Section: Anatomy

Original Research Article

A STUDY ON CHILOTIC INDEX OF HUMAN HIP BONE AS A PARAMETER TO ASSESS SEXUAL DIMORPHISM IN SOUTH INDIAN POPULATION

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ABSTRACT

Background: Determining the sex of skeletal remains is a central task in both forensic medicine and bioarchaeology. Beyond the general skeletal features that differ between the sexes, the pelvic girdle carries additional sexually dimorphic characteristics that are well documented across many mammalian species. Among the bones of the skeleton, the pelvis is the single most useful indicator of sex, followed by the skull, although complete certainty is rarely possible unless the entire skeleton is recovered. **Materials and Methods:** This study examined 90 adult dried human hip bones of known sex. Using a digital Vernier caliper, the pelvic and sacral segments of the chilotic line were measured and the Chilotic Index was calculated for each specimen. All observations were tabulated and analysed statistically. **Result:** The pelvic segment of the chilotic line was found to be longer in females than in males. The mean Chilotic Index in males was 115.68 ± 11.8, compared with 95.72 ± 15.18 in females, so the index was consistently higher in males. The difference between the sexes was highly significant ($P < 0.0001$). **Conclusion:** The pelvic segment of the chilotic line is longer in females than in males, while the Chilotic Index and the total length of the chilotic line are both greater in males. Together, these variables provide a reliable basis for determining the sex of an adult human hip bone.

INTRODUCTION

Among skeletal elements, the hip bone is the most reliable indicator of biological sex, followed by the skull. Sexual dimorphism refers to the physical differences in size and appearance that distinguish males and females of a given species, and according to Gray's Anatomy, the sexual differences seen in adult bone are inevitably tied to function. The degree of dimorphism also varies between populations depending on body build. The hip bone is widely regarded as the most reliable single indicator of sex in the human skeleton, and it differs between the sexes in morphology independent of overall size, largely because male and female pelves serve different reproductive functions under the influence of sex steroid hormones. This dimorphism represents a specific adaptation in females for childbearing: the female pelvis has evolved a larger pelvic canal to allow passage of a large-headed fetus, while dimensions such as bi-acetabular width and antero-posterior depth remain constrained by the biomechanical demands of upright, bipedal locomotion.[1-7]

Although every bone carries some information about sex and ancestry, reliable forensic sex estimation depends on the degree of dimorphism present in the element being studied. Females, in particular, tend to be misclassified more often than males, especially when the ischiopubic complex is used. Because of this, numerous studies have sought an index that identifies sex in the human hip bone with greater accuracy, and a range of metrical parameters has been developed for this purpose.[8-14]

Methods for estimating sex from skeletal remains fall broadly into three categories. The first relies on visual or morphological criteria — subjective assessment of features such as the subpubic angle, greater sciatic notch, preauricular sulcus and auricular area. As a general rule, male bones are larger and more robust than female bones, but because the ranges of variation for the two sexes overlap, the accuracy of this approach depends heavily on the experience of the observer.[1,3,15-20]

The second category uses direct measurement, or metric techniques, such as the ischiopubic index, pubic angle and pubic length. The main limitation of this approach is that it requires most of the bone to be intact, and the resulting measurements and indices must be compared against reference charts of male and female values — a process that becomes time-

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consuming when a large series of skeletons is under study.[21-25]

The third category, discriminant function analysis, was first introduced into anthropology by Fisher. Its principal advantage is that it allows sexual assessment even of poorly preserved remains. However, relatively little work using this method has been carried out in Indian populations, and the present study was undertaken partly to address this gap through discriminant analysis of chilotic index data.[9]

A number of sex-determination techniques have focused on specific parts of the hip bone, including the pubic bone (Phenice, 1969),[10] the sciatic notch (Kelly, 1979; Letterman, 1941), the sacroiliac joint (Iscan and Derrick, 1984),[11] and the acetabulum (Schulter-Ellis et al., 1983, 1985).[16] Building on this body of work, earlier authors identified a demarcating point for the chilotic index that could reliably classify the sex of a human hip bone.

The relevant terms used for these measurements are defined as follows. The chilotic (brim or lip) line is the line extending from the iliopectineal eminence, or pubo-iliac point, to the nearest point on the anterior auricular margin — this portion is the pelvic segment — and continuing from there to the iliac crest, which forms the sacral segment. The Chilotic Index (CI) is calculated as the sacral segment divided by the pelvic segment, multiplied by 100. Using the chilotic line and the index derived from it, the sex of a hip bone can be assessed with confidence approaching 97%. The present study set out to characterise sexual dimorphism of the human hip bone with respect to the Chilotic Index in adult dry hip bone specimens.

