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Research Paper: The Diagnostic Value of Anthropometric Characteristics of Ilium for Sex Estimation Using Pelvic Radiographs

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ABSTRACT

Background: Sex estimation is an essential part of forensic identification. This study was conducted on the Iranian people to determine pelvic bones anthropometric characteristics.

Methods: Radiography of 180 pelvic bones (90 males and 90 females) was studied. We measured the height of ilium, inter-acetabular distance, acetabular diameter, the greatest breadth of the pelvis, breadth of pelvic inlet, and the presence of the beaklike bony extension in both sexes.

Results: We found a significant difference between men and women regarding their mean height of ilium, acetabular diameter, inter-acetabular distance, breadth of the pelvic inlet in all studied X-rays. The highest accuracy for sex estimation was related to the height of ilium (77%). The prevalence of the beaklike bony extension was 43% in the studied population, 70% in males and 18% in females.

Conclusion: When human skeletal remains containing pelvic bones are available, standard radiographic images along with other findings can be helpful in predicting the sex.

1. Introduction

Sex estimation is one of the most important criteria for forensic identification; however, it is not always easy to determine it by skeletal remains. In fact, all morphologic and morphometric criteria are in a range that overlap each other. It is a common scenario in forensic medicine that corps is dismembered before identification. Sometimes, only skeletal remnants or parts of the body are available. In these situations, sex estimation becomes more difficult and problematic [1, 2]. Pelvic girdle has better sex-specific characteristics in comparison to other body areas and have the best bones for sex identification [3]. A number of studies have already been conducted on the pelvic radiography in different populations [4-8].

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Taking pelvic bone X-ray is much easier than finding human skeletal remains in the environment or separating these bones, also it is easy to determine the anthropometric dimensions of the bone by radiographs. Thus, we aimed to determine and compare the dimensions of ilium bone in adult patients based on their pelvic X-ray images.

2. Materials and Methods

We conducted a cross-sectional and descriptive-analytic study to determine the anthropometric characteristics of ilium for sex estimation using pelvic radiographs of the Iranian patients at Sina Hospital, Tehran, in 2017. We included all Iranian patients over the age of 20 years referred to the Radiology Department of Sina Hospital by their physicians to have an anteroposterior pelvic radiograph. We excluded patients with known congenital or acquired skeletal diseases or pelvic trauma. According to a previous study [9] and based on the below formula, a sample size of 180 (90 women and 90 men) was determined for the study. The sampling was done randomly.

$$n=\frac{(Z_{1-\frac{\alpha}{2}}+Z_{1-\beta})(\sigma^2_1+\sigma^2_2)}{\Delta^2}$$

The pelvic radiographs were taken under standard conditions with patients lying down in supine position acquiring an anteroposterior image with no angling of the X-ray tube. Using the Picture Archiving and Communication System software (PACS), we measured the height of ilium (the maximum distance between midpoint of the acetabulum and the upper point of the iliac crest), inter-acetabular distance (the distance between left and right middle points of the acetabular fossa), acetabular diameter (the maximum vertical diameter of the acetabulum), pelvis breadth (the maximum distance between the two most lateral parts of the iliac crests), pelvic inlet breadth (the maximum distance between the two most lateral parts of the pelvic inlet) and presence of the beaklike bony extension (this is a bony protrusion on the inner edge of the large sciatic notch that ends up towards the Arcuate line) (Figures 1, 2, 3, and 4).

