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Morphometric Assessment of Ischiopubic Index in Western U.P Population

Roopa Bisht^{1*}, Raushan Kumar², Harsh Maurya³, Md. Aamir Khan⁴, Hani Patel⁵, Reeshabh Kumar⁶, Krupanshi Nileshbhai Panchal⁷, Prof. (Dr.) Rajul Rastogi⁸

¹Assistant Professor, Department of Medical Radiological Imaging & Therapeutic Techniques, Smt. LP Patel Institute of Allied Health Sciences & Technology, Bhaikaka University, Karamsad, Gujarat, India. Email: roopabisht3092000@gmail.com, ORCID: 0009-0009-1869-725X

²Assistant Professor, College of Allied and Healthcare Sciences, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India. Email: singhraushan01@gmail.com, ORCID: 0009-0009-4149-2295.

³Assistant Professor, Department of Radiology & Imaging Technology, Guru Nanak Paramedical College, Dhahan Kaleran, Punjab, India. Email: harshmaurya822@gmail.com

⁴Assistant Professor, School of Paramedical and Allied Health Sciences, AIHS, Faridkot, Punjab, India. Email: mdmdaamirkhan7860@gmail.com

⁵Assistant Professor, Department of Medical Radiological Imaging & Therapeutic Techniques, Smt. LP Patel Institute of Allied Health Sciences & Technology, Bhaikaka University, Karamsad, Gujarat, India. Email: hanipatel3101@gmail.com

⁶Nursing Officer, Department of Anesthesiology, AIIMS Guwahati, Changsari, Guwahati, India. Email: rksing.25@gmail.com

⁷Assistant Professor, Department of Medical Radiological Imaging & Therapeutic Techniques, Smt. LP Patel Institute of Allied Health Sciences & Technology, Bhaikaka University, Karamsad, Gujarat, India. Email: krupanshipanchal98@gmail.com

⁸Professor, Radiodiagnosis, Teerthanker Mahaveer Medical College & Research Center, Teerthanker Mahaveer University, Moradabad, Uttar-Pradesh, India. Email: rajulrst@yahoo.co.in, ORCID: 0000-0001-6407-9756

ABSTRACT:

Background/aim: Population-specific data on the ischiopubic index in living populations remain limited, with most studies relying on dry bones rather than digital radiographic analysis using RadiAnt DICOM software. This study aimed to assess sexual dimorphism and evaluate the reliability and diagnostic accuracy of the ischiopubic index for sex determination in a living Western Uttar Pradesh population using pelvic radiographs.

Materials and Methods: This prospective, cross-sectional study included 214 adults (118 males, 96 females; mean age 38.90 ± 12.15 years) referred for pelvis AP radiographs at Teerthanker Mahaveer Hospital, Moradabad, India. Gender differences were assessed using a t-test and a point-biserial correlation; age-group differences were assessed using ANOVA; and accuracy and the ROC curve were used to assess the diagnostic accuracy of the Ischiopubic Index for gender determination.

Results: Mean IL, PL, and IPI were 8.02 ± 0.74 cm, 8.15 ± 0.65 cm, and 102.55 ± 12.14 , respectively. Significant sexual dimorphism was observed ($p < 0.001$); males had greater

IL (8.39 ± 0.64 cm), while females had greater PL (8.47 ± 0.64 cm) and IPI (112.45 ± 9.55). The IPI showed excellent diagnostic accuracy (AUC = 0.941). No significant age-related differences were found ($p > 0.05$).

Conclusion: The ischiopubic index demonstrated clear and highly significant sexual dimorphism with excellent diagnostic accuracy, making it a simple, reliable, non-invasive, and highly effective parameter for sex determination in the Western Uttar Pradesh population. This study provides valuable population-specific normative data on pelvic morphometry using digital radiography. The findings have important implications in forensic anthropology, medico-legal investigations, anatomical research, and clinical radiology practice.

1. INTRODUCTION

The human pelvis exhibits distinct morphological differences between the sexes and serves as an important indicator for sex determination (1–4). Its anatomical variations are important in anthropological, forensic, obstetrical, and radiological studies (1,2,5). The hip bone is formed by the fusion of three bones: the ilium, ischium, and pubis, which unite at the acetabulum (6). The ilium forms the superior part, while the ischium and pubis contribute to the posterior and anterior portions of the acetabular cavity, respectively (5). As complete fusion generally occurs by 20 years of age, pelvic-based sex estimation is considered reliable only in adults (7).