Pelvic sexual dimorphism is detectable as early as the fetal period and continues through childhood, becoming markedly more pronounced at puberty, when male and female hip bones can be readily distinguished on general morphology alone (Brůžek 2002).[21]

MATERIALS AND METHODS

This study examined 90 adult dry hip bones — 43 male and 47 female — drawn from the bone bank of the Institute of Anatomy, Madras Medical College, Chennai. The primary focus was on bones that were fully ossified and free of pathological deformity. Bones were included if they were undamaged, completely ossified, and free of pathological deformity. Bones were excluded if they were damaged, bore artefacts, belonged to infants or children, showed congenital defects, or were incompletely ossified. This deliberate exclusion of unsuitable specimens reflects the study's commitment to a rigorous exploration of the chilotic index.

Side and sex were first determined from nine morphological features of each bone, each rated on a scale of 1 to 9: the preauricular sulcus, greater sciatic notch, obturator foramen, iliac fossa, pubic symphysis, ischiopubic ramus inversion or eversion, ventral arc, subpubic concavity, and the ridge on the medial aspect of the ischiopubic ramus. Objective sexing was subsequently carried out by measuring twelve features on each hip bone.

Considerable care was taken to minimise manual error, and all measurements were made with a digital Vernier caliper. The parameters analysed were the pelvic segment of the chilotic line, the sacral segment of the chilotic line, and the Chilotic Index (CI = sacral segment / pelvic segment × 100), where the chilotic (brim or lip) line is defined as the line running from the iliopectineal eminence or pubo-iliac point to the nearest point on the anterior auricular margin (the pelvic segment), and continuing from there to the iliac crest (the sacral segment). Each fixed landmark was first marked with a pencil, after which measurements were taken with the digital Vernier caliper and recorded in millimetres in an MS Excel worksheet. This approach ensured a systematic and rigorous methodology for characterising sexual dimorphism in the population studied.

RESULTS

All 90 adult dry human hip bones were measured for the chilotic line, and the resulting observations were analysed statistically.

1. Pelvic Segment of the Chilotic Line

The pelvic segment of the chilotic line ranged from 37.9 to 70.1 mm in male hip bones, with a mean of 54.76 mm, while in female hip bones it ranged from 41.4 to 67.9 mm, with a mean of 56.1 mm [Table 1].

Figure 1A: Chilotic line — the line extending from the iliopectineal eminence to the nearest point on the anterior auricular margin represents the pelvic segment.

Figure 1B: Chilotic line — the line extending from the anterior auricular margin to the iliac crest represents the sacral segment.

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Table 1: Pelvic segment of chilotic line — comparison

Bone	Range	Mean	Standard Deviation (SD)
Male Hip bone	37.9 – 70.1 mm	54.76 mm	6.46
Female Hip bone	41.4 – 67.9 mm	56.1 mm	6.68

Sacral Segment of the Chilotic Line: The sacral segment of the chilotic line ranged from 46.4 to 73.1 mm in male hip bones, with a mean of 62.85 mm, while in female hip bones it ranged from 34.3 to 69.7 mm, with a mean of 53.19 mm [Table 2].

Table 2: Sacral segment of chilotic line — comparison

Bone	Range	Mean	Standard Deviation
Male Hip bone	46.4 – 73.1 mm	62.85 mm	5.56
Female Hip bone	34.3 – 69.7 mm	53.19 mm	7.1

Chilotic Index: The mean total chilotic line length was 117.61 mm ± 10.4 in male hip bones and 109.28 mm ± 11.2 in female hip bones. The mean Chilotic Index was correspondingly higher in males, at 115.68 ± 11.8, than in females, at 95.72 ± 15.18.

Table 3: Mean and SD of total chilotic line and Chilotic Index — comparison

Bone	Chilotic Line – Total	Chilotic Index
Male Hip bone	117.61 mm ± 10.4	115.68 ± 11.8
Female Hip bone	109.28 mm ± 11.2	95.72 ± 15.18

