Fetal Ilium as a Tool For Sex Determination: Discriminant Functional Analysis

Aarti[1], Luv Sharma[2], Kamal Singh[1]

[1]Professor, Department of Anatomy, [2]Professor, Department of Forensic Medicine, Pt. B. D. Sharma PGIMS, Rohtak, Haryana, India

Abstract

Background: Sex determination has been the most intriguing puzzle for forensic pathologists and anthropologists for which efforts are being done since long. Sexual dimorphism is well established in the adult pelvis and it is known to provide the highest level of information about sexual dimorphism. This study was conducted to know whether this dimorphism exists in fetal bones?

Method: A total of 34 pairs of fetal pelvis bones (22 Males + 12 Females), age ranging from 4 months to full term were collected from unidentified dead fetuses brought in the Department of Forensic Medicine for the routine medicolegal autopsies, to study for sexual dimorphism in the Department of Anatomy, Pt. B. D. Sharma PGIMS, Rohtak. Samples were divided in 2 age groups and various metric parameters were recorded with the help of digital vernier caliper. Data obtained was subjected to descriptive & discriminant functional analysis.

Conclusion: Results of Descriptive and Discriminant Functional Analysis showed that sex determination can be done with 100% of accuracy by using different combinations of parameters of fetal ilium. This study illustrates that sexual dimorphism exists from early fetal life & after mid pregnancy; it can be clearly established by discriminant functional analysis.

This research was limited in its analysis due to less availability of specimens as this represents only the results in north Indian population. Future studies should be done to explore different populations to better understand the sexual dimorphism in fetal bones of different geographic contexts.

Key Words: *Fetal Ilium; Sexual Dimorphism; Iliac Length.*

Introduction

Sex determination is crucial for both archaeological inference and identification in forensic contexts. Forensic pathologists and anthropologists are trying to resolve the mystery of sex determination since long. Although sexual dimorphism is well established with the adult pelvis and it is considered to supply the best level of data about sexual dimorphism.[1] However, studies on fetal specimens have reported contradictory results.[2-4] Sexually distinctive features of fetal and neonatal pelvis have been reported.[5] After that, there are many attempts to develop both metrical and morphological techniques for estimating sex in juvenile skeletons. The most consistent results so far have been obtained from morphological analysis of the ilium.[6] Some researchers are of opinion that secondary sexual characteristics did not appear until puberty, so are the chances of estimating sex of foetal remains, while some have reported the

Corresponding Author:
Dr. Kamal Singh
Professor, Department of Anatomy,
Pt. B. D. Sharma PGIMS, Rohtak, Haryana (India)
Email: drkamalanatomy@gmail.com
Mob. No. +91-9804500007

sexual differences in foetal ilium.[7-10] The purpose of this research is to establish whether fetal specimens can be sexed accurately by discriminant analysis on ilium bone.

Material And Methods

The study was conducted in Department of Anatomy in collaboration with Department of Forensic Medicine, Pt. B. D. Sharma PGIMS Rohtak. A total of 34 pairs of fetal pelvis bones (22 Males + 12 Females), age ranging from 4 months to full term were collected unidentified dead fetuses brought in the Department of Forensic Medicine for the routine medicolegal autopsies during a period of three years. Only intact fetal pelvic bone sample from known and recognizable sex were collected. Fragmentary and unidentifiable fetal remains were not included in the study. Any gross malformation, congenital anomalies and fragmented bones were excluded from the study.

MEASUREMENTS FOR THE STUDY

Collected samples were divided in the following groups as shown in table 1.

TABLE 1: Showing the group division of the male & female fetal ilium bone specimens.

Specimen Sex/Side	Fetal Ilium Bone Specimen (Male)				Fetal Ilium Bone Specimen (Female)			
	<6 Months		>6 Months		<6 Months		>6 Months	
	Left	Right	Left	Right	Left	Right	Left	Right
Name of Group	1a	1b	2a	2b	3a	3b	4a	4b

Each sample was measured separately and the following measurements were noted after careful examination. (Fig.1).

