Sexing Of The Adult Hip Bone

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Abstract : The hip bone is the most commonly used bone in medicolegal examination for the determination of sex of human skeletal remains. In recent studies it was observed that many of the commonly used parameters were not much reliable. The aim of the present study was to develop a parameter which is easy to apply and can determine the sex in most of the hip bones with 100% accuracy. The material of the study consisted of 210 adult hip bones from individuals of known sex (147 male and 63 female). The following four linear measurements were taken which reflected the differences in size of the pelvic cavity in the two sexes (i.e., length of the arcuate line ; length of the ilial part of arcuate line, length of the sacropelvic line and height of the pelvic cavity). All these measurements showed statistically significant differences ($P < 0.001$) between males and females. However, when "demarking points" (DPs) of these parameters were worked out, these were of little value in the identification of sex. Therefore, three indices based on the above four linear measurements were developed i.e., "height of pelvic cavity / length of arcuate line" ; "height of pelvic cavity / length of ilial part of arcuate line" and "length of sacropelvic line / length of arcuate line". When DPs of these indices were worked out it was revealed that the index "height of pelvic cavity / length of arcuate line" was an excellent parameter, which identified 78% of male and 88% of female hip bones of right side and 74% of male and 77% of female hip bones of left side.

Key words : Sex determination ; demarking points, medicolegal examination, height of pelvic cavity, arcuate line

Introduction :

As compared to other bones of the body the hip bone provides most skeletal differences between the sexes. This is due to the fact that the female pelvis is specially adopted for child bearing. Because of this reason, the hip bone has been the most frequently used bone for sexing of the human skeleton. Many researchers have developed various metrical parameters and indices for the determination of sex (for example Derry, 1923 ; Straus, 1927 ; Washburn, 1949 ; Davivong, 1963 ; Jovanovic and Zivanovic, 1965 ; Jovanovic et al, 1968 ; Singh and Potturi, 1978 ; Schulter Ellis, 1983 ; Turner, 1986).

Three commonly used parameters by Derry (chilotic line index), Washburn (ischio-pubic index) and Schulter Ellis (acetabulum-pubic index) claimed to identify sex in a high percentage of hip bones. Using the chilotic line index Derry (1923) sexed 40% of the hip bones, while Washburn (1949) claimed that 84% male and 100% female American skeletons could be identified by using his ischio-pubic index. Schulter Ellis (1983) could determine sex in 97% of cases in both American Whites and Blacks by using the acetabulum-pubic index.

The reliability of many commonly used parameters was evaluated on a large number of hip bones by Mewa Lal (1993). He found that most of these parameters when, subjected to vigorous statistical analysis, were not effective. For example by using the three most commonly used parameters i.e., acetabulum - pubic index, ischio-pubic index and chilotic line index he was able to sex very few hip bones after their "demarking points" (DPs) were determined (vide infra). Pal et al. (2002) had the same results when they checked the reliability of above three parameters. They found that the chilotic line index could identify only 11.29% of the female and 9.09% of the male bones, while ischio-pubic index could sex only 17.7% of the females and 27.27% of the males. Surprisingly, the acetabulum - pubic index could identify only a few male bones (12.58%) but could not identify a single female bone. The possible reasons for this discripancy are analysed in the Discussion paragraph.

The only available parameter which could identify a large number of bones (up to 88% of right and 75% left male bones and 100% of the right and 92% of the left female bones) was based on measurements of the greater sciatic notch (Singh and Potturi, 1978). However, the drawbacks of this study were that : it used the tip of ischial spine as a landmark which is usually broken in bones when they are received for medicolegal examination, a triflanged stainless steel caliper is needed to measure the angle of the sciatic notch, and that these angles were to be reconstructed on paper.

The aim of the present study was to develop indicators which are easy to apply and can determine the sex of large percentage of bones.