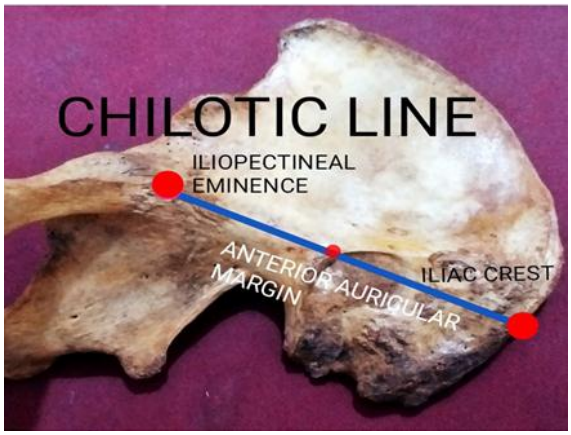

Figure 2: Mean Chilotic Index

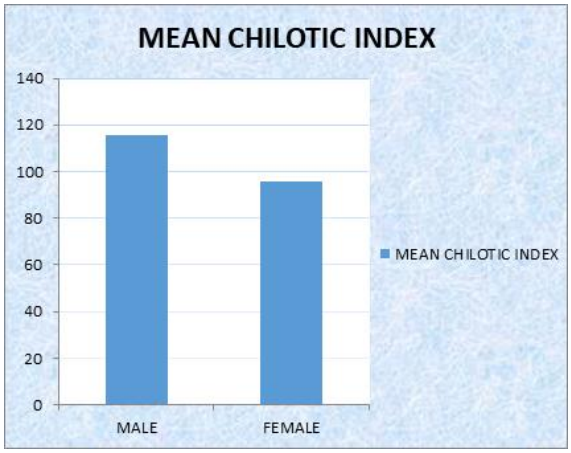

Figure 3: Mean Chilotic Index

When the Chilotic Index values were grouped into class intervals, male bones showed their highest frequency — about 37% — in the 106–115 interval, followed by 23% in the 116–125 interval, 21% in the 126–135 interval, 14% in the 96–105 interval, and 5% in the 85–95 interval. Among female bones, the highest frequency — about 45% — fell in the 86–95 interval, followed by 17% each in the 55–65 and 96–105 intervals, 15% in the 76–85 interval, and 6% in the 66–75 interval.

DISCUSSION

This study examined 90 dried adult hip bones of known sex. The nature and degree of sexual differentiation in the skeleton has long interested anatomists and anthropologists, and carries practical importance from an obstetric perspective as well. A number of earlier studies have used chilotic line segments and the Chilotic Index for sex assessment, and the present work follows the same approach.

Jeneeta Baa et al. (2018) reported that a Chilotic Index above 100 identifies a male hip bone with 100% accuracy; in their series, the index ranged from 102.77 to 139.46, with a mean of 118.32, in males, and from 61.63 to 98.17, with a mean of 84.84, in females — findings that correlate well with the present results (male CI 115.68 ± 11.8; female CI 95.72 ± 15.18). Pal GP et al. reported mean values of 109 in males and 89 in females, again close to the present findings, while Ahmed MM, Jeelani M and Tarnum SA, studying a North Karnataka population (2015), reported mean values of 117.86 and 79.88 in males and females respectively, closely matching the male values obtained here. Vivek K Nirmale et al., examining regional and racial variation in the Chilotic Index, reported values of 120.22 and 97.58 in males and females respectively, and Pranu Chakravarthy and Shifan Khanday (2018), studying a South Indian population, reported values of 115.7 and 77.6, similar to the male mean reported by Ahmed et al. In the Saurashtra region, Vijay Kanjaria et al. (2019) reported considerably higher Chilotic Index values of 142.42 in males and 123.74 in females.

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The broader range of hip bone morphological variation has traditionally been investigated through qualitative trait assessment combined with linear metrics (Buikstra and Ubelaker 1994; Rogers and Saunders 1994). Derry,[26] reported mean values for the pelvic segment, sacral segment and total chilotic line of 54.5 mm, 59.9 mm and 124.4 respectively in males, and 59.1 mm, 60.8 mm and 120.5 respectively in females.

Earlier authors typically classified hip bones into three categories — male, female, and an indeterminate group for specimens that could not be confidently assigned to either sex. The present study extends this approach by further dividing the male and female categories into definite and probable subgroups, which increased the overall reliability of classification. Two measurements and one derived index were considered and subjected to univariate, bivariate and multivariate analysis.

Table 4: Present study compared with previous studies

S.No	Name of the Study	Chilotic Index – Male	Chilotic Index – Female
1	Pal GP et al (2004)	109	89
2	Ahmed MM et al (2015)	116.3	110.5
3	Vivek K Nirmale et al (2017)	120.22	97.58
4	Jeneeta Baa et al (2018)	118.32	84.84
5	Pranu Chakravarthy et al (2018)	115.7	77.6
6	Vijay Kanjaria et al (2019)	142.42	123.74
7	Sarada Toleti et al (2024)	120.22	97.58
8	Present study	115.68 ± 11.8	95.72 ± 15.18

This review of the literature indicates that comparatively few studies have reported metrical data on the pelvic and sacral segments of the chilotic line separately, alongside the Chilotic Index, in this population. The present study addresses this gap by calculating the pelvic and sacral segments of the chilotic line independently, providing clear standards to differentiate male and female hip bones — the pelvic segment proving longer in females, and the Chilotic Index proving higher in males.

CONCLUSION

This study found that the pelvic segment of the chilotic line is longer in females, with a mean value of 56.1 mm (range 41.4–67.9 mm), than in males, with a mean of 54.7 mm (range 37.9–70.1 mm). The total chilotic line, however, is longer in males than in females, and the Chilotic Index is correspondingly higher in males, with a mean of 115.68, than in females, with a mean of 95.72. Taken together, these findings show that the biological sex of a hip bone can be assessed reliably using the Chilotic Index. The chilotic index measured in dried human hip bone is therefore a useful and practical tool for gender determination in forensic analysis and anthropology.

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