

Sex Determination by Analysis of Patella Measurements in New Delhi Population

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Abstract

In this study the patella bones from both right and left sides were taken out of 60 individuals (30 males and 30 females). Bones were kept in 5% sodium hypochlorite solution for a week for maceration, and then dried and following measurements were taken: Maximum Length, Maximum Width, Maximum Thickness and Lateral Articular Facet Breadth in millimeters, and Weight in grams. Statistical analysis was done using SPSS 27.0. Descriptive statistics were obtained for each measurement. The North Indian population was compared with other populations. In the present study, the mean maximum height of the right side was 37.51 mm+3.17 SD for females and 41.54 mm+2.76 SD for males, while the mean of the left side was 37.91 mm+2.95 SD for females and 42.61 mm+2.97 SD for males. The sexual dimorphism was significant statistically, with a p-value <0.001 for both sides. The projected cut off value on the right side was 39.56 mm with a projected sensitivity of 86.7% and projected specificity of 73.3%, while on the left side cut off value was 38.76 mm with a projected sensitivity of 93.3% and projected specificity of 63.3%. The mean maximum breadth of right side was found to be 37.16 mm+3.07 SD for females and 42.99 mm+2.51 SD for males while the mean maximum breadth of left side was found to be 37.88 mm+2.95 SD for females and 42.61 mm+2.97 SD for males. The sexual dimorphism was found to be significant statistically with a p value <0.001 for both sides. The projected cut off value on right side was 40.48 mm with a projected sensitivity of 90.0% and projected specificity of 96.7% while on left side cut off value was 39.85 mm with a projected sensitivity of 90.0% and projected specificity of 83.3%. In the present study, measurements taken on patella bone showed higher mean values for males as compared with females (p<0.001).

Keywords: Patella • Sex determination • Bone • Measurements

Introduction

There is paucity of data for sex determination from human skeleton. Sex determination is necessary in various medico legal, sexual assault cases etc. It is challenging to determine age and sex in cases of mutilated or skeletonized remains. This problem also arises in sexual crimes where genital mutilation is a common phenomenon and cases where the dead body is destroyed by scavenging activities [1]. Sex may require to be established positively in one direction or the other for the following reasons: 1) For simple identification in a living or dead person; 2) to decide whether an individual can exercise certain civil rights reserved to one sex only; 3) For deciding questions relative to legitimacy, divorce, paternity, affiliation and also to some criminal offences. Krogman (1962) comments that he scored 100 per cent accuracy in sex determination using the whole skeleton, 95% on the pelvis, 92% on the skull, 98% on the pelvis plus skull, 80% on long bones and 98% on long bones plus pelvis [2]. The uterus is the organ in the body most resistant to decomposition. However, the prostate is also quite persistent and resists putrefaction for a relatively longer duration of time. Noticeable sex differences do not become apparent until after puberty, usually in the 15-18-year period, though specialized measurements on the pelvis can indicate the sex even in foetal material [3].

Several factors inveigh against a high degree of accuracy in the sexing of

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unknown material. Among them are : (1) the often fragmentary or isolated nature of the remains available for the study; (2) the evident age (at time of death) of the remains; (3) intrinsic variability and the absence of any objective standards. The patella, from the Latin for "small plate", is a flat, inverted triangular bone situated on the front of the knee-joint [3]. In humans, the patella is the largest sesamoid bone in the body [4]. It articulates with the femur and covers and protects the anterior articular surface of the knee joint [5]. The patella ossifies from a single centre, which usually makes its appearance in the second or third year, but may be delayed until the sixth year [6]. More rarely, the bone is develops by two centres, placed side by side. Ossification is completed around the age of puberty [7].

Materials and Methods

The present study was carried out at Department of Forensic Medicine and Toxicology, Lady Hardinge Medical College. Patella bone from both right and left sides was taken out of 60 individuals (30 males and 30 females). Bones were kept in 5% sodium hypochlorite solution for a week for maceration, and then dried and following measurements were taken: Maximum Length, Maximum Width, Maximum Thickness and Lateral Articular Facet Breadth in millimetres and Weight in grams (Table 1). Statistical analysis was done using SPSS 27.0. Descriptive statistics were obtained for each measurement. Males and females were analysed separately. Using a two-sample t-test for the parametric data, the mean values of the six measurements were compared between the two sexes to

Table 1. Description of Measurements.

| Measurement | Description |
|--|--|
| Maximum Height (MH) | Greatest distance between the base and the apex |
| Maximum Breadth (MB) | Greatest distance between the medial and the lateral sides |
| Maximum Thickness (MT) | Greatest distance between the anterior and the posterior sides |
| Lateral Articular Facet Breadth (LAFB) | Distance between the lateral edge of patella and the median ridge of articular facet |
| Weight (W) | Weight of patella |

determine if statistically significant differences exist. Receiver operator curve was also applied. Discriminant Equation was obtained.