Materials And Methods :

Material for the study consisted of 210 adult hip bones from individuals of known sex out of which 147 were from males (74 of the right and 73 of the left

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side) and 63 from females (33 right and 30 left side bones). These bones were obtained from various sources i.e., Medicolegal Institute, Government of Madhya Pradesh, Bhopal ; Department of Forensic Medicine, Gandhi Medical College, Bhopal ; Rukmanibai Gardi Medical College, Ujjain and Modern Dental College and Research Centre, Indore. Only those bones were choosen for study which were intact and free from any pathalogical or congenital anomaly.

Based on general observations that the female pelvis is broad and shallow while male is narrow and deep, the following linear measurements were defined. The measurements were recorded in centimeters.

Length of the arcuate line : This was measured by a twine thread between the points A and C (Fig. 1). Point A was obtained by extending the anterior end of arcuate line to the nearest point on the posterior margin of symphyseal surface of pubis. Point C was obtained by extending the curved indistinct posterior end of arcuate line to the nearest point on the anterior auricular margin (Fig. 1).

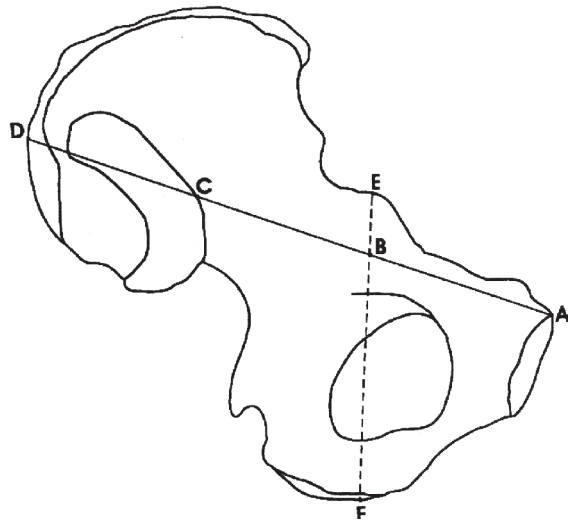

Fig. 1 : The sacropelvic surface of hip bone showing various parameters.
AC - length of arcuate line ; BC - length of ilial part of arcuate line ;
CD - length of sacropelvic line and EF - height of pelvic cavity.

Length of ilial part of arcuate line : This was measured between point B and C (Fig. 1). Point B was marked on arcuate line by dropping a vertical line from the most prominent part of iliopubic eminence.

The arcuate line being a curved one, was measured by a twine thread between point A and C (arcuate line) and between B and C (ilial part of arcuate line). These points were marked on the thread and distances were measured in centimeters.

Length of the sacropelvic line : This line was measured between points C and D (Fig. 1) and was obtained by extending the curved arcuate line posteriorly, from anterior auricular margin (point C) to the nearest point on iliac crest (point D). This measurement was taken by a sliding Caliper.

Height of pelvic cavity : This was measured between points E and F with the help of a sliding caliper. Point E was taken as the highest point on iliopubic eminence and the point F was located farthest from point E on ischial tuberosity (Fig. 1).

The data obtained for each parameter was analysed statistically to find the range, mean and standard deviation (S.D.) in both the sexes. The student 't' test was applied to know whether these differences of means between two sexes were statistically significant. These parameters were then subjected to demarking points (DPs) analysis. The DPs analysis indicated that the four parameters above were of little value for identification of sex. Therefore, based on the above four linear measurements the following three indices were defined. These indices reflected the functional differences between the pelves of the two sexes.

a. $\frac{\textit{Height of pelvic cavity x 100}}{\textit{Length of arcuate line}}$

b. $\frac{\textit{Height of pelvic cavity x 100}}{\textit{Length of ilial part of arcuate line}}$

c. $\frac{\textit{Sacropelvic line x 100}}{\textit{Length of arcuate line}}$

Values of different indices were drawn in the form of squared bar diagrams where the abscissa represented the values and the ordinate the number of cases. The results for both the sexes were drawn in the same diagram, so that the number of cases for each sex and the overlapping range could easily discerned (Figs. 2 & 3). For every index range, mean

and S.D. were calculated. The DPs were worked out in the line with Jit and Singh (1966). The effectivness of each index was assessed by calculating the percentage of male and female bones selected by each DP for that index.

