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OSTEOMETRIC ANALYSIS OF PATELLA FOR SEXUAL DIMORPHISM

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ABSTRACT

Identification is the act of establishing the identity. The establishment of identity may be required upon in cases of fresh corpses, decomposed corpses, mutilated, dismembered corpses and skeletonised material. The pelvic bone and skull are the first choices for morphological sexing if not recovered in fragmentary states. If pelvic bones and skull are recovered in a fragmentary state, other bones such as the patella can be used for sex determination from osteometric analysis. The present study shows that there are definite sexual osteometric differences between male and female patella bones from the population of Haryana. For both sides, MAXH had the maximum AUC (0.971 for right and 0.980 for left side), thus indicating it can be used for differentiation between males and females. For right and left sides, the projected sensitivity of MAXH was 97% and 98% respectively and projected specificity was 89.1% and 85.6% respectively. These findings implied that single value of patella parameters can be used for differentiation in 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 Haryana. The present study produced standard for sex determination from patella. Therefore, these new standard will be useful for forensic experts.

KEYWORDS: MAXH, MAXB, MAXT.

INTRODUCTION

Identification is the act of establishing the identity. The establishment of identity may be required upon in cases of fresh corpses, decomposed corpses, mutilated, dismembered corpses and skeletonised material.[1] Mutilation of the dead body is either done by criminal to destroy all traces of identity and thus facilitate the disposal of the dead[2] or it may be caused by scavengers. It is not easy to determine the age and sex in cases of mutilated or skeletonised remains. This problem also arises in sexual crimes where genital mutilation is common phenomenon and also in cases where dead body is destroyed by scavenging activities.

There are two methodological approaches to sexing human remains: morphological and osteometric. Morphologic techniques focus on the shape of the bony configurations that are macroscopically visible and differ between males and females.[4] Osteometric analysis, based on bone dimensions, is the method of choice for skeletal parts like long bones that do not exhibit clearly definable shape variants. Most of the older studies of sex differences in the skeleton (skull and pelvis mainly) centred on morphological traits in a descriptive manner. The newer studies focus on morphometry in a largely quantitative and statistical sense.[3]

The pelvic bone and skull are the first choices for morphological sexing if not recovered in fragmentary states. If pelvic bones and skull are recovered in a fragmentary state, other bones such as the patella can be used for sexual dimorphism using metric analysis. Morphological and metric features of some bones that display sexual differences have been described.[5] These include the pelvis[6], the cranium[7], bones of the upper[8] and lower limbs.[9] Recently, there has been an increased interest in the use of metrical methods in sex assignment. The most commonly used metrical method is discriminant function analysis.[9] Nearly every bone has been subjected to discriminant function analysis[9] but not much literature has been found on the usefulness of measurements of the patella in the determination of sex using this method. Forensic anthropologists often do not have the luxury of being presented with complete skeleton for analysis in personal identification. As most forensic cases presented to forensic anthropologists are not always complete, other bones like patella could be used for sex determination as in this study.

Ossification of the patella

The patella ossifies from a single center, which usually makes its appearance in the second or third year, but may be delayed until the sixth year. More rarely, the bone is

develops by two centers, placed side by side. Ossification is completes around the age of puberty.[10]

MATERIALS AND METHODS

The present study was undertaken in the Department of Forensic Medicine, Pandit Bhagwat Dayal Sharma Post Graduate Institute of Medical Sciences, Rohtak, Haryana. A total of 400 subjects including both sexes were chosen during postmortem examination. Only intact patellae from known sex subjects were chosen for the study however patellae showing any signs of pathology and showing any kind of abnormality (congenital as well as acquired) were excluded from the study.

Measurements

The following measurements of each patella were taken to know the sexual dimorphism:-

1. Maximum height (MAXH)—the greatest distance between the base and apex.
2. Maximum breadth (MAXB)—the greatest distance between the medial and lateral sides.
3. Maximum thickness (MAXT)—the greatest distance between the anterior and posterior surface.

OBSERVATIONS AND RESULTS

For this purpose 400 specimen were taken from the two genders.

Table 1: Shows gender wise distribution of samples:-

Table 1: Gender wise distribution of samples.

SN	Gender	No. of samples	Percentage
1	Male	199	49.8
2	Female	201	50.2

Out of 400 samples included in the study, a total of 199 (49.8%) were taken from male and 201 (50.2%) were obtained from females.

Table 2: Shows age and gender wise comparison of samples obtained in two groups:-

Table 2: Age wise Comparison of two groups.