Results

Out of 60 samples included in the study, a total of 30 (50%) were taken from male and 30 (50%) were obtained from females (Table 2).

Comparison of different parameters between male and female

The mean maximum height, maximum weight, maximum thickness, lateral articular facet breadth and weight of right patella for male group were 41.54 mm ± 2.76SD, 42.99 mm ± 2.51 SD, 21.39 mm ± 1.84 SD, 26.44 mm ± 2.08 SD, and 17.87 grams ± 3.07 SD respectively (Table 3).

The mean Maximum Height, Maximum Weight, Maximum Thickness, Lateral Articular Facet Breadth and Weight of left patella for male group were 41.72 mm

± 2.62 SD, 42.61 mm ± 2.97 SD, 20.76 mm ± 1.48 SD, 25.44 mm ± 2.04 SD, and 17.95 grams ± 3.23 SD respectively (Table 4).

Comparison of different parameters between right side and left side of males

The mean maximum height, maximum width, maximum thickness, lateral articular facet breadth, and weight of right side of patella for males were 41.54 mm ± 2.76 SD, 42.99 mm ± 2.51 SD, 21.39 mm ± 1.84 SD, 26.44 mm ± 2.08 SD, and 17.87 grams ± 3.07 SD respectively (Table 5).

Comparison of different parameters between right side and left side of female

The mean maximum height, maximum width, maximum thickness, lateral articular facet breadth, and weight of right side of patella for females were 37.51 mm ± 3.17 SD, 37.16 mm ± 3.07 SD, 18.42 mm ± 1.78 SD, 21.65 mm ± 2.72 SD, 12.08 grams ± 2.14 SD respectively (Table 6).

Roc analysis for predictive efficacy of independent parameters

The Area under curve (AUC) for Maximum height, maximum width, maximum thickness, lateral articular facet breadth and weight of right patella were 0.868, 0.958, 0.900, 0.909, and 0.958 respectively. The Area under curve (AUC) for Maximum height, maximum width, maximum thickness, lateral articular facet

Table 2. Gender wise distribution of samples.

| S.No | Gender | No. of Samples | Percentage |
|------|--------|----------------|------------|
| 1 | Male | 30 | 50 |
| 2 | Female | 30 | 50 |

Table 3. Comparison of different parameters of right side between male and female.

| Parameters | Male | | Female | | p value |
|------------|--------------|---------------|--------------|-------------|---------|
| | Mean ± SD | Range | Mean ± SD | Range | |
| Right side | | | | | |
| MH | 41.54 ± 2.76 | 35.47-48.56 | 37.51 ± 3.17 | 25.75-42.32 | <0.001 |
| MW | 42.99 ± 2.51 | 37.37-47.33 | 37.16 ± 3.07 | 28.14-41.23 | <0.001 |
| MT | 21.39 ± 1.84 | 18.15 ± 27.02 | 18.42 ± 1.78 | 13.94-21.80 | <0.001 |
| LAFB | 26.44 ± 2.08 | 22.03-30.86 | 21.65 ± 2.72 | 17.25-28.29 | <0.001 |
| W | 17.87 ± 3.07 | 11.56-23.99 | 12.08 ± 2.14 | 8.05-16.17 | <0.001 |

Table 4. Comparison of different parameters of left side between male and female.

| Parameters | Male | | Female | | p value |
|------------|--------------|-------------|--------------|-------------|---------|
| | Mean ± SD | Range | Mean ± SD | Range | |
| Left side | | | | | |
| MH | 41.72 ± 2.62 | 35.86-46.88 | 37.91 ± 2.95 | 32.12-44.49 | <0.001 |
| MW | 42.61 ± 2.97 | 35.68-48.99 | 37.88 ± 2.80 | 29.41-42.60 | <0.001 |
| MT | 20.76 ± 1.48 | 17.73-24.98 | 18.36 ± 1.94 | 13.67-22.21 | <0.001 |
| LAFB | 25.44 ± 2.04 | 20.36-29.28 | 22.08 ± 2.44 | 17.30-27.37 | <0.001 |
| W | 17.95 ± 3.23 | 10.58-24.70 | 12.31 ± 2.28 | 7.99-17.22s | <0.001 |