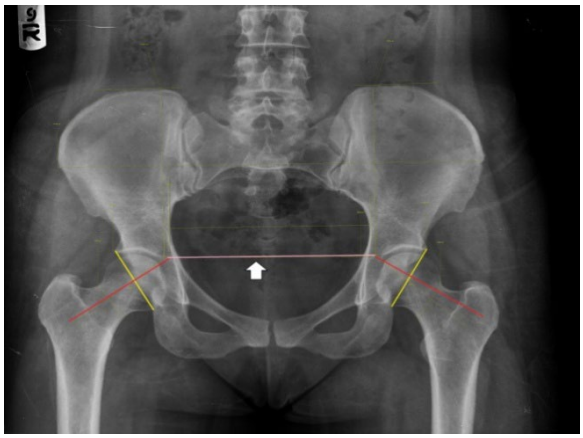

Figure 2. Inter-acetabular distance

Arrow: Inter-acetabular distance (the distance between the left and right middle points of the acetabular opening)

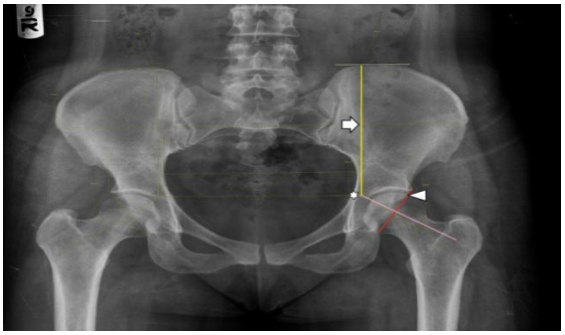

Figure 1. Maximum height of the ilium and acetabular diameter

Arrow: Maximum height of Ilium (The distance between the midpoint of the acetabulum and the upper point of the iliac crest); Arrow point: Acetabular diameter (Maximum vertical diameter of the acetabulum)

All measurements were performed in a blinded setting. According to the age range of the studied population and the initial analysis, the results were evaluated in three age groups of 20-34, 35-49, and over 50 years in order to assess the accuracy of the criteria in different age groups. All analyses were performed in SPSS V. 19 and $P<0.05$ were considered

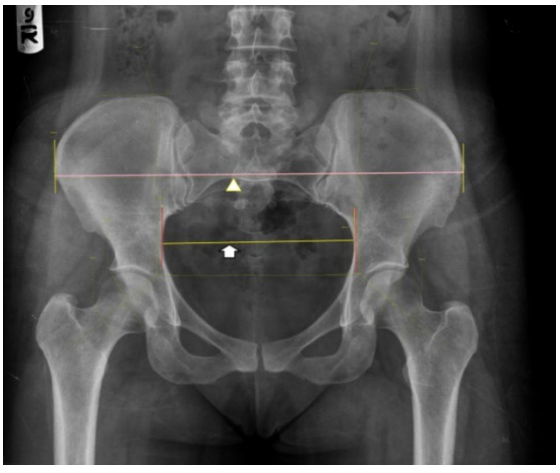

Figure 3. The greatest breadth of pelvis and breadth of the pelvic inlet

Arrow: The greatest breadth of pelvic (Maximum distance between the two most lateral parts of the iliac crests); Arrow point: Breadth of pelvic inlet (Maximum distance between the two most lateral parts of the pelvic inlet)

