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Original Article

Gender determination from diagnostic factors on anteroposterior pelvic radiographs

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Abstract

Background: Gender determination from skeletal remains is one of the primary factors in forensic medicine. This study aimed to identify the gender of patients referred to the radiology ward of the Rasoul Akram Hospital of Tehran using anteroposterior pelvic radiography.
Methods: A total of 200 patients (100 male and 100 female) referred to the radiology ward of the Rasoul Akram Hospital for anteroposterior pelvic radiography during 2013−2014 were included in this study. After taking a standard radiographic image of all patients in the supine position and an anteroposterior view of the pelvis, factors including subpubic angles, pubic angle, X angle, ischiopubic index, ratio of the length of the symphysis pubis to the mid and minimum width of the pubis body, and ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus were measured on radiographs. The Student *t* test and receiver operating characteristic curve were used to compare the data of male and female patients. Values were significant at $p < 0.05$.
Results: All the evaluated variables were significantly different in male and female patients ($p = 0.000$), with the highest level of measurement accuracy noted in the subpubic angle, Pubic Angle 1, X angle, Pubic Angle 2, minimum width of the pubic superior ramus, and ischiopubic index. Length of the symphysis pubis, length of the pubis, and ratio of the length of the pubis to the minimum width of the pubic superior ramus showed the lowest accuracy.
Conclusion: The results of this study revealed that the evaluation of the radiographic images of pelvic bones by assessing the mentioned factors can be useful for sex determination from skeletal remains. However, ethical considerations should also be taken into account while using these factors.

Keywords: forensic anthropology; gender determination; radiography

1. Introduction

One the main factors in forensic identification is gender determination. Sex determination of damaged or mutilated corps, or skeletal remains is a principal stage in medicolegal examination.[1] Different parts of the body are utilized in the determination of sex, such as the pelvis, long bones with an epiphysis and a metaphysis in skeletons, skull, pubis, paranasal sinuses, foramen magnum, maxillary sinuses, and teeth.[1−5]

It is generally believed that the pelvis is possibly the most accurate bone in the human body for gender determination, with the accuracy being 95% when completed.[6] In addition, it is estimated that the accuracy of gender identification from the subpubic angle, ventral arc, and composite is approximately 98%.[7]

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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Gender determination of skeletons, particularly those of the victims of war or explosions that cause skeletal fragmentation, is not an easy procedure to undertake and complete successfully.[8] Matching certain characteristics identified on dead bodies with data recorded during the life of an individual is very important in forensic medicine, and can be performed by fingerprint analysis, radiological methods, deoxyribonucleic acid matching, anthropological methods, and other means that can facilitate sex identification.[9] Radiography can contribute to gender determination by providing precise dimensions for which special formulas can be applied.[10]

It is widely accepted that skeletal characteristics vary among different populations; therefore each population should have specific standards to improve the accuracy of identification.[11] In this study, factors related to the pelvic bone including subpubic angles, pubic angles, X angles, length of the pubis, length of the ischium, ischiopubic index, pubis body width, ratio of the length of the symphysis pubis to the width of the pubis body, and ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus have not been assessed in prior studies and in Iran (except for the subpubic angle and ischiopubic index, which were evaluated in previous studies).

This study aimed to identify the gender of the patients who were referred to the radiology ward of the Rasoul Akram Hospital of Tehran using anteroposterior pelvic radiography.

2. Methods

Our study consisted of 100 male and 100 female patients who were referred by the physician to the radiology ward of the Rasoul Akram Hospital for anteroposterior pelvic radiography during 2013–2014. Exclusion criteria included non-Iranian patients, individuals under 18 years of age, patient dissatisfaction with study participation, patients with congenital or acquired skeletal abnormalities, individuals with hip fracture and underlying bone diseases, low-quality radiographic image, and pregnancy and childbirth during the last 3 months. After taking a standard radiographic image of patients in the supine position and an anteroposterior view of the pelvis (the distance of ray source was 100 cm from the patient and the tube was without any angle), these images were stored digitally, and the sex and age of patients were recorded on them. The variables were measured by ISK PACS CC workstation software. To increase numerical accuracy, measurements were carried out twice and the average was recorded. Both the measured variables and the methods of measurement are shown in Table 1 and Fig. 1.