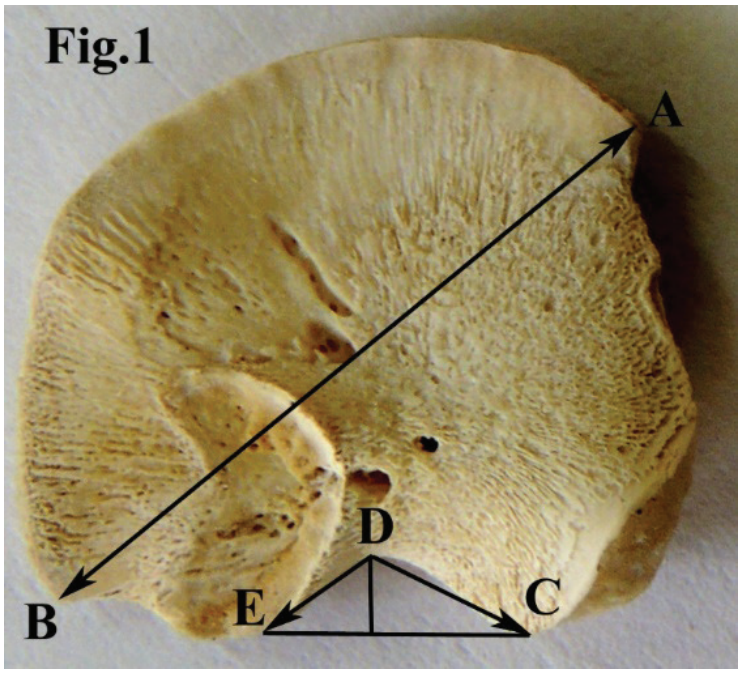

Fig.1: Showing Metric Parameters of Fetal Ilium: Iliac Length (A-B), Sciatic Notch Angle (D), Sciatic Notch Width (C-E), Sciatic Notch Depth (Perpendicular line at D), Anterior Sciatic Notch Length (E-D), Posterior Sciatic Notch Length (C-D)

Metric Parameters of Fetal Ilium

1. Iliac Length (mm): Maximum Length from anterior to posterior iliac spine (A to B).[11]

2. Sciatic Notch Angle (^{0}): Using the apex of the notch (D) as the angle point of origin, the maximum angle was formed by the anterior and posterior edges of the sciatic notch (Angle C-D-E).

3. Sciatic Notch Width (mm): Maximum Breadth from anterior and posterior sciatic notch edges (C to E).

4. Sciatic Notch Depth (mm): Maximum length of line drawn perpendicular from notch apex (D) to horizontal axis created by sciatic notch width (C to E).

5. Anterior Sciatic Notch Length (mm): Maximum Length from Anterior sciatic notch edge to Apex (E to D).

6. Posterior Sciatic Notch Length (mm): Maximum length from Posterior sciatic notch edge to Apex (C to D).

These were measured by the digital vernier caliper with the least count of 0.01 mm. All the measurements were taken by the same investigator in the same setting. Each reading was taken thrice at the interval of 1 month, and statistically analyzed to rule out intra-observer error. The results of the study were computed and analyzed with SPSS software 16. Normal Descriptive Statistics i.e., Mean, standard deviation & P-Value as well as Canonical discriminant function coefficients in Discriminant Function Analyses were performed. The discriminant function formula is as follows:

$$F(X) = A1X1 + A2X2 + ... + ANXN + C$$

Where F(X) represents the discriminant function score, X1 to XN are the measured variables, A1 to AN are the unstandardized coefficients of each variable and C is the function's constant.

Results

Descriptive statistics of both the sexes for Left & Right sides of Fetal Ilium Bone were analyzed and compared respectively (Table 2 & 3).

Parameters which showed the statistically significant difference on comparison among left sides of the same age group are: posterior sciatic notch length on comparison between Group 1a & Group 3a, iliac length & sciatic notch width on comparison between Group 2a & Group 4a (Table 2).

TABLE 2: DESCRIPTIVE STATISTICS OF THE LEFT ILIAC BONE MEASUREMENTS

Sr. No.	Morphometric Parameter	< 6 Months (Mean ± SD)			> 6 Months (Mean ± SD)		
		Male (Group 1a)	Female (Group 3a)	P Value	Male (Group 2a)	Female (Group 4a)	P Value
1	Iliac Length (mm)	15.1±2.24	16.6±1.19	0.138	26.27±1.66	21.20±1.35	0.000
2	Sciatic Notch Angle (0)	123±9.91	121±5.46	0.569	120±5.58	121±4.50	0.770
3	Sciatic Notch Width (mm)	5.04±0.94	5.17±0.36	0.756	8.01±0.45	7.23±0.45	0.008
4	Sciatic Notch Depth (mm)	1.13±0.31	1.55±0.09	0.090	2.36±0.49	2.13±0.50	0.397
5	Anterior Sciatic Notch Length (mm)	3.07±0.63	2.73±0.21	0.230	4.35±0.18	4.24±0.62	0.713
6	Posterior Sciatic Notch Length (mm)	2.55±0.38	3.47±0.44	0.000	4.89±0.81	4.20±0.75	0.131

On comparison of right sides of both the sexes in the same age group a statistically significant difference was observed in the following parameters: anterior sciatic notch length on comparison between Group 1b & Group 3b; and in iliac length, sciatic notch width, anterior sciatic notch length & posterior sciatic notch length on comparison between Group 2b & Group 4b (Table 3).