Table 5. Comparison of different parameters between right side and left side of males.

| Parameters | Right side | | Left side | | p value |
|------------|--------------|-------------|--------------|-------------|---------|
| | Mean ± SD | Range | Mean±SD | Range | |
| MH | 41.54 ± 2.76 | 35.47-48.56 | 41.72 ± 2.62 | 35.86-46.88 | 0.80 |
| MW | 42.99 ± 2.51 | 37.37-47.33 | 42.61 ± 2.97 | 35.68-48.99 | 0.59 |
| MT | 21.39 ± 1.84 | 18.15±27.02 | 20.76 ± 1.48 | 17.73-24.98 | 0.15 |
| LAFB | 26.44 ± 2.08 | 22.03-30.86 | 25.44 ± 2.04 | 20.36-29.28 | 0.06 |
| W | 17.87 ± 3.07 | 11.56-23.99 | 17.95 ± 3.23 | 10.58-24.70 | 0.91 |

Table 6. Comparison of different parameters between right side and left side of female.

| Parameters | Right side | | Left side | | p value |
|------------|------------|-------------|------------|-------------|---------|
| | Mean ± SD | Range | Mean±SD | Range | |
| MH | 37.51±3.17 | 25.75-42.32 | 37.91±2.95 | 32.12-44.49 | 0.61 |
| MW | 37.16±3.07 | 28.14-41.23 | 37.88±2.80 | 29.41-42.60 | 0.34 |
| MT | 18.42±1.78 | 13.94-21.80 | 18.36±1.94 | 13.67-22.21 | 0.90 |
| LAFB | 21.65±2.72 | 17.25-28.29 | 22.08±2.44 | 17.30-27.37 | 0.51 |
| W | 12.08±2.14 | 8.05-16.17 | 12.31±2.28 | 7.99-17.22 | 0.68 |

breadth and weight of left patella were 00.821, 0.892, 0.859, 0.867, and 0.934 respectively (Table 7).

The cut off values for classifying males and females for maximum height, maximum width, maximum thickness, lateral articular facet breadth, and weight of right patella were 39.56 mm, 40.48 mm, 19.91 mm, 24.96 mm, and 15.16 grams respectively. The cut off values for classifying males and females for maximum height, maximum width, maximum thickness, lateral articular facet breadth, and weight of left patella were 38.76 mm, 39.85 mm, 20.02 mm, 23.45 mm, and 14.37 grams respectively (Table 8, Figures 1 and 2).

Derivation of discriminant equation and it's classifier value (Table 9).

Discriminant equation obtained:

$$DF = -0.03 \times \text{Max Height right} + 0.04 \times \text{Max Height left} + 0.163 \times \text{Max width right} - 0.05 \times \text{Max width left} + 0.114 \times \text{Max thickness right} - 0.069 \times \text{Max thickness left} + 0.332 \times \text{LAFB right} - 0.221 \times \text{LAFB left} + 0.638 \times \text{weight right} - 0.368 \times \text{weight left}$$

Classifier value for discrimination of males = $DF > 0.008$.

The discriminant function was 90% sensitive and 93.3% specific in prediction of males, for females the sensitivity could be stated as 93.3% and specificity as 90% (Table 10).

The discriminant function was 90% sensitive and 93.3% specific in prediction

Table 7. Outcome of receiver operator curve analysis for patella morphometry.

| Right | | | | | |
|-------|-----------|-------|-------------------------|---------------------------|---------------------------|
| S.No | Parameter | AUC | Projected cut-off value | Projected Sensitivity (%) | Projected Specificity (%) |
| 1 | MH | 0.868 | 39.56 | 86.7 | 73.3 |
| 2 | MB | 0.958 | 40.48 | 90.0% | 96.7% |
| 3 | MT | 0.900 | 19.91 | 83.3% | 83.3% |
| 4 | LAFB | 0.909 | 24.96 | 83.3% | 93.3% |
| 5 | W(grams) | 0.958 | 15.16 | 83.3% | 96.7% |
| Left | | | | | |
| S.No | Parameter | AUC | Projected cut-off value | Projected Sensitivity (%) | Projected Specificity (%) |
| 1 | MH | 0.821 | 38.76 | 93.3% | 63.3% |
| 2 | MB | 0.892 | 39.85 | 90% | 83.3% |
| 3 | MT | 0.859 | 20.02 | 83.3% | 86.7% |
| 4 | LAFB | 0.867 | 23.45 | 93.3% | 73.3% |
| 5 | W(grams) | 0.934 | 14.37 | 96.7% | 83.3% |