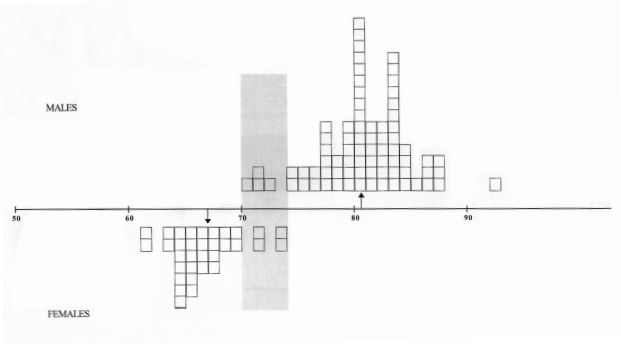

Fig. 2 : Squared bar diagram of the index "height of pelvic cavity / length of arcuate line" of the hip bones of the right side. The abscissa represents the values and the ordinate the number of cases. The arrow points to the mean value and stippled area indicates the number of overlapping cases of both sexes.

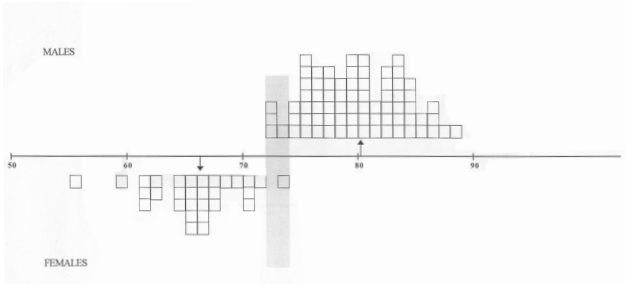

Fig. 3 : Squared bar diagram of the index "height of pelvic cavity / length of arcuate line" of the hip bones of the left side.

Results :

The linear measurements for right and left hip bones are presented in Table 1 (pooled left and right male hip bones) and Table 2 (pooled left and right female hip bones). No statistical significant difference was observed between the right and the left hip bones in both the sexes. Table 3 presents the comparison of measurements of the various parameters in the males and the females on the right side. Data of similar measurements on the left side, are presented in Table 4. The student 't' test revealed statistical significant differences of the various measurements i.e., height of pelvic cavity and length of the sacropelvic line was significantly more in the males, while the total length of arcuate line and the ilial part of arcuate line was more in the females. But, when DPs for each parameter were worked out it was found that these parameters were of little value in determination of the sex.

Table 5 presents the range, mean, SDs and identification points of various indices in the male and in the female hip bones of the right side. Table 6 presents data of similar indices of the hip bones of the left side. All three indices showed statistically significant differences between the male and the female hip bones. The index "height of pelvic cavity / length of arcuate line" on right side was significantly higher in males ($P < 0.001$). The index varied from 71-92 with a mean of 80.77± 3.55 in hip bones of right side in the males, while in the females it ranged from 62-74 with a mean of 67 ± 3.70.. Since none of the female bones had an index more than 74, any hip bone having index more than 74 (identification point) could be assigned as male hip bone. Similarly, the lowest index for male hip bone (71) was the identification limit for females i.e., any bone below the index of 71 was assigned as a female hip bone . By this method 94.59% of the male and 87.87% of the female hip bones could be identified. (Table 5). The remaining hip bones (4 female & 4 male) could not be identified because they lay within the overlapping zone (i.e., between 71 and 74) (Fig. 2). Where as, on the left side 1 female and 4 male hip bones could not be identified as they were in the overlapping zone i.e., between 73 and 74 (Table 6 and Fig. 3). However, it may so happen that these identification points may not determine the sex of an unknown bone (i.e., from out side the sample) with accuracy (see "Discussion"). Hence, to overcome this problem DPs for all the three indices were worked out.