TABLE 3: DESCRIPTIVE STATISTICS OF THE RIGHT ILIAC BONE MEASUREMENTS

Sr. No.	Morphometric Parameter	< 6 Months (Mean ± SD)			> 6 Months (Mean ± SD)		
		Male (Group 1b)	Female (Group 3b)	P Value	Male (Group 2b)	Female (Group 4b)	P Value
1	Iliac Length (mm)	15.26±2.24	16.62±1.06	0.178	26.44±1.64	21.17±1.54	0.000
2	Sciatic Notch Angle (0)	122±8.53	127.3±5.39	0.213	121±3.92	122.6±6.28	0.552
3	Sciatic Notch Width (mm)	5.19±0.81	5.48±0.72	0.469	8.11±0.12	7.34±0.73	0.012
4	Sciatic Notch Depth (mm)	1.39±0.36	1.46±0.30	0.703	2.12±0.18	1.89±0.36	0.141
5	Anterior Sciatic Notch Length (mm)	2.69±0.37	3.15±0.56	0.047	4.09±0.20	3.71±0.39	0.037
6	Posterior Sciatic Notch Length (mm)	2.92±0.46	2.99±0.35	0.734	5.07±0.31	4.49±0.62	0.041

On applying discriminant function analysis on the measurements of fetal ilium more astonishing results came out which showed that these parameters provide us a good criterion in estimating significance of percentage accuracy in determination of sex (Table 4 & 5).

TABLE 4: DISCRIMINANT FUNCTION ANALYSIS SHOWING % ACCURACY FOR SEX DETERMINATION BY TAKING INDIVIDUAL PARAMETERS OF LEFT & RIGHT SIDES OF FETAL ILIUM BONE IN LESS THAN 6MTHS AGE GROUP.

Sr. No.	Parameters	Age Group: Less than 6 Months Correctly Classified (%) BY DFA					
		Left Side			Right Side		
		Group 1a (Male)	Group 3a (Female)	Total	Group 1b (Male)	Group 3b (Female)	Total
A	Iliac Length (mm)	71.4	66.7	70	71.4	66.7	70
B	Sciatic Notch Angle (0)	57.1	66.7	60	42.9	66.7	50
C	Sciatic Notch Width (mm)	42.9	66.7	50	57.1	66.7	60
D	Sciatic Notch Depth (mm)	71.4	100	80	71.4	33.3	60
E	Anterior Sciatic Notch Length (mm)	57.1	66.7	60	57.1	66.7	60
F	Posterior Sciatic Notch Length (mm)	85.7	66.7	80	57.1	66.7	60

On applying DFA on the individual parameters in age group of less than six month (Group 1a & 3a) has produced a sex determination accuracy of 85.7% in males with posterior sciatic notch length; 100% in females with sciatic notch depth; and 80% accuracy with sciatic notch depth & posterior sciatic notch length in both on left side. Whereas, a sex determination accuracy of 71.4% in males with iliac length & sciatic notch depth; 66.7% in females with all the parameters except sciatic notch depth; and 70% accuracy with iliac length in both on right side in Group 1b & 3b (Table 4).

TABLE 5: DISCRIMINANT FUNCTION ANALYSIS SHOWING % ACCURACY FOR SEX DETERMINATION BY TAKING INDIVIDUAL PARAMETERS OF LEFT & RIGHT SIDES OF FETAL ILIUM BONE IN MORE THAN 6MTHS AGE GROUP

Sr. No.	Parameters	Age Group: More than 6 Months to Full Term Correctly Classified (%) BY DFA					
		Left Side			Right Side		
		Group 2a (Male)	Group 4a (Female)	Total	Group 2b (Male)	Group 4b (Female)	Total
A	Iliac Length (mm)	100	100	100	100	100	100
B	Sciatic Notch Angle (0)	25.3	66.7	42.9	75	66.7	71.4
C	Sciatic Notch Width (mm)	50	66.7	57.1	100	33.3	71.4
D	Sciatic Notch Depth (mm)	75	33.3	57.1	75	66.7	71.4
E	Anterior Sciatic Notch Length (mm)	50	33.3	42.9	75	66.7	71.4
F	Posterior Sciatic Notch Length (mm)	50	33.3	42.9	75	66.7	71.4

On applying DFA on the individual parameters in age group of more than six month (Group 2 & 4) has produced a sex determination accuracy of 100% in Males with Sciatic Notch Width; and 100%in males, females and both with Iliac Length on both right and left sides. A 100% of accuracy for sex determination has been observed with different combinations of parameters of fetal ilium (Table 5).