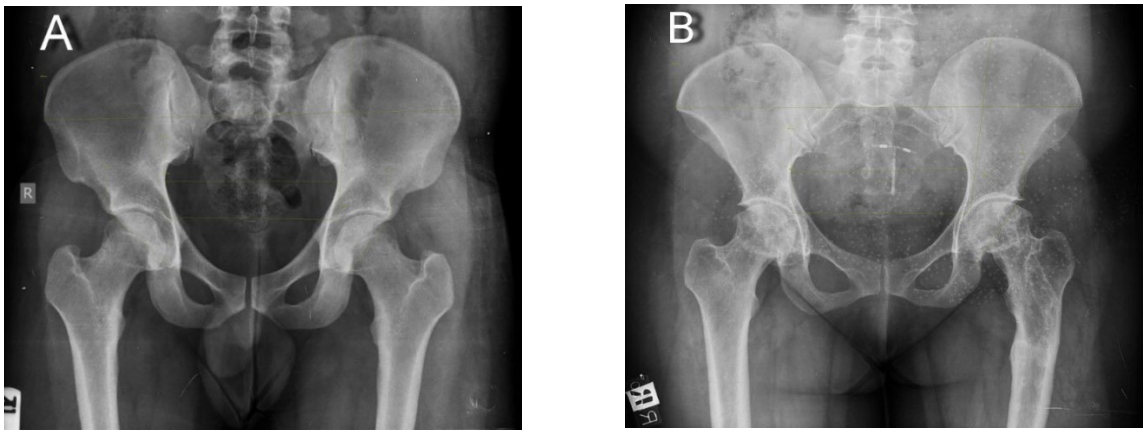

Figure 4. Beaklike bony extensions

A: Bilateral beaklike bony extension, B: No beaklike bony extension

statistically significant. Data analysis was performed using central indices and data distribution. The Student t-test was used to compare the mean of variables in both genders.

3. Results

The Mean±SD age of the 180 participants (90 men and 90 women) was 44.41±15.8 years (43±17.3 in males and 45.8±13.9 in females) (Table 1). There was no significant difference between sexes regarding their mean age (P=0.220).

As shown in Table 2, the mean ilium height was higher in males (P<0.0001, AUC=0.77). The mean acetabular diameter was higher in males (P<0.0001, AUC=0.84). The mean inter-acetabular distance was shorter in males (P<0.0001, AUC=0.77). The mean pelvic inlet breadth was smaller in males (P<0.0001, AUC=0.81). The mean the pelvis breadth was 33.7 cm in males and 33.6 cm in females (P=0.676).

The measured pelvic bone characteristics were significantly different between both sexes in all age groups except for the pelvis breadth (Table 3). Comparison of all

Table 1. The mean age (y) of the studied population, sex-specific

Sex	Mean±SD	Median	Mode	95% Confidence Interval	
Male	43.0±17.3	38	22	39.3	46.6
Female	45.8±13.9	46	56	42.9	48.8
Total	44.4±15.8	42	35	42.1	46.7

P<0.05 is considered statistically significant.

Table 2. The comparison of Mean, SD, minimum and maximum of the height of ilium, inter-acetabular distance, acetabular diameter, greatest breadth of pelvis, and breadth of pelvic inlet between the two sexes

Parameter, cm	Male			Female			P*
	Mean±SD	Min	Max	Mean±SD	Min	Max	
Height of Ilium	15.4±1.0	12.8	18.4	14.5±0.8	12.6	16.7	<0.0001
Inter-acetabular distance	14.4±1.0	12.3	16.4	15.5±1.1	13.6	18.5	<0.0001
Acetabular diameter	6.6±0.4	5.7	7.3	6.0±0.4	5.3	7.2	<0.0001
Pelvic breadth	33.6±2.1	28.5	38.8	33.7±3.1	29.5	56.0	0.676
Breadth of pelvic inlet	14.5±0.9	12.3	16.3	15.7±1.0	13.5	18.2	<0.0001

* P<0.05 is considered statistically significant.

Table 3. The comparison of Mean, SD, minimum and maximum of the height of ilium, inter-acetabular distance, acetabular diameter, greatest breadth of pelvis and breadth of pelvic inlet between the two sexes in each age group