Table 7 shows the calculated range, DPs and percentage of bones identified by DPs in the males and the females on the right side. The calculated range for various indices was obtained by substracting and adding 3 S.D. to the mean (Mean ± 3 S.D.). The calculated range for the index "height of pelvic cavity / length of arcuate line" on right side, was between 70.12 to 91.42 in males while the index for the females was between 55.90 to 78.10. Thus any hip bone having an index more than 78.10 was assigned as male and that below 70.12 was identified as female with 100% accuracy. With the help of this index 78.37% of male and 87.87% of right hip bones in the females could be identified. Similarly, on the left side 74.28% of hip bones in the males and 76.66% of hip bones in the females could be identified (Table 8). However, the other two indices ("height of pelvic cavity

/ ilial part of arcuate line" and "sacropelvic line / length of arcuate line") could identify only a few of the hip bones in both the sexes (Table 7 and 8), thus they were of little use.

Table 1
Measurements of various parameters in 74 right and 73 left male hip bones, in centemeters.

		Length of Arcuate Line	Length of Ilial Part of Arcuate Line	Length of Sacropelvic Line	Height of Pelvic Cavity
Right Side	Range	10.80 - 13.80	5.10 - 6.90	5.10 - 7.90	8.70 - 11.60
	Mean	12.30	6.10	6.60	9.90
	S.D.	0.65	0.43	0.52	0.52
Left Side	Range	11 - 14.10	5 - 7.60	5.50 - 7.70	8.80 - 11
	Mean	12.30	6.10	6.60	9.90
	S.D.	0.74	0.57	0.51	0.53
	'T' Test (Right / Left)	0	0	0	0

Table 2
Measurements of various parameters in 33 right and 30 left females hip bones, in centimeters

		Length of Arcuate Line	Length of Ilial Part of Arcuate Line	Length of Sacropelvic Line	Height of Pelvic Cavity
Right Side	Range	11.60 - 14.40	5.40 - 7.50	5.20 - 6.70	7.80 - 10
	Mean	13.06	6.50	5.80	8.80
	S.D.	0.74	0.53	0.72	0.44
Left Side	Range	12 - 15.70	5.40 - 8	4.20 - 6.50	7.80 - 9.70
	Mean	13.20	6.70	5.80	8.80
	S.D.	0.84	0.61	0.50	0.47
	'T' Test (Right / Left)	0	0	0	0

Table 3
Comparision of the measurements for various parameters in the males and the females on right side

(Male = 74, Female = 33)

		Height of Pelvic Cavity	Length of Arcuate Line	Ilial part of Arcuate Line	Length of Sacropelvic Line
Males	Range	8.70 - 11.60	10.80 - 13.80	5.10 - 6.90	5.10 - 7.90
	Mean	9.90	12.30	6.10	6.60
	S.D.	0.52	0.65	0.43	0.52
Females	Range	7.80 - 10	11.60 - 14.40	5.40 - 7.50	5.20 - 6.70
	Mean	8.80	13.06	6.50	5.80
	S.D.	0.44	0.74	0.53	0.72
	'T' Test (Male / Female)	11.70	5.10	3.70	4.18
	P Value	P < 0.001	P < 0.001	P < 0.001	P < 0.001

Table 4
Comparision of the measurements for various parameters in the males and the females on left side

(Male = 70, Female = 30)

		Height of Pelvic Cavity	Length of Arcuate Line	Ilial part of Arcuate Line	Length of Sacropelvic Line
Males	Range	8.80 - 11	11 - 14.10	5.76	5.50 - 7.70
	Mean	9.90	12.30	6.10	6.60
	S.D.	0.53	0.74	0.57	0.51
Females	Range	7.80 - 9.70	12 - 15.70	5.40 - 8	4.20 - 6.50
	Mean	8.80	13.20	6.70	5.80
	S.D.	0.47	0.84	0.61	0.50
	'T' Test (Male / Female)	11.00	5.29	5.00	7.54
	P Value	P < 0.001	P < 0.001	P < 0.001	P < 0.001