Table 8. Sensitivity, specificity, PPV, NPV, accuracy of cut off values.

| | Cut off | Sensitivity | Specificity | PPV | NPV | Accuracy |
|------------------------------|---------|-------------|-------------|--------|--------|----------|
| Maximum height right (mm) | 39.56 | 86.7% | 73.3% | 76.47% | 84.62% | 80.0% |
| Maximum width right (mm) | 40.48 | 90.0% | 96.7% | 96.43% | 90.62% | 93.33% |
| Maximum Thickness right (mm) | 19.91 | 83.3% | 83.3% | 83.3% | 83.3% | 83.3% |
| LAFB right (mm) | 24.96 | 83.3% | 93.3% | 92.6% | 84.8% | 88.3% |
| Weight right (grams) | 15.16 | 83.3% | 96.7% | 96.1% | 85.3% | 90.0% |
| Maximum height left (mm) | 38.76 | 93.3% | 63.3% | 71.8% | 90.5% | 78.3% |
| Maximum width left (mm) | 39.85 | 90% | 83.3% | 84.4% | 89.3% | 86.7% |
| Maximum thickness left (mm) | 20.02 | 83.3% | 86.7% | 86.2% | 83.8% | 85.0% |
| LAFB left (mm) | 23.45 | 93.3% | 73.3% | 77.8% | 91.7% | 83.3% |
| Weight left (grams) | 14.37 | 96.7% | 83.3% | 85.3% | 96.15% | 90.0% |

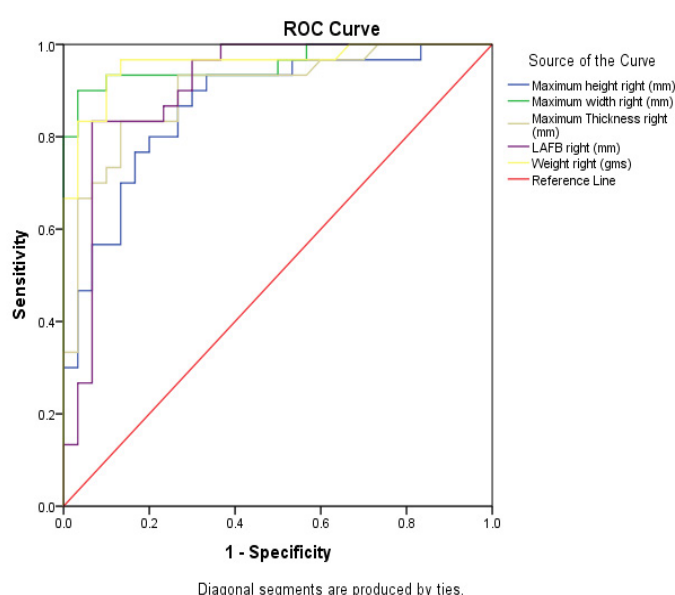


Figure 1. ROC analysis showing AUC for different patella morphometric parameters (right side).

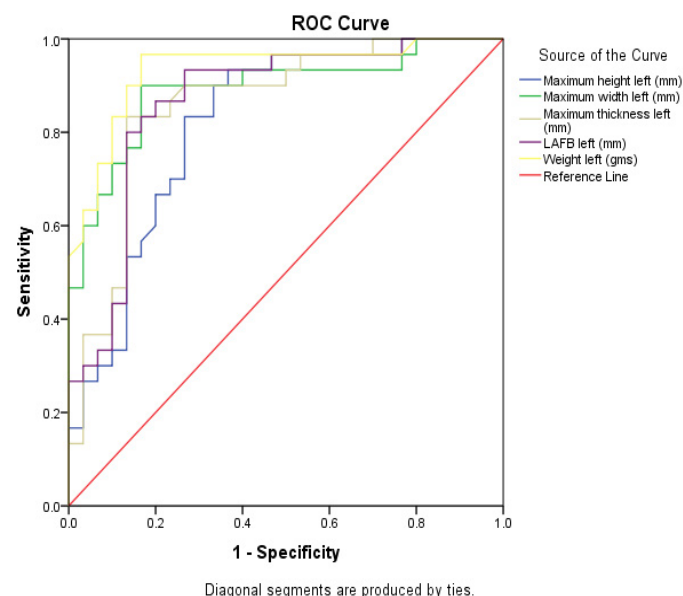


Figure 2. ROC analysis showing AUC for different patella morphometric parameters (left side).