2.1. Statistical analysis

Data were analyzed using IBM SPSS version 20.0. Gender differences were determined using the independent t test, and significance regarding the differentiation point was determined using the receiver operating characteristic (ROC) curve. Ultimately, values were significant at $p < 0.05$.

3. Results

The age range of the population extended from 18 years to 90 years, with an average age of 48.77 years. Two hundred individuals were evaluated; of them, 50% were men and 50% were women. The mean age of the men was 45.03 years and that of the women was 52.20 years. The measured variables were compared using the independent t test. The results showed that the subpubic angle, pubic ramus angle (Pubic Angles 1 and 2), and X angle were significantly different in men and women, as shown in Table 2.

Table 1
Evaluated factors and the way of their measurement.

Factors (unit)	Measurement
Subpubic angle (degree)	By drawing two tangent lines to the lower margin of the pubic ramus and measuring the intersection of these two imaginary lines with a point in the lower and middle parts of the interpubic disc (evident radiolucency in the graph)
Length of pubis (mm)	By calculating the distance of reference point of acetabulum to the midpoint of the symphysis pubis
Length of ischium (mm)	By calculating the distance of reference point of the acetabulum to the farthest edge of the ischium
Ischiopubic index	By dividing the length of the pubis by the length of the ischium multiplied by 100
Pubic ramus angle (degree)	Measured in two ways
Pubic Angle 1	Angle between the two lines drawn from the middle part of the symphysis pubis to the longitudinal axis of the superior and inferior symphysis pubis
Pubic Angle 2	Angle between the two lines drawn along the longitudinal axis of the upper part of the pubic superior ramus to the lower part of inferior ramus
X angle (degree)	Angle which is made by a line which is one sides of the subpubic angle's and a line that connects the top edge of the acetabulum to outermost portion of the ischium
Minimum width of superior pubic ramus (mm)	
Pubis body width (mm)	Measured in two ways
Minimum width of pubis body	The shortest distance between the inner edge of symphysis pubis and the inner edge of obturator hole
Midwidth of pubis body	The shortest distance between the midpoint of symphysis pubis and the inner edge of obturator hole
Ratio of length of symphysis pubis to width of pubis body	Quotient of the length of the symphysis pubis to the width of the pubis body × 100
Ratio of length of symphysis pubis to the minimum width of pubic superior ramus	Quotient of the length of the symphysis pubis to the minimum width of the pubic superior ramus × 100

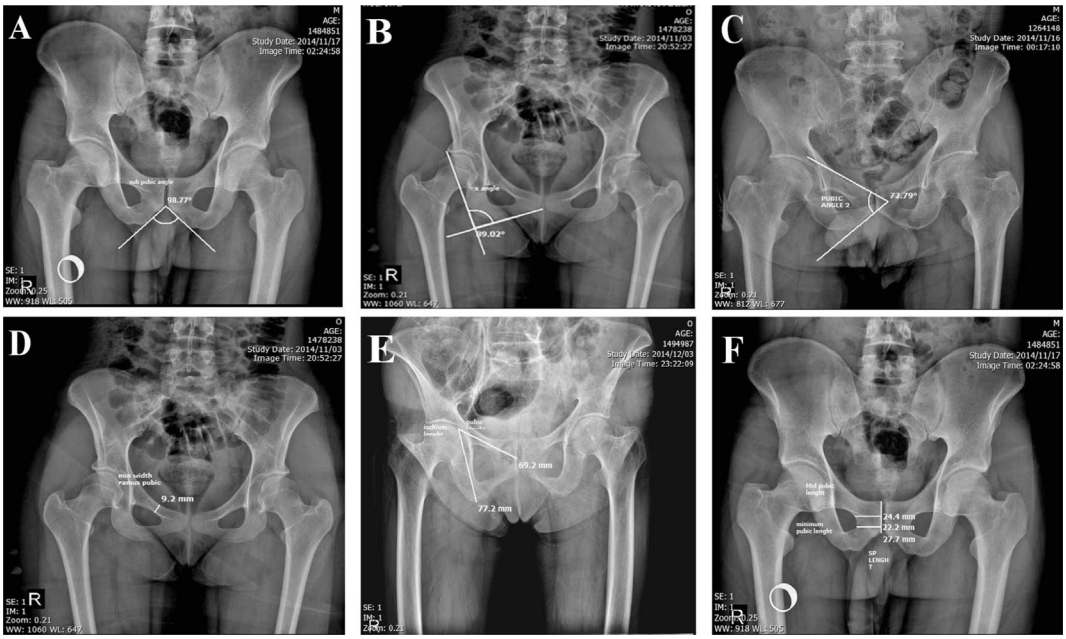

Fig. 1. Ways of measurement of various parameters using anteroposterior pelvic radiographs. (A) Subpubic angle. (B) X angle. (C) Pubic Angle 2. (D) Minimum width of pubic superior ramus. (E) Length of the ischium and pubis. (F) Symphysis pubis length and the mid and minimum width of the pubis body.