Age group	Total	Males (n=199)		Females (n=201)	
		No.	%	No	%
≤18 Yrs	18	7	3.5	11	5.5
18-40 Yrs – Young adult	276	115	57.8	161	80.1
40-60 Yrs – Middle age	88	64	32.2	24	11.9
≥60 Yrs – Old age	18	13	6.5	5	2.5

χ^2=30.284 (df=3); p<0.001.

Majority of samples, irrespective of gender were in the age group 18-40 years, however, proportion of samples in age group ≥40 years was higher in males (38.7%) as compared to females (14.4%). Statistically, this difference was significant (p<0.001).

Table 3: Shows comparison of different parameters according to gender:-

Table 3: Comparison of different parameters according to gender.

Parameter	Female (n=201)			Male (n=199)			Significance	
	Range	Mean	SD	Range	Mean	SD	t	P
Right side								
MAXH	45.7-31.11	35.90	2.73	50.84-35.33	43.18	2.81	-26.245	<0.001
MAXB	40.8-30.03	36.13	3.00	52.86-34.14	42.36	2.96	-20.891	<0.001
MAXT	22.31-14.05	18.35	1.83	25.75-17.11	21.74	1.72	-19.060	<0.001
Left side								
MAXH	41.62-30.14	35.19	2.82	50.31-34.28	42.76	2.93	-26.334	<0.001
MAXB	41.61-30.14	35.86	3.32	52.18-31.37	41.92	2.92	-19.393	<0.001
MAXT	22.35-14.1	18.14	1.74	25.79-18.01	21.19	1.76	-17.448	<0.001

For all the parameters at both the sides, the difference in mean values of males and females was significant statistically. It was observed that for all parameters males had higher mean value as compared to females (p<0.001).

Table 4: Shows impact of Age (Males) (n=199):-

Table 4: Impact of Age (Males) (n=199).

Parameter	≤18Yrs (n=7)		18-40 Yrs (n=115)		40-60 Yrs (n=64)		≥60 Yrs (n=13)		ANOVA	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	P
Right side										
MAXH	43.44	2.83	43.00	2.67	43.14	3.07	44.84	2.40	1.714	0.165
MAXB	41.70	2.07	42.24	2.68	42.54	3.54	42.88	2.72	0.396	0.756
MAXT	22.73	1.93	21.72	1.68	21.61	1.74	21.93	1.93	0.933	0.426
Left side										
MAXH	42.92	3.57	42.60	2.76	42.67	3.15	44.46	2.67	1.619	0.186
MAXB	41.12	2.57	41.75	2.79	42.09	3.09	43.01	3.28	0.993	0.397
MAXT	21.89	2.29	21.24	1.65	20.96	1.82	21.49	2.05	0.895	0.445

Among males no significant differences in measurements across different age groups were observed on all the parameters.

Table 5: Shows impact of Age (Females) (n=201):-

Table 5: Impact of Age (Females) (n=201).

Parameter	≤18 Yrs (n=11)		18-40 Yrs (n=161)		40-60 Yrs (n=24)		≥60 Yrs (n=5)		ANOVA	
	Mean	SD	Mean	SD	Mean		Mean	SD	F	P
Right side										
MAXH	34.94	2.00	35.99	2.75	35.65	2.90	36.27	2.99	0.607	0.611
MAXB	35.42	2.74	36.24	3.07	35.71	2.84	36.21	2.52	0.425	0.735
MAXT	18.28	2.21	18.44	1.75	17.96	1.93	17.62	3.02	0.763	0.516
Left Side										
MAXH	34.21	2.28	35.31	2.83	34.81	2.91	35.30	3.52	0.687	0.561
MAXB	35.05	2.96	35.97	3.40	35.37	3.08	36.19	2.86	0.470	0.704
MAXT	17.93	1.59	18.19	1.71	18.05	1.91	17.23	2.66	0.568	0.637

Among females too, statistically no significant difference in mean values of different parameters was observed among different age groups.

However, in order to reconfirm that age does not change the nature of difference between males and females for different parameters, a comparison of different parameters between males and females was also made for different age groups as shown in Tables 6 to 9.

Table 6: Shows comparison of different parameters according to gender in age group ≤18 Yrs:-

Table 6: Different parameters according to gender in age group ≤18 Yrs.

Parameter	Male (n=7)		Female (n=11)		Significance	
	Mean	SD	Mean	SD	T	P
Right side						
MAXH	43.44	2.83	34.94	2.00	7.49	<0.001
MAXB	41.70	2.07	35.42	2.74	5.17	<0.001
MAXT	22.73	1.93	18.28	2.21	4.37	<0.001
Left side						
MAXH	42.92	3.57	34.21	2.28	6.35	<0.001
MAXB	41.12	2.57	35.05	2.96	4.45	<0.001
MAXT	21.89	2.29	17.93	1.59	4.34	0.001

In age group ≤18 years, a significant difference in mean measurements of different parameters was observed for all the parameters at both the sides.