Table 9. Derivation of discriminant equation and its classifier value.

| Function | Eigenvalue | % of Variance | Cumulative % | Canonical Correlation |
|----------|--------------------|---------------|--------------|-----------------------|
| 1 | 2.916 ^a | 100.0 | 100.0 | 0.863 |

Table 10. Predicted classification results.

| | Sex | Predicted Group Membership | | Total |
|-------|--------|----------------------------|--------|-------|
| | | Male | Female | |
| Count | Male | 27 | 3 | 30 |
| | Female | 2 | 28 | 30 |
| % | Male | 90.0 | 10.0 | 100.0 |
| | Female | 6.7 | 93.3 | 100.0 |

of males, for females the sensitivity could be stated as 93.3% and specificity as 90%.

Discussion

In the present study, measurements taken on patella bone showed higher mean values for males as compared with females ($p < 0.001$) which is consistent with previous studies [8-16]. In the present study, the mean maximum height of the right side was 37.51 mm+3.17 SD for females and 41.54 mm+2.76 SD for males, while the mean of the left side was 37.91 mm+2.95 SD for females and 42.61 mm+2.97 SD for males. The sexual dimorphism was significant statistically, with a p -value < 0.001 for both sides. The projected cut off value on the right side was 39.56 mm with a projected sensitivity of 86.7% and projected specificity of 73.3%, while on the left side cut off value was 38.76 mm with a projected sensitivity of 93.3% and projected specificity of 63.3%. The accuracy for classifying males and females based on left and right was 78.3% and 80% respectively.

The mean maximum breadth of right side was found to be 37.16 mm+3.07 SD for females and 42.99 mm+2.51 SD for males while the mean maximum breadth of left side was found to be 37.88 mm+2.95 SD for females and 42.61 mm+2.97 SD for males. The sexual dimorphism was found to be significant statistically with a p value < 0.001 for both sides. The projected cut off value on right side was 40.48 mm with a projected sensitivity of 90.0% and projected specificity of 96.7% while on left side cut off value was 39.85 mm with a projected sensitivity of 90.0% and projected specificity of 83.3%. These values are comparable with the studies done both in India and around the world. The mean maximum height values for males obtained by Akhlaghi M, et al. [8], Sakaue K [9], Kemkes-Grottenthaler A [10], Peckmann TR and Fisher B [11], Narayanan S [12], Indra L, et al. [13], Teke HY, et al. [14], Mahfouz M, et al. [15], Abdel WMA, et al. [16], Zhan, and Abdelaleem were 44.70, 41.1 mm, 43.8 mm, 44.8 mm, 41.42 mm, 44.2 mm, 46 mm, 48.4 mm, 43.2 mm and 42.27 mm respectively. Some authors have used radiological methods for studying patella. Abdel obtained a mean of 45.4 mm for females, which is higher than most other works and higher than the cut off value obtained in the current study [16]. He used radiological methods to obtain the parameters in the Egyptian population [16]. Teke HY, et al. obtained mean of 41.3 mm and 35.84 mm for males and females, respectively, using MRI images for calculation [14]. He obtained the accuracy of 87% and 91% for males and females, respectively [14]. There are variations in the accuracy using radiological methods, which needs further research.

The discriminant function obtained in current study was 90% sensitive and 93.3% specific in prediction of males, for females the sensitivity could be stated as 93.3% and specificity as 90%. The accuracy of discriminant function obtained by Peckmann TR and Fisher B [11], Indra L, et al. [13], Mahfouz M, et al. [15], Moneim WMA, et al. [16] were 85%, 85.5%, 90.3%, 87.5% and 91.4% respectively. Accuracy obtained by the present study is more or less similar to other studies.

Conclusion

In all the cases, all the parameters of patella of both sides, the difference in mean values of males and females was statistically significant ($p < 0.001$). These findings imply that single value of patella parameters can also be used for identification of gender. Using these techniques, the determination of sex can be accomplished by comparing the dimension of unknown patella bone with the cut off value for the population of New Delhi.

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