Table 2
Comparison of the subpubic angle, pubic ramus angle (Pubic Angles 1 and 2), and X angle in men and women.

Angles (degree)	Maximum degree	Minimum degree	Mean ± SD	SE	*p*
Subpubic angle					<0.001
Men	140.8	68.9	101.51 ± 13.4	1.34	
Women	169.6	87.3	135.47 ± 14.8	1.48	
Pubic ramus angle					
Pubic Angle 1					<0.001
Men	92.13	35.75	70.97 ± 8.19	0.81	
Women	109.25	67.97	89.21 ± 7.39	0.73	
Pubic Angle 2					<0.001
Men	89.95	52.43	72.53 ± 7.92	0.79	
Women	94.35	39.1	60.21 ± 8.66	0.86	
X angle					<0.001
Men	100.6	64.93	79.92 ± 7.2	0.72	
Women	117.07	71.19	92.99 ± 9.29	0.92	

SD = standard deviation; SE = standard error.

The ROC curve was used to determine the discriminatory power of these angles (Fig. 2). For the subpubic angle, the area under the curve was 94% for sex differentiation (Fig. 2A). In the study population, applying a differentiation point of 115.92°, sensitivity of 91%, specificity of 92%, and accuracy of 91.5%, the subpubic angle was different in men and women. In the studied population, significant differences were noted in the average size of the subpubic angle between men and women, with the average size in women being significantly more than that in men ($p < 0.000$). For Pubic Angles 1 and 2 and for sex differentiation, the area under the curve was 94% and 86.4%, respectively (Figs. 2B and 2C). For Pubic Angle 1, the differentiation point was 79.42°, sensitivity 92%, specificity 84%, and accuracy 88%; therefore, there was a difference in the subpubic angle between men and women. For Pubic Angle 2, the differentiation point, sensitivity, specificity, and accuracy were, respectively, 67.98, 76%, 85%, and 80.5%. Significant differences were seen between in average size of Pubic Angles 1 and 2 between men and women, with the average size in men being significantly more than that in women ($p < 0.000$). The area under the curve was 87% for X angle (Fig. 2D), and the differentiation point, sensitivity, specificity, and accuracy, were 85.95, 83%, 82%, and 82.5%, respectively, which show differentiation between men and women. There was a significant difference between X angle size in men, and the length of the pubis, length of the ischium, and ischiopubic index were significantly different in men and women as well (Table 3).

To determine the discriminatory power of the ischiopubic index, the ROC curve was used (Fig. 3). The area under the curve for sex differentiation was 83.5% for the ischiopubic index. In the study population with a differentiation point of 100.47°, sensitivity of 82%, specificity of 78%, and accuracy of 80%, the ischiopubic index was different in men and women. In the studied population, significant differences were seen between in mean of the ischiopubic index and the length of the pubis between men and women, such that both of them were significantly more in women than in men ($p < 0.000$).

Table 4 shows that the length of the symphysis pubis, width of the pubis body, and ratio of the length of the symphysis pubis to the width of the pubis body were significantly different in men and women ($p < 0.000$).

According to Fig. 4, the under curve surface for the length of the symphysis pubis, midwidth of the pubis body, minimum width of the pubis body, ratio of the length of the symphysis pubis to the minimum width of the pubis body, and ratio of the length of the symphysis pubis to the midwidth of the pubis