Table 7: Comparison of different parameters according to gender in age group 18-40 Yrs:-

Table 7: Different parameters according to gender in age group 18-40 Yrs.

Parameter	Male (n=115)		Female (n=161)		Significance	
	Mean	SD	Mean	SD	T	P
Right side						
MAXH	43.00	2.67	35.99	2.75	21.10	<0.001
MAXB	42.24	2.68	36.24	3.07	16.87	<0.001
MAXT	21.72	1.68	18.44	1.75	15.65	<0.001
Left side						
MAXH	42.60	2.76	35.31	2.83	21.35	<0.001
MAXB	41.75	2.79	35.97	3.40	14.96	<0.001
MAXT	21.24	1.65	18.19	1.71	14.84	<0.001

In age group 18-40 years, a significant difference in mean measurements of different parameters was observed for all the parameters at both the sides. Thus the trend was same as for ≤18 years age group.

Table 8: Comparison of different parameters according to gender in age group 40-60 Yrs:-

Table 8: Different parameters according to gender in age group 40-60 Yrs.

Parameter	Male (n=64)		Female (n=24)		Significance	
	Mean	SD	Mean	SD	T	P
Right side						
MAXH	43.14	3.07	35.65	2.90	10.35	<0.001
MAXB	42.54	3.54	35.71	2.84	8.47	<0.001
MAXT	21.61	1.74	17.96	1.93	8.51	<0.001
Left side						
MAXH	42.67	3.15	34.81	2.91	10.63	<0.001
MAXB	42.09	3.09	35.37	3.08	9.08	<0.001
MAXT	20.96	1.82	18.05	1.91	6.59	<0.001

In age group 40-60 years, a significant difference in mean measurements of different parameters was observed for all the parameters at both the sides.

Table 9: Comparison of different parameters according to gender in age group ≥60 Yrs:-

Table 9: Different parameters according to gender in age group ≥60 Yrs.

Parameter	Male (n=13)		Female (n=5)		Significance	
	Mean	SD	Mean	SD	T	P
Right side						
MAXH	44.84	2.40	36.27	2.99	6.36	<0.001
MAXB	42.88	2.72	36.21	2.52	4.75	<0.001
MAXT	21.93	1.93	17.62	3.02	3.63	0.002
Left side						
MAXH	44.46	2.67	35.30	3.52	5.99	0.000
MAXB	43.01	3.28	36.19	2.86	4.09	0.001
MAXT	21.49	2.05	17.23	2.66	3.64	0.002

In age group ≥60 years, a significant difference in mean measurements of different parameters was observed for all the parameters at both the sides.

These evaluations suggested that within gender, age has no significant impact on patella morphometry; however, between genders statistically significant differences were observed for all the patella parameters. These findings implied that single value of patella parameters can be used for differentiation in gender. However, within same gender, patella morphometry parameters have a little or no role in age determination.

Roc Analysis for Predictive Efficacy of Independent Parameters

Table 10: Outcome of Receiver Operator Curve analysis for Patella morphometry in prediction of male gender:- Cut-off values ≥.

SN	Parameter	AUC	Projected cut-off value	Projected Sensitivity (%)	Projected Specificity (%)
Right Side					
1	MAXH	0.971	39.185	97.0	89.1
2	MAXB	0.954	39.105	92.5	80.1
3	MAXT	0.921	19.81	87.9	82.1
Left Side					
1	MAXH	0.970	38.32	98.0	85.6
2	MAXB	0.927	38.635	93.5	80.1
3	MAXT	0.906	19.175	94.0	80.1

For both sides, MAXH had the maximum AUC (0.971 for right and 0.980 for left side), thus indicating it can be used for differentiation between males and females. For right and left sides, the projected sensitivity of MAXH was 97% and 98% respectively and projected specificity was 89.1% and 85.6% respectively.