Table 5
Range, mean, S.D. and identification point (I.P.) of various indices in the two sexes on the right side

		Ht. of P.C. x 100 / Length of Arc. Line	Ht. of P.C. x 100 / Ilial Part of Arcuate Line	Sacropelvic line x 100 / Length of Arcuate Line
Males	Range	71 - 92	136 - 194	42 - 62
	Mean	80.77	163.20	53.50
	S.D.	3.55	11.10	4.33
	I.P.	> 74	> 166	> 53
	% Identified	94.59%	37.83%	53.00%
Females	Range	62 - 74	114 - 166	33 - 53
	Mean	67.00	133.80	44.50
	S.D.	3.70	11.35	4.44
	I.P.	< 71	< 136	< 42
	% Identified	87.87%	60.60%	27.00%
	'T' Value (Male / Female)	18.11	12.50	9.78
	P Value	P < 0.001	P < 0.001	P < 0.001

Table 6
Range, mean, S.D. and identification point (I.P.) of the various indices in the two sexes on left side

		Ht. of P.C. x 100 / Length of Arc. Line	Ht. of P.C. x 100 / Ilial Part of Arcuate Line	Sacropelvic line x 100 / Length of Arcuate Line
Males	Range	73 - 89	136 - 196	44 - 63
	Mean	80.37	163.70	53.90
	S.D.	4.03	14.32	4.01
	I.P.	> 74	> 164	> 51
	% Identified	94.52%	45.71%	72.80%
Females	Range	56 - 74	108 - 164	32 - 51
	Mean	66.30	131.70	43.7
	S.D.	3.79	12.92	4.92
	I.P.	< 73	< 136	< 44
	% Identified	96.66%	63.33%	50.00%
	'T' Value (Male / Female)	16.80	10.95	10.20
	P Value	P < 0.001	P < 0.001	P < 0.001

Table 7
Demarking points for the various indices on the right side

S. No.	Index	Sex	Mean + S.D.	Calculated Range (Mean + 3 S.D.)	Demarking Points (D.P.)	Percentage beyond D.P.
1.	Ht. of Pel. Cavity x 100 / Arcuate Line	M	80.77 ± 3.55	70.12 - 91.42	> 78.10	78.37%
		F	67.00 ± 3.70	55.90 - 78.10	< 70.12	87.87%
2.	Ht. of Pel. Cavity x 100 / Ilial. Part of Arcuate Line	M	163.20 ± 11.10	129.90 - 196.50	> 167.85	31.08%
		F	133.80±11.35	99.75 - 167.85	< 129.90	30.30%
3.	Sacropelvic Line x 100 / Arcuate Line	M	53.50 ± 4.33	40.51 - 66.49	> 57.82	20.27%
		F	44.50 ± 4.44	31.18 - 57.82	< 40.51	24.20%

Table 8
Demarking points for the various indices on the left side

S. No.	Index	Sex	Mean + S.D.	Calculated Range (Mean + 3 S.D.)	Demarking Points (D.P.)	Percentage beyond D.P.
1.	Ht. of Pel. Cavity x 100 / Arcuate Line	M	80.37 ± 4.03	68.28 - 92.46	> 77.67	74.28%
		F	66.30 ± 3.79	54.93 - 77.67	< 68.28	76.66%
2.	Ht. of Pel. Cavity x 100 / Ilial. Part of Arcuate Line	M	163.70 ± 14.32	120.74 - 206.66	> 170.46	31.40%
		F	131.70±12.92	92.94 - 170.46	< 120.74	16.66%
3.	Sacropelvic Line x 100 / Arcuate Line	M	53.90 ± 4.01	41.87 - 65.93	> 58.46	12.85%
		F	43.70 ± 4.92	28.94 - 58.46	< 41.87	23.33%

Discussion :