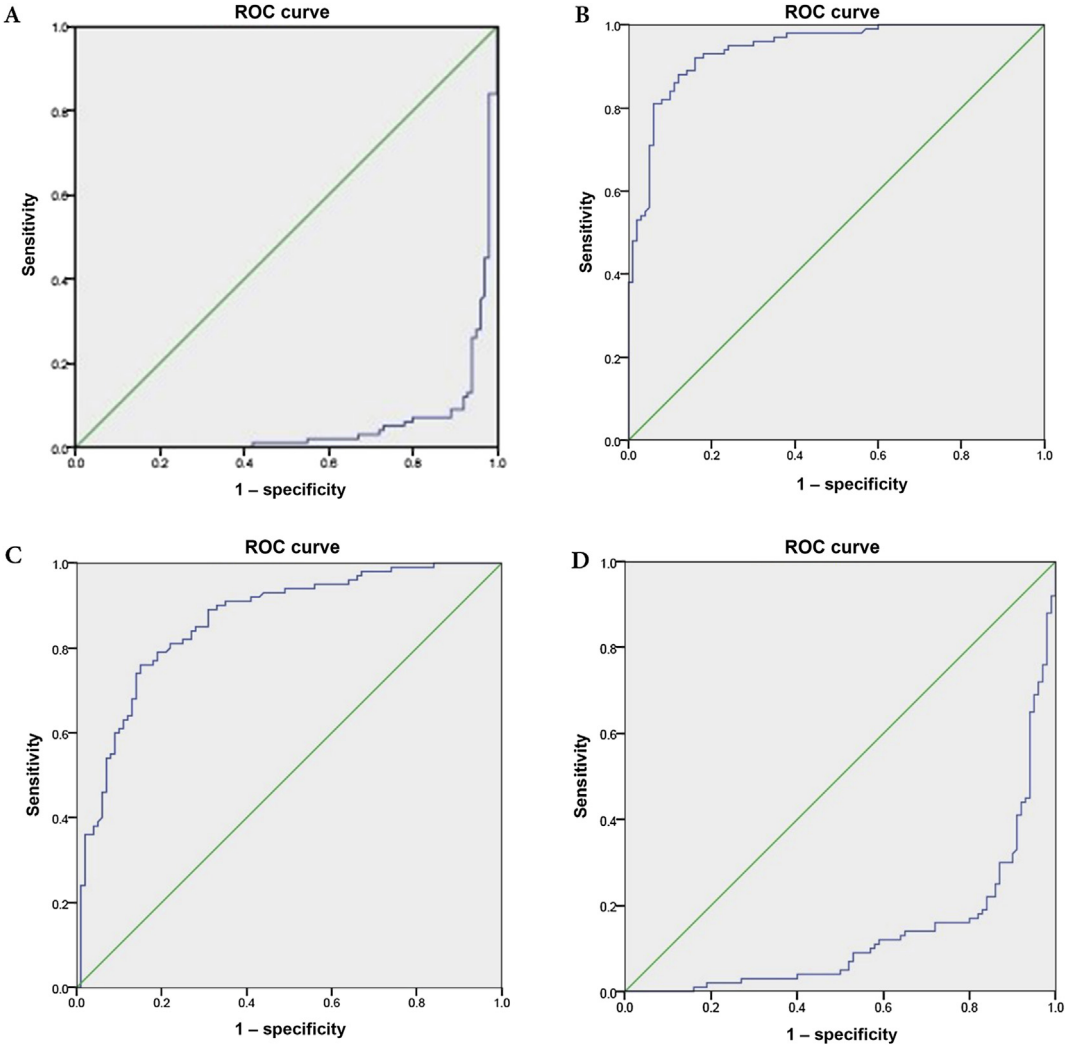

Fig. 2. ROC curve for the predictive power of various angles in detecting gender. (A) Subpubic angle. (B) Pubic Ramus Angle 1. (C) Pubic Ramus Angle 2. (D) X angle. ROC = receiver operating characteristic.

Table 3
Comparison of the length of the pubis, length of the ischium, and ischiopubic index in men and women.

Variables	Maximum (mm)	Minimum (mm)	Mean ± SD	*p*
Length of pubis				<0.001
Men	98.2	63.2	82.10 ± 7.21	
Women	103.8	68.4	87.35 ± 7.78	
Length of ischium				<0.001
Men	106. 7	55.1	84.51 ± 7.95	
Women	112.3	58.4	81.52 ± 8.83	
Ischiopubic index				<0.001
Men	137.67	66.74	94.28 ± 9.18	
Women	134.99	80.61	107.96 ± 11.54	

SD = standard deviation.

body were 65.8%, 78.8%, 83.6%, 81.1%, and 79.8%, respectively. All the mentioned items were significantly different between men and women ($p < 0.000$). The mean length of the symphysis pubis in men, the minimum and midwidth of the pubis in women, and the mean ratio of the length of the