Discussion

Determination of sex had been the subject of interest since the eighteenth century. The difficulty in recognizing & applying morphological traits to the fetal bones has already been established & the methods prove unreliable when applied to different samples varying in the expression of morphological traits. Adult traits established for sexual dimorphism can't be replicated & projected to fetal remains.[12] In the adult pelvis, the primary focussed area is the sciatic notch for sex determination. The same has been tried to project on fetal remains but with contrasting results.

Descriptive analysis of the present study showed that sciatic notch is wider in males than females in both the age groups (Group 1 & 2) and deeper in females in age group <6 months) and deeper in males in age groups >6 months. Thomson observed that the sciatic notch is wider and shallower in females than in males, the reason being the examined intact pelvis and measured the width

of the sciatic notch as the length from the anterior greater sciatic notch to the margin of the sacrum that met the posterior inferior iliac spine posteriorly[13] & it does not correspond to the standardized measurement currently applied. While Fazekas & Kosa (1978) stated that males show more significant notch depth and females display larger notch lengths.[14]

Schutkowski examined the Spitalfields London Juvenile Skeletal Collection, which contained individuals aged from birth to 11 years. The greater sciatic notch depth and angle, iliac crest curvature, and arch criterion were studied and it was concluded that the sciatic notch was mainly useful for the determination of sex. The visual assessment of sciatic notch angle determined angles more than 900 as females and ~ 900 as males. But the present study showed that sciatic notch angle was more than 1200 in all the age groups in both males and females.[3] So, the sciatic notch has not been proved to be a good indicator of sex in fetal remains. Schutkowski used the fetal iliac bone outlines, especially the sciatic notch & proposed discriminant analysis, to determine the sex of fetus and infants based on the ilium, but did not consider age as criteria.[4] Discriminant analysis is a versatile statistical method used to classify observations into two or more groups/categories or assign subjects to one group among several known groups. It has been used over descriptive analysis by researchers on various bone morphometric analyses to correctly classify the amongst the known groups.[15-17] The discriminant analysis of fetal ilium by a 3D geometric morphometric approach with multi-slice computed tomography and results did not show any difference between male and female shapes in all age groups.[18]

The results of this study show that by discriminant analysis classification of sex can be done with 100% accuracy by taking fetal iliac length as criteria in late fetal age & early fetal age sex can be classified with 80% accuracy by taking Posterior Sciatic Notch as criteria and with 100% accuracy by the combination of parameters.

Embryological Basis

Ilium is the first bone to appear in both the cartilaginous template and the ossification centres. The sacroiliac joint both a synovial and synarthrosis joint is clearly formed by 10 weeks of intrauterine life.[19] The three fetal pelvic bones are visible by ultrasound early in development; specifically, the iliac wings are evident by the end of the first trimester.[20] Differences found in male and female pelvis reflect influences of hormones, particularly testosterone, on the development of the embryo as it progresses from an unsexed to sexed individual approximately the 8th week of intrauterine life.[21, 22] At this time, testosterone is secreted at high levels and this continues until roughly the 20th week of intrauterine life. Male and female pelvic dimorphism has been clearly evident by 24th to 25th weeks of intrauterine life[9, 23] with specific differences found in the angle and breadth of the sciatic notch, sub-pubic angle, and ischial length.[8, 9, 14, 24]

Conclusion

This study illustrates that sexual dimorphism exists from early fetal life & after mid-pregnancy; it can be clearly established by discriminant functional analysis. The findings in our study showed that discriminant functional analysis of fetal ilium bone determination of sex can be done with nearly 100% of accuracy and this can be used as a potential tool for forensic investigation for evaluation of sex in severely mutilated and decomposed bodies during post-mortem examination. Although a smaller number of samples and the only north-Indian population is a limitation to the study, future studies should explore different populations to better understand the sexual dimorphism in fetal bones of different geographic contexts.