DISCUSSION

1. For this purpose **400 samples (cases)** were obtained from the two genders with 199 samples (49.8%) from males and 201 samples (50.2%) from females. Patellae of both sides were taken from each case and three variables were measured from each patella.
2. The **comparison of four age groups** of both sex were made. Four age groups were ≤18 yrs, 18-40 yrs (young adult), 40-60 yrs (middle age) and ≥60 yrs (old age). Majority of the samples were in the age group 18-40 yrs, however proportion of samples in age group ≥40 yrs was higher in males (38.7%) as compared to females (14.4%).
3. Comparison of different **parameters** of patella bone were made according to gender:-

Measurements taken on patella bone showed higher mean values for males as compared with females ($p<0.001$) which is consistent with previous study.[14]

a. Maximum height (MAXH) - the greatest distance between the base and apex

In the present study, the mean MAXH of right side was found to be 35.90mm±2.73SD for females and 43.18mm±2.81SD for males while the mean MAXH of left side was found to be 35.19mm±2.82SD for females and 42.76mm±2.93SD 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 39.185mm with a projected sensitivity of 97% and projected specificity of 89.1% while on left side cut off value was 38.32mm with a projected sensitivity of 98% and projected specificity of 85.6% which is consistent with the previous studies done by Rathbun and Rathbun[11] and O'Connor in her final Master thesis.[12]

b. Maximum breadth (MAXB) - the greatest distance between the medial and lateral sides

The mean MAXB of right side was found to be 36.13mm±3SD for females and 42.36mm±2.96SD for males while the mean MAXB of left side was found to be 35.86mm±3.32SD for females and 41.92mm±2.92SD 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 39.105mm with a projected sensitivity of 92.5% and projected specificity of 80.1% while on left side cut off value was 38.635mm with a projected sensitivity of 93.5% and projected specificity of 80.1% which is consistent with the previous studies done by Rathbun and Rathbun[11] and O'Connor in her final Master thesis.[12]

c. Maximum thickness (MAXT) - the greatest distance between the anterior and posterior surface

The mean MAXT of right side was found to be 18.35mm±1.83SD for females and 21.74mm±1.72SD for males while the mean MAXT of left side was found to be 18.14mm±1.74SD for females and 21.19mm±1.76SD 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 19.81mm with a projected sensitivity of 87.9% and projected specificity of 82.1% while on left side cut off value was 19.175mm with a projected sensitivity of 94% and projected specificity of 80.1% which is consistent with the previous studies done by O'Connor in her final Master thesis[12] and Introna & co-workers.[13]

4. Impact of age

No significant statistical differences in measurements across different age groups were observed on all the parameters in both males and females.

5. Comparision of different parameters according to gender in different age groups

- In all (n=400) cases, a significant difference in mean measurements of different parameters was observed for all the parameters at both the sides in all age groups (≤18, 18-40, 40-60, ≥60yrs).

These evaluations suggested that within gender, age has no significant impact on patella morphometry, however, between genders statistically significant differences were observed for all the patella parameters. These findings implied that single value of patella parameters can be used for differentiation in gender; however, within same gender patella morphometry parameters have a little or no role in age determination.

6. Outcome of Receiver Operator Curve analysis for Patella morphometry in prediction of male gender

For both sides, MAXH had the maximum AUC (0.971 for right and 0.980 for left side), thus indicating it can be used for differentiation between males and females. For right and left sides, the projected sensitivity of MAXH was 97% and 98% respectively and projected specificity was 89.1% and 85.6% respectively.

7. The **discriminant function** was 96% sensitive and 93.5% specific in prediction of males, for females the sensitivity could be stated as 93.5% and specificity as 96%.

The present study shows that there are definite sexual osteometric differences between male and female patella bones from the population of Haryana. The present study suggested that within gender, age has no significant impact on patella morphometry; however, between genders statistically significant differences were observed for all the patella parameters. For both sides, MAXH had the maximum AUC, thus indicating it can be used for differentiation between males and females. These findings implied that single value of patella parameters can be used for differentiation in 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 Haryana. The present study produced standard for sex determination from patella. Therefore, these new standard will be useful for forensic experts.

CONCLUSION & SUMMARY

a) For all the parameters (in all the cases) at both the sides in all the age groups, the difference in mean values of males and females was statistically significant. For all parameters males had higher mean value as compared to females ($p<0.001$).
b) The study suggested that between genders, statistically significant differences were observed for all the patella parameters. These findings implied that single values of patella parameters can be used for differentiation in gender.
c) For both sides, MAXH had the maximum AUC (0.971 for right and 0.980 for left side), thus indicating it can be used for differentiation between males and females. For right and left sides, the projected sensitivity of MAXH was 97% and 98% respectively and projected specificity was 89.1% and 85.6% respectively.

To conclude, the present study shows that there are definite sexual osteometric differences between male and female patella bones from the population of Haryana and suggested that between genders statistically significant differences were observed for all the patella parameters. These findings implied that single value of patella parameters can be used for differentiation in 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 Haryana.

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