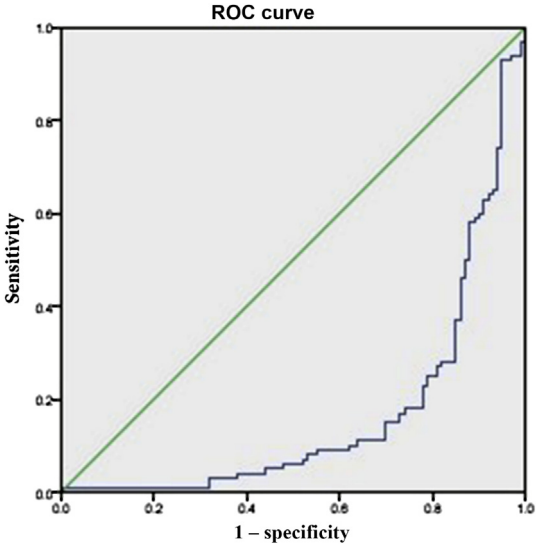

Fig. 3. ROC curve for the predictive power of the ischiopubic index in detecting gender. ROC = receiver operating characteristic.

Table 4
Comparison of the length of the symphysis pubis, width of the pubis body, and ratio of the length of the symphysis pubis to the width of the pubis body in men and women.

Variables	Maximum (mm)	Minimum (mm)	Mean ± SD	*p*	Differentiation Point (mm)	Sensitivity (%)	Specificity (%)	Accuracy (%)
Length of symphysis pubis				<0.001	24.65	80	48	64
Men	46	16.7	79.78 ± 6.25					
Women	52.7	13.6	26.13 ± 7.03					
Minimum width of pubis				<0.001	27	72	72	78
Men	32.7	18.5	24.20 ± 2.92					
Women	38.7	19.9	28.98 ± 3.71					
Midwidth of pubis body				<0.001	28.45	61	83	72
Men	36.8	21.2	27.48 ± 3.53					
Women	41.3	23.9	31.51 ± 3.59					
Ratio of length of symphysis pubis to minimum width of pubis body				<0.000	92.23	91	60	75.5
Men	204.35	60.28	124.59 ± 29.42					
Women	150.39	43.53	83.43 ± 22.13					
Ratio of length of symphysis pubis to midwidth of pubis body				<0.001	86.74	84	62	73
Men	176.83	58.19	109.05 ± 21.83					
Women	150.39	43.53	83.43 ± 22.13					

SD = standard deviation.

symphysis pubis to the minimum and midwidth of the pubis in men were higher than the corresponding factors in the opposite sex.

A comparison of the mean of the minimum width of the pubic superior ramus and the ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus were significantly different in men and women ($p < 0.000$), as demonstrated in Table 5.

According to the ROC curve, the under curve surface for the ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus was 63% (Fig. 5). The differentiation point, sensitivity, specificity, and accuracy were, respectively, 13 mm, 74%, 86%, and 80% for the minimum width of the pubic superior ramus, and 203.69 mm, 57%, 75%, and 66% for the ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus; this shows the differentiation between men and women. The difference between the minimum width of the pubic superior ramus and the ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus was significant, as the mean of the former was higher in men and the latter was higher in women ($p < 0.000$).

4. Discussion

Researchers believe that identifying sex from the skeletal remains is the main and primary point of anthropologists' research and forensic medicine. In addition, characteristics of various populations differ from each other in terms of size and proportion, and these differences affect gender assessment. In this study, the pelvis bone was assessed, which has important differences in sex differentiation. The radiographic method was used in the current study. Here, the ratio between the points were also measured, due to differences in the magnification of radiological films and the implementation of the size of radiographs with the actual size of the bone, in addition to the measurement of the absolute distances between points. In the current work, the mean of the pubic angle, length of the symphysis pubis, width of the pubis body, minimum width of the pubic superior ramus, and ratio of the length of the symphysis pubis to the minimum length of the pubic superior ramus were measured, which appear to be factors that were not evaluated on pelvis radiographs in previous studies. However, the mean values of the subpubic angle and ischiopubic index were evaluated in previous works.