Age Group	Sex / Parameter, cm	Male			Female			P*	Total		
		Mean±SD	Min	Max	Mean±SD	Min	Max		Mean±SD	Min	Max
20-34 years old	Height of ilium	15.5±1.0	13.6	17.6	14.4±0.8	12.6	15.5	<0.0001	15.1±1.0	12.6	17.6
	Inter-acetabular distance	14.3±1.0	12.3	16.2	15.4±1.1	13.6	18.4	<0.0001	14.8±1.2	12.3	18.4
	Acetabular diameter	6.5±0.5	5.8	7.3	6.0±0.5	5.3	7.2	0.001	6.3±0.5	5.3	7.3
	Greatest breadth of pelvis	33.5±2.2	28.6	37.9	32.7±1.9	29.5	36.1	0.147	33.2±2.1	28.7	37.9
	Breadth of the pelvic inlet	14.5±1.0	12.3	16.0	15.5±0.9	14.1	17.4	<0.0001	15.0±1.1	12.3	17.4
35-49 years old	Height of ilium	15.5±1.2	12.8	18.4	14.7±0.8	12.9	16.4	0.002	15.1±1.2	12.8	18.4
	Inter-acetabular distance	14.6±1.1	12.3	16.4	15.7±1.1	14.2	18.5	0.001	15.2±1.2	12.3	18.5
	Acetabular diameter	6.6±0.4	5.7	7.3	6.0±0.4	5.3	7.0	<0.0001	6.3±0.5	5.3	7.3
	Greatest breadth of pelvis	33.7±2.3	28.5	38.8	34.6±4.4	30.2	56.0	0.356	34.2±3.6	28.5	56.0
	Breadth of the pelvic inlet	14.6±1.0	12.7	16.3	15.9±0.9	14.2	17.6	<0.0001	15.3±1.2	12.7	17.6
≥50 years old	Height of ilium	15.1±0.9	12.9	17.5	14.3±0.8	12.8	16.7	<0.0001	14.7±1.0	12.8	17.5
	Inter-acetabular distance	14.2±0.9	12.3	16.0	15.5±1.1	13.6	18.2	<0.0001	15.0±1.2	12.3	18.2
	Acetabular diameter	6.6±0.3	5.9	7.2	6.0±0.3	5.4	6.6	<0.0001	6.3±0.5	5.4	7.2
	Greatest breadth of pelvis	33.5±1.8	29.7	37.7	33.7±1.9	30.4	38.8	0.722	33.6±1.9	29.7	38.9
	Breadth of the pelvic inlet	14.5±1.0	12.8	15.7	15.8±1.0	13.5	18.2	<0.0001	15.2±1.1	12.8	18.2

* P<0.05 is considered statistically significant.

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measured criteria was not significantly different between age groups (P>0.05).

Using ROC curves, sensitivity, specificity, and accuracy for sex estimation, the height of ilium, inter-acetabular distance, pelvic inlet breadth and acetabular diameter in determined remarking points were calculated (Figures 5, 6, 7, and 8). The accuracies of sex estimation were 77%, 72%, 71% and 67% for the height of ilium, acetabular diameter, breadth of pelvic inlet and inter-acetabular distance, respectively (Table 4). The highest accuracies for sex determination were seen for the ilium height (71%) and pelvic inlet breadth (71%) in the 20-34 years age-group and acetabular diameter in the 35-49

Table 4. Specificity, sensitivity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and accuracy of the height of ilium, inter-acetabular distance, acetabular diameter, and breadth of the pelvic inlet

Parameter, cm	D.Point*	Sensitivity	Specificity	PPV	NPV	Accuracy
Height of ilium	14.89	70	70	70	70	77%
Inter-acetabular distance	14.71	67	55	65.7	70.5	67%
Acetabular diameter	6.04	78	52	67.2	81.2	72%
Breadth of the pelvic inlet	14.92	72	57	68.6	76	71%

* D.Point: Demarking Point

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Table 5. Specificity, sensitivity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and accuracy of the height of ilium, inter-acetabular distance, acetabular diameter, and breadth of the pelvic inlet in different age groups

Age Group	Parameter, cm	D.Point	Sensitivity	Specificity	PPV	NPV	Accuracy
20-34 years	Height of ilium	15.28	61	87	87	61	71%
	Inter-acetabular distance	14.71	70	64	57	75	66%
	Acetabular diameter	6.27	61	74	77	57	66%
	Breadth of pelvic inlet	15.25	65	76	65	76	71%
35-49 years	Height of ilium	15.30	63	81	74	71	72%
	Inter-acetabular distance	15.16	64	70	71	63	67%
	Acetabular diameter	6.24	81	80	89	84	87%
	Breadth of pelvic inlet	15.53	64	81	80	67	76%
≥50 years	Height of ilium	14.96	70	78	72	76	74%
	Inter-acetabular distance	15.02	67	83	83	68	74%
	Acetabular diameter	6.36	77	89	85	82	83%
	Breadth of pelvic inlet	15.28	69	80	81	69	74%

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years and ≥50 years age groups with 87% and 83%, respectively (Table 5).

