not be generalized to direct measurements of bones, left foot measurements, or non-Iranian populations.

5. Conclusion

The first and mean of all metatarsal bones L×W had the best accuracy for sex discrimination (86.9% and 85.2%). The first metatarsal width and the mean width of all metatarsal bones had an accuracy of 82.6% and 84.2%, respectively. These indexes can be used to differentiate males from females in Iran.

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Conflict of Interest

The authors declared no conflicts of interest regarding the publication of this paper

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