The mean values of the subpubic angle in this study were 101.51 ± 13.4 in men and 135.47 ± 14.8 in women, with the mean being significantly more in women than in men. In the study of Igbigbi and Nanono-Igbigbi[12], the mean values of the subpubic angle were 93.86 ± 21.12 and 116.11 ± 17.79 in men and women, respectively. These angles were larger in an Iranian population than in a black Ugandan study group, which shows the impact of ethnic and regional differences. In the study of Oladipo et al[13] on pelvis radiographs of an Indian population, the mean values of the subpubic angles were 102.31 ± 12.5 in men and 143.28 ± 15.82 in women. In the work of Oladipo et al,[14] the mean values were 109.38 ± 10 in men and 119.48 ± 12.06 in women in a Nigerian population. In the study of Vasheghi Farahani[15], the mean values of the subpubic angle were 116.31 ± 23.67 and 140.53 ± 14.33 in male and female, respectively. The results of these studies were inconsistent with the result of the current study, wherein the angle was larger in female than in male, and the size of the angles were almost similar to the angle size of this study. In the study of Small et al[16] focusing on black and white South African populations, the mean values of the subpubic angle in male and female were, respectively, 70.67 ± 9.36 and 93.86 ± 11.15 in the white population, and 63.9 ± 11.08 and 84.1 ± 8.9 in the black population. The subpubic angle was