Ethical Clearance: The samples were postmortem samples taken from unidentified bodies during routine medicolegal autopsies done by one of the authors himself. Thus, ethical clearance is not required.

Source of Funding: Self.

Conflict of Interest: Nil.

References

1. Scheur L, Black S. Developmental Juvenile Osteology: Amsterdam, Neitherlands: Elsevier Academic Press. 2000.
2. Genove S. Estimation of sexual differences in the hip bone: metric differences and morphological differences. Bulletins and Memoirs of the Anthropological Society of Paris. 1959; 10:3-95.
3. Schutkowski H. Sex determination of infant and juvenile skeletons: I. Morphognostic Features. American Journal of Physical Anthropology. 1993; 90:199-205.
4. Sutter RC. Nonmetric subadult skeletal sexing traits: I. A blind test of the accuracy of eight previously proposed methods using prehistoric known-sex mummies from Northern Chile. Journal of Forensic Sciences. 2003; 48:1-9.
5. Fehling H. Die Form des Beckens beim Fötus und Neugeborenen und ihre Beziehung zu der beim Erwachsenen. Archives of Gynecology and Obstetrics. 1876; 10:1-80.
6. Schutkowski H. Sex determination of fetal neonate skeletons by means of discriminant analysis. International Journal of Anthropology. 1987; 2(4):347-52.
7. Weiss K. On the systematic bias in skeletal sexing. American Journal of Physical Anthropology. 1972; 37:239-250.
8. Holcomb SMC, and Konigsberg LW. Statistical study of sexual dimorphism in the human fetal sciatic notch. American Journal of Physical Anthropology. 1995; 97:113-125.
9. Boucher BJ. Sex differences in the fetal sciatic notch. Journal of Forensic Sciences. 1955; 2:51-54.
10. Boucher BJ. Sex differences in the foetal pelvis. American Journal of Physical Anthropology. 1957; 15:581-600.
11. Schaefer M, Black S, and Scheuer L. Juvenile Osteology: A laboratory and field manual. New York: Elsevier/Academic Press. 2009.
12. Cardoso HF, Saunders SR. Two arch criteria of the ilium for sex determination of immature skeletal remains. Forensic Science International. 2008; 178:24-29.
13. Thomson A. The sexual differences of the foetal pelvis. Journal of Anatomy and Physiology. 1899; 33:359.
14. Fazekas IG, Kosà F, Kerner E. Forensic Fetal Osteology. Budapest: Akadémiai Kiadó. 1978.
15. Singh K, Chhabra S, Sirohiwal BL, Yadav SPS. Morphometry of malleus a possible tool in sex determination. Journal of Forensic Research. 2012; 3:6.
16. Singh K, Rohilla A, Rohilla J. Incus morphometry: a possible tool in sex determination. Journal of Forensic Research. 2016; 7:2.
17. Singh K, Rohilla A. Sexual dimorphism in stapes by discriminant functional analysis. International Journal of Research in Medical Sciences. 2017 Aug; 5(8): 3534-3539.
18. Bilfeld M F, Dedouit F, Rousseau H, Sans N, Braga J, Rougé D, & Telmon N. Human coxal bone sexual dimorphism and multislice computed tomography: geometric morphometric analysis of 65 adults. Journal of forensic sciences. 2012; 57(3), 578-588. https://doi.org/10.1111/j.1556-4029.2011.02009.x
19. McAuley JP, and Uhthoff HK. The development of the pelvis. In: Uhthoff HK, editor. The embryology of the human locomotor system. Berlin: Springer-Verlag. 1990.
20. Medearis AL, and Shields JR. Normal fetal and pelvic anatomy: A cross-section review. Clinical Obstetrics and Gynecology. 1984; 27(2):276-285.
21. Arey L. Developmental Anatomy: A textbook and laboratory manual of embryology. Philadelphia: WB Saunders Company. 1966.
22. Knickmeyer R, Baron-Cohen S. Fetal testosterone and sex differences. Early Human Development. 2006; 82:755-760.
23. Merrot T, Panuel M, Bourliere B, Kathia C, Philip N, Dutour O. Expression of sexual dimorphism in the fetal pelvic girdle. Reports from the Academy of Sciences. Serie III, Sciences de la vie. 2001; 324(2):137-141. doi:10.1016/s0764-4469(00)01279-8. PMID: 11280045.
24. Vlak D, Roksandic M, and Schillaci MA. Greater sciatic notch as a sex indicator in juveniles. American Journal of Physical Anthropology. 2008; 137:309-315.