The prevalence of the beaklike bony extension was 43% in the studied population, 70% in males and 18% in females. In the studied population, the beaklike bony extension was bilateral in 36%, right-sided in 3%, and left-sided in 4%. For identified cases, the beaklike bony extension was bilateral in 61% of men and 11% of women.

In all age groups, the prevalence of the beaklike bony extension was statistically significant between the sexes

Table 6. The prevalence rates of beaklike bony extension in the two sexes across different age groups

Age Group	Sex	Absence, No.(%)	Presence		Total, No.(%)	P*
			Unilateral, No.(%)	Bilateral, No.(%)		
20-34 years	M	11(33)	-	22(67)	33(100)	0.0001
	F	19(83)	1(4)	3(12)	23(100)	
	Total	30(54)	1(4)	25(45)	56(100)	
35-49 years	M	5(18)	4(15)	18(67)	27(100)	0.0001
	F	24(77)	4(13)	3(10)	31(100)	
	Total	29(50)	8(14)	21(36)	58(100)	
≥50 years old	M	11(37)	4(13)	15(50)	30(100)	0.0001
	F	31(86)	1(3)	4(11)	36(100)	
	Total	42(64)	5(8)	19(29)	66(100)	

* P<0.05 is considered statistically significant.

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Table 7. The comparison of the prevalence rates of beaklike bony extension in men, across different ages groups

Age Group	Absence, No. (%)	Presence		Total, No. (%)	P*
		Unilateral, No. (%)	Bilateral, No. (%)		
20-34 years	11(33)	-	22(67)	33(100)	
35-49 years	5(18)	4(15)	18(67)	27(100)	0.073
≥50 years	11(37)	4(13)	15(50)	30(100)	
Total	27(30)	8(9)	55(61)	90(100)	

* P<0.05 is considered statistically significant.

Table 8. The comparison of the prevalence rates of beaklike bony extension in women across different age groups

Age Group	Absence, No. (%)	Presence		Total, No. (%)	P*
		Unilateral, No. (%)	Bilateral, No. (%)		
20-34 years	19(83)	1(4)	3(13)	23(100)	
35-49 years	24(77)	4(13)	3(10)	31(100)	0.609
≥50 years	31(86)	1(3)	4(11)	36(100)	
Total	74(82)	6(7)	10(11)	90(100)	

* P<0.05 is considered statistically significant.

(P=0.0001) (Table 6). In males or females, the prevalence of beaklike bony extension in different age groups had no significant differences (P>0.05) (Tables 7 and 8).

4. Discussion

Multiple studies have been conducted on the pelvis for sex estimation using different methods, including measuring the height of ilium and acetabular diameter [9-15]. In our study, the mean ilium height was higher in males, yet it was less than previous studies conducted by Sitek et al. (2012) on Polish people [9], Steyn et al. (2008) on Greek people [10], Patriquin et al. (2005) in South Africans [11], and Scoth et al. (1893) in New Zealand people [12]. The discrepancy could be due to differences in study methods, measurements, and populations. In these studies [10-12], the height of the ilium was measured from the highest point of the iliac crest to the lowest point of the ischial tuberosity, but we used the method