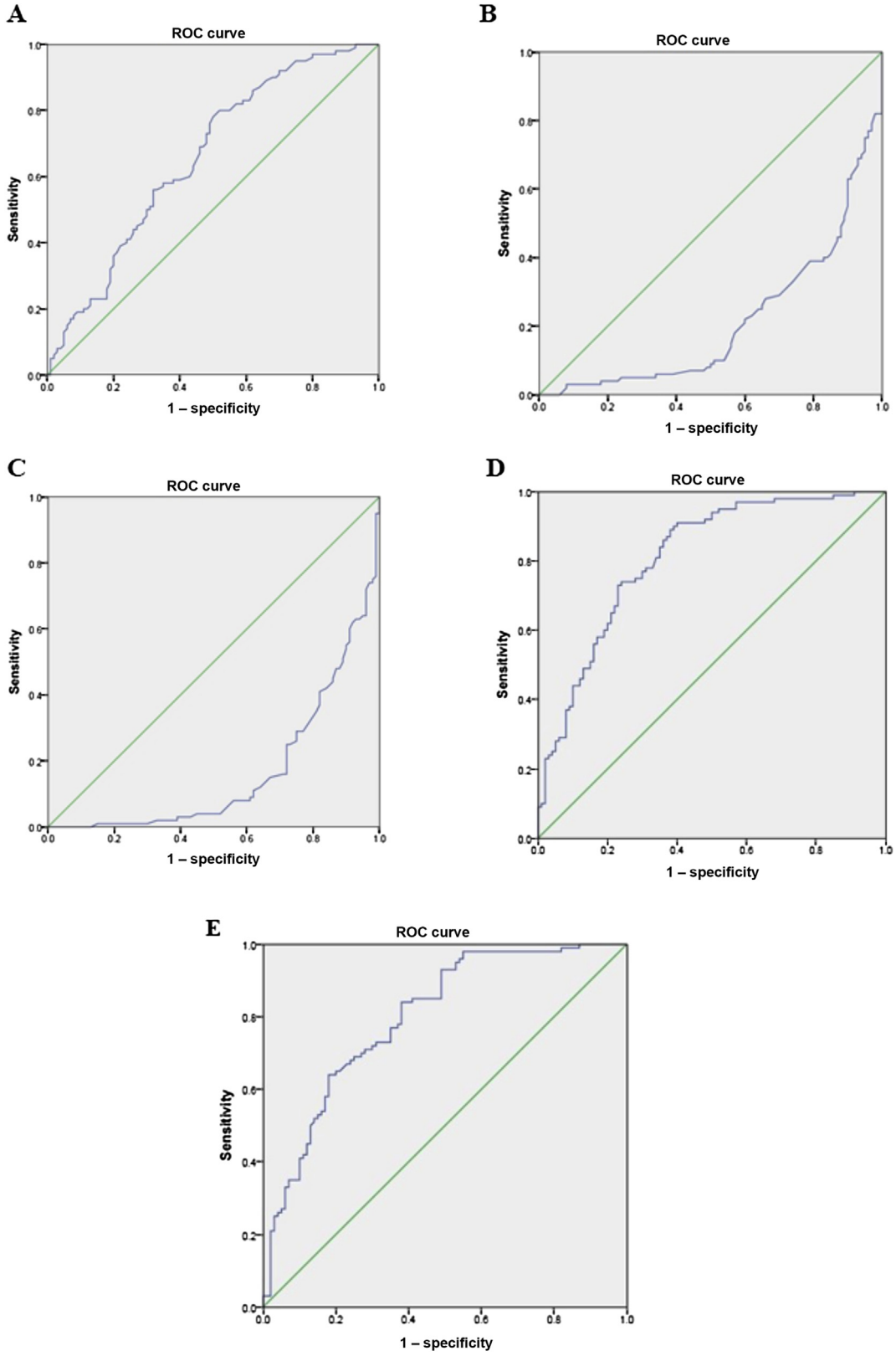

Fig. 4. Predictive power of ROC curve for the length of the symphysis pubis, width of the pubis body, and ratio of the length of the symphysis pubis to the width of the pubis body in detecting gender. (A) Length of the symphysis pubis. (B) Midwidth of the pubis body. (C) Minimum width of the pubis body. (D) Ratio of the length of the symphysis pubis to the minimum width of the pubis body. (E) Ratio of the length of the symphysis pubis to the midwidth of the pubis body. ROC = receiver operating characteristic.

significantly larger in the black population than in the white one, and the size of the angle was significantly different in male and female. The subpubic angle in the black population was larger than that in the Iranian population in both men and women. The difference between the result of this study and the results of other studies can be attributed to the shape of the pubic bones, the wide pelvis of Iranians, height differences, and environment.

The mean values of the ischiopubic index in the current study were 94.28 ± 9.18 in male and 107.96 ± 11.54 in female. In this study, the length of the pubis in male and that in female were 82.10 ± 7.21 mm and 87.35 ± 7.78 mm, respectively, and the length of the ischium was 87.51 ± 7.95 in men and 81.52 ± 8.83 in women. In the study of Ekanem et al[17] in Nigeria, the length of the pubis was 56.6 mm and 75.6 mm in male and female, respectively. The length of the ischium was 69.9 mm and 63.6 mm in men and women, respectively, and the ischiopubic index was 94.2 mm in men and 118.8 mm in women. Okoseimiema and Udoaka[18] revealed that the length of the pubis was 74.99 mm in male and 84.88 mm in female, and the mean length of the ischium was 85.03 in male and 79.52 mm in female. Additionally, values of the ischiopubic index were 88.65 and 106.45 in men and women, respectively. In a study by Oladipo et al,[13] the mean values for the length of the pubis, length of the ischium, and ischiopubic index were 78.51 ± 12.4 mm, 85.58 ± 11.6 mm, and 91.66 ± 5.86, respectively, for Urhobo men, and 92.39 ± 7.08 mm, 81.97 ± 12.00 mm, and 114.93 ± 18.14, respectively, for Urhobo women. In addition, the mean values for the length of the pubis, length of the ischium, and ischiopubic index were 82.20 ± 10.62 mm, 83.84 ± 10.82 mm, and 98.40 ± 9.37, respectively, for Itsekiri males, and 92.05 ± 6.36 mm, 85.03 ± 14.59 mm, and 111.03 ± 18.37 for their women counterparts, respectively, which show a significant difference among the sexes. In the study of Ekanem et al,[19] the mean values for the ischiopubic index were 101.05 for men and 115.99 for women, and the mean value for the pubic length was significantly longer in women, whereas the ischial length was significantly higher in men. Results of previous studies and that of the current study have determined that the ischial length is larger in male while the pubic length is larger in female, and the mean value of the ischiopubic index was significantly higher in women. In the present work, the mean values of ischial length and pubic length were almost similar with that of the study of Okoseimiema and Udoaka,[18] and were lower than the Ekanem study[17], which may be due to the wider pelvis in the Iranian population. The mean value of the ischiopubic index for men in the current study was higher than that in other studies; however, for women, it was lower than that in other studies, which may be due to the effect of ethnicity, environment, or age of participants.

In the present study, the mean values of Pubic Angles 1 and 2 were significantly higher in male than in female. In addition, the X angle was significantly higher in female, which may be because, in women, the pelvic bone is wider and more

Table 5
Comparison of the mean values of the minimum width of the pubic superior ramus and the ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus between men and women.