As stated earlier the findings of Mewa Lal (1993) and Pal et al (2002) have indicated that the most commonly used indices (chilotic line, ischio-pubic and acetabulum - pubic), for determination of sex from the hip bones, were of little value when subjected to DP analysis. To certain extent this might be because of racial variation but, the main cause may be that these authors used limiting points, based on overlapping range of their own samples and did not subject their data to more vigorous statistical analysis (Singh and Potturi, 1978). Limiting points (identification points) for all the three indices of the present study are presented in Table 5 and 6. The overlapping range of males and females for the index "height of pelvic cavity / length of arcuate line" for right and left side hip bones are given in the form of squared bar diagrams (Figs. 2 and 3). These limiting or identification points are good only for the bones of the present study. The above mentioned limiting points may not give correct identification of sex when applied to some other unknown bones of the same area, population or race. This is due to the fact that the biological variables may show wide variations which the limiting points may not cover, even if the sample size is large. This problem may easily be overcome by substracting and adding the three SDs to the mean value (± 3 S.D.). The mean ± 3 S.D. will give the range that covers 99.75% of the population of that area (Rao, 1962). The range thus obtained (Mean ± 3 S.D.), known as calculated range (Tables 7 and 8) and the limiting points determined on the basis of this range are the "demarking points" (Jit and Singh, 1966). As most of the previous workers have used identification points and not the DPs, this may be the cause of discripancy as observed by Mewa Lal (1993) and Pal et al (2002).

The DPs are simple to work out as compared to multivariate analysis. An additional advantage of this method is that it is not necessary that all the parameters of a bone should cross the DPs before the sex can be assigned. Even if a single parameter crosses the DP it would identify the sex of unknown bone with 100% accuracy. It has been worked out by Singh and Gangrade (1968) that it is necessary to determine the DPs separately for each race, and even for different regions of the same population.

Though it is a common observation that the female pelvis is shallow and wide as compared to the male but, surprisingly none of the previous workers have utilized this fact to work out any parameter to determine the sex. In the present study, the various linear measurements and three indices were developed so that the size of true pelvic cavity can be roughly deduced from the measurements of a single hip bone. As the male pelvic cavity is narrower, it was expected that the arcuate line in the males should be shorter. Necessity to transmit more weight leads to larger sacropelvic surface in the males, so it was expected that sacropelvic line should be longer in males. Similarly, shallower pelvic cavity in females (which has direct relation to child birth) is reflected in shorter height of the true pelvis. The "sacropelvic line / arcuate line" index reflects the size of sacropelvic surface. The index "height of pelvic cavity / ilial part of arcuate line" was developed to assess the size of the posterior segment of the pelvic cavity. It was expected that this segment of the pelvic cavity should be roomy in the females. The index "height of pelvic cavity/length of arcuate line" reflected the size of the

true pelvic cavity.

All the four linear measurements and indices showed very high statistical significant differences between the two sexes (Tables 3, 4, 5 and 6). When their DPs were calculated all these parameters (except index “height of pelvic cavity / length of arcuate line”) were of little value in the identification of the sex (Tables 7 and 8). This was due to the fact that there were little differences in the mean values of the two sexes (Tables 3 and 4). On the other hand, though the index for “height of pelvic cavity / ilial part of arcuate line” had marked difference between the mean values of the males and the females, but at the same time as their SDs were also high (Tables 7 and 8) the overlapping region was also large. Thus this index could sex only a few hip bones (Tables 7 and 8).

The index “height of pelvic cavity / length of arcuate line” was found to be a very useful criterion for sex determination as it could identify 78.37% of male and 87.87% of female hip bones of right side, and 74.28% of male and 76.66% of female hip bones of the left side. However, these results are only valid for the population of Madhya Pradesh State of India as the DPs for this index may vary from population to population.

The index "height of pelvic cavity/length of arcuate line" was evaluated for sensitivity and specificity for the data of Table 7, the sensitivity for males was 80% and specificity 97% while for females it was 91% & 98% respectively. For the data of Table 8, the sensitivity was 72% and specificity 92% for males while for females it was 77% & 100% respectively.

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