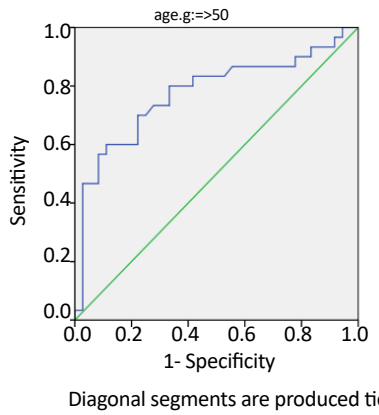

Figure 5. The ROC curve for the predictive value of the height of ilium in sex estimation

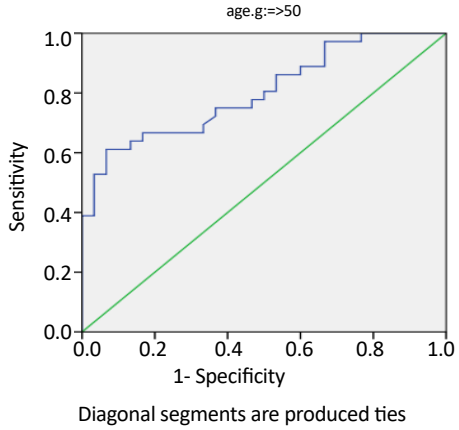

Figure 6. The ROC curve for the predictive value of the inter-acetabular distance in sex estimation

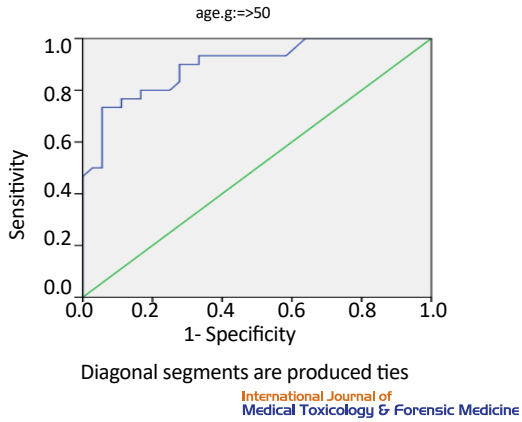

Figure 7. The ROC curve for the predictive value of the acetabular diameter in sex estimation

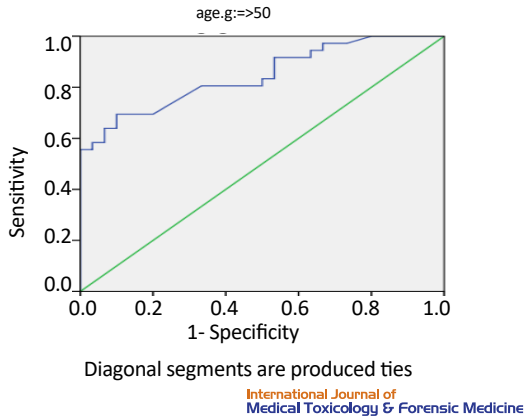

Figure 8. The ROC curve for the predictive value of the breadth of the pelvic inlet in sex estimation

similar to the study by Sitek et al. (2012) [9], which used the distance between the midpoint of acetabulum and the highest point of the iliac crest.

Similar to the study on Polish people [9], in our study inter-acetabular distance was longer in females. Milch (1954) study [16] reported a significantly longer inter-acetabular distance in males. This difference is primarily due to different measurement techniques as the latter study used the distance between the superior ridges of the acetabular fossa as inter-acetabular distance.

Like most other studies [9, 13, 17], we found that the acetabular diameter was significantly longer in males compared to that in females. The accuracy of acetabular diameter for sex estimation was 72% in our study, which is lower than that found in the study by Patriquin et al. (2005) on South African people [11] (84%) and what reported by Steyn et al. (2008) in Greeks (83.9%) [10]. This difference is probably due to ancestral and population differences. However, in our study, the accuracy was similar to the above studies at the age of over 35.