Variables	Maximum (mm)	Minimum (mm)	Mean ± SD	*p*
Minimum width of pubic superior ramus				<0.001
Men	21.1	8.1	14.45 ± 2.51	
Women	19.3	7.1	10.92 ± 2.26	
Ratio of length of symphysis pubis to minimum width of pubic superior ramus				<0.001
Men	295. 92	111.33	207.85 ± 36.92	
Women	456.58	83.94	246.42 ± 73.08	

SD = standard deviation.

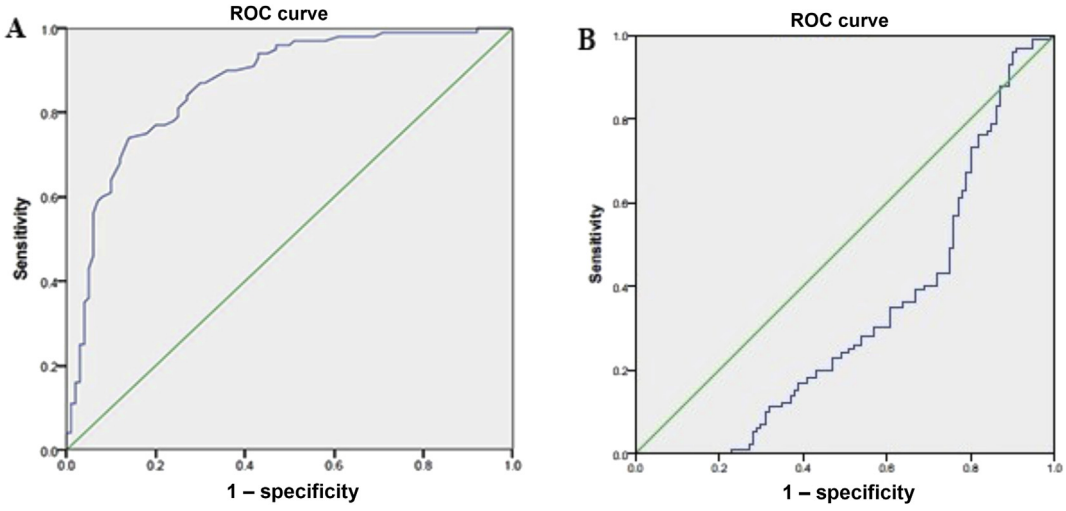

Fig. 5. Predictive power of the ROC curve for the minimum width of pubic superior ramus and the ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus in detecting gender. (A) Minimum width of pubic superior ramus. (B) Ratio of the length of the symphysis pubis to the minimum width of the pubic superior ramus. ROC = receiver operating characteristic.

horizontal, and the subpubic angle is more open. In men, the angle is closer and perpendicular to the pelvic walls.

The mean value of the pubis body width was significantly higher in male. The symphysis pubis length was higher in male because men are taller and their pelvis bones are longer. The mean value of the minimum width of the pubic superior ramus, and the ratio of the symphysis pubis length to the width of the pubis body and the minimum of the pubic superior ramus width were significantly higher in women. The mean of the ratio of the symphysis pubis length to the mid and minimum width of the pubis body was significantly higher in male. It seems that the larger length of the symphysis pubis in male and their larger body size, compared with the wider pelvis bone and greater width of the pubis body of female, are responsible for this. The mean value for the ratio of the symphysis pubis length to the minimum width of the pubic superior ramus was higher in female, which could be due to the symphysis pubis length and larger width of the pubic superior ramus in men due to their larger body size and the shape of the pelvis bone. However, we could not find any relevant studies to compare these findings with.

In this study, the greatest accuracy in measurement was applied to the subpubic angle, Pubic angle 1, X angle, Pubic angle 2, minimum width of the pubic superior ramus, and ischiopubic index. The symphysis pubis length, length of the pubis, and ratio of the length of the pubis to the minimum width of the pubic superior ramus showed the lowest accuracy.

In conclusion, the results of this study revealed that the evaluation of the radiographs of pelvic bones by assessing factors, including the subpubic angle, pubic angle, X angle, minimum width of the pubic superior ramus, and ischiopubic index, and other factors can be useful for sex determination from skeletal remains. According to the results of the current and previous studies, it is determined that the result of each area are useful for that region and the ethnic variations seen in the evaluated factors shows the impact of races and ethnicities on the anthropometric factors of the pelvis bone, and shows the importance of using the indigenous criteria for each region in sex determination in forensic medicine.

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