Similar to other studies [6, 9], we found that the greatest breadth of the pelvis was higher in females, yet the difference was not statistically significant, which could be due to the similarity between the two sexes in this population or a small sample size which could not highlight this difference.

Our findings about the breadth of pelvic inlet was similar to findings by Abolhassani et al. (2003) [17], Steyn et al. (2008) [10], Sitek et al. (2012) [9], and Scoth et al. (1893) [12] that studied on Iranian, Greek, Polish, and New Zealand people, respectively. We found that the breadth of the pelvic inlet was significantly higher in females, yet the mean breadth of the pelvic inlet was different between these studies which could be due to the methodological differences.

In our study, we found that the height of ilium had the highest sex estimation accuracy with 77% and the lowest sex determining accuracy was found with the inter-acetabular distance with 67%. Considering the fact that accurate prediction of sex by chance is 50%, so the criterion does not seem to be reliable in predicting sex. We could not find a comprehensive study comparing the accuracy of different anthropometric features of ilium for sex estimation.

We could not find another study with similar age groups to compare the accuracy of the height of ilium, inter-acetabular distance, acetabular diameter, and breadth of the pelvic inlet for sex estimation. As our findings in all age groups showed, except for the greatest breadth of the pelvis, other iliac characteristics were significantly different between the two sexes. We found a relatively similar accuracy for different iliac morphometric characteristics across different age groups. However, the accuracy of the acetabulum diameter was higher in the people aged over 35 years.

In comparing the mean values of the ilium height, inter-acetabular distance, acetabular diameter, the greatest breadth of the pelvis and breadth of the pelvic inlet between different age groups, no significant difference was observed in the whole population and within each sex, which could be attributed to the absence of overt osseous changes with increase in age or insufficient sample size to reach significant difference.

In 79 (44%) cases, we found the beaklike bony extension. In our participants, 63 (70%) males and 16 (18%) females had the beaklike bony extension, which is similar to the result found by Gülekon et al. (2002) in Turkish population [18]. In our study, the majority of cases with beaklike bony extensions were symmetric and bilateral (61% in men and 11% in women). Very few unilateral cases were identified unlike the results of Gulekon et al. study, which could be contributed to ancestry and population differences or study design.

5. Conclusion

The maximum information obtained from available bones in skeletal remains is necessary for sex estimation. However, the weight of different anthropometric criteria in a bone is not the same, and this can make the sex estimation more challenging.

In our study, the height of ilium, inter-acetabular distance, acetabular diameter and breadth of the pelvic inlet were different between the two sexes. Given the accuracy of the ilium height in sex estimation (77%) and accuracies of over 70% for the acetabular diameter and breadth of the pelvic inlet in the studied population, when skeletal remains, including pelvis are available, but it is not possible to directly assess the metric criteria due to the presence of dried soft tissues, the standard radiographic images along with other findings can help to predict the sex. However, this accuracy for sex estimation is considerably less than the overall value of the pelvis bone, itself.

This study was conducted in adult Iranian population and the findings cannot be necessarily generalized to other populations. In addition, since measurements were done on radiographic images, actual measurement of the bony structures might not necessarily yield to correlate numbers.

Ethical Considerations

Compliance with ethical guidelines

The research protocol approved by the Ethics Committee of Tehran University of Medical Sciences, Tehran, Iran. Informed consent form was obtained from all study subjects.

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Authors contributions

Designing the study: Masoumeh Varzandeh, Mitra Akhlaghi, Vahid Yousefinejad; Participating in acquisition of data: Masoumeh Varzandeh, Maryam Vasheghani Farahani; Analyzing data: Vahid Yousefinejad; Managing data: Farinaz Mousavi, Somayeh Karimi Jashni; Writng the first draft and other critically revise: Masoumeh Varzandeh, Mitra Akhlaghi, Vahid Yousefinejad; and Approving final version of the manuscript and accountable for all aspects of the work: All authors.

Conflict of interest

The authors declared no conflict of interest.

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