Several pelvic indices have been proposed for sex determination, including the Chilotic line index described by Derry, the ischiopubic index introduced by Washburn, and the acetabulum-pubic index proposed by Schuller Ellis (8–10). Among these, the ischiopubic index demonstrated high accuracy, with Washburn reporting successful identification of 84% of males and 100% of females in American skeletal samples (11). Evaluation of sex-related pelvic variations is clinically important, as females with a relatively narrow pelvic cavity may experience greater challenges during natural childbirth than those with a wider pelvic cavity (2,12–14).

A Prospective study was conducted on the Morphometric assessment of Ischiopubic index in Western U.P. Population using 214 normal adult anterior-posterior radiographs of the pelvis (118 males and 96 females) that were fully screened for any pathology. The study revealed that 7.90 cm and 8.47 cm are the mean pubic lengths of males and females, respectively. In comparison, 8.39 cm and 7.56 cm are the mean ischial lengths of males and females, respectively. In males and females, the mean ischiopubic indices were found to be 94.50 and 112.45, respectively. The mean values of this index were found to be statistically significant ($p < 0.001$). In conclusion, this explained significant higher sexual differences in the ischiopubic index observed in females compared to males.

The present study aimed to generate population-specific data on ischial and pubic lengths and evaluate the utility of the ischiopubic index for sex determination in the Western Uttar Pradesh population without pelvic pathology or bony deformities. With advances in medical imaging, these measurements can now be accurately assessed on digital radiographs using DICOM software(15). Traditionally, pelvic measurements are obtained using osteometric boards, callipers, and measuring scales (15).

2. MATERIAL AND METHODS

This prospective cross-sectional study was conducted in the Department of Radiological Imaging Techniques, Teerthanker Mahaveer Hospital and Research Centre, Moradabad, Uttar Pradesh, India, between March 2025 and March 2026. A total of 214 healthy Indian adults (118 males and 96 females) aged 20–70 years who underwent standard anteroposterior (AP) Pelvis radiographs for routine indications were included after obtaining written informed consent. Subjects with a history of pelvis trauma, fracture, surgery, bone T.B, osteoarthritis, osteomalacia, Implants, prostheses, congenital anomalies and poor image quality were excluded. All radiographs were acquired using the Fujifilm Smart FDR 800 mA Digital Radiography system with standardized technical parameters (80–85 kVp, 20–30 mAs, and 100 cm source-to-image distance). Measurements of Ischial length (IL), Pubic length (PL) and Ischiopubic Index (IPI) were performed digitally on RadiAnt DICOM Viewer software by a single observer. IL was measured as the vertical distance from the anterior aspect of the ischial tuberosity to the nearest rim of the acetabulum. PL was measured as the length from the superior-most aspect of the pubic symphysis to the nearest rim of

the acetabulum, shown in **Figure 1**. IPI was calculated as the ratio of the length of the pubis and the length of the ischium by 100. Data were analyzed using SPSS version 22.0.



Figure 1: Measurement of pelvis parameters (PL and IL)

3. RESULTS

3.1 Demographic Characteristics of Study Participants

A total of 214 adult subjects were included in the present study, comprising 118 males and 96 females. The participants were divided into five age groups: 20–30 years, 31–40 years, 41–50 years, 51–60 years and 61–70 years. The mean age of the study population was 38.90 ± 12.15 years. The majority of the participants belonged to the 20–30 years age group, comprising 67 participants (31.30%). Male participants constituted 55.1% of the total study population, whereas females accounted for 44.9%.

3.2 Morphometric Assessment of Pelvis Parameters

The morphometric measurements of all pelvis parameters are shown in **Table 1**. The mean Ischial Length was 8.02 ± 0.74 cm, the mean Pubic Length was 8.15 ± 0.65 cm, and the mean Ischiopubic Index (IPI) was 102.55 ± 12.14 .

Table 1: Morphometric measurements of all pelvic parameters

Parameters	Range	Mean (SD)
IL (cm)	6.00 to 9.90	8.02 ± 0.74
PL (cm)	6.38 to 10.00	8.15 ± 0.65
IPI	74.74 to 156.7	102.55 ± 12.14

All vales were Range and Mean SD.

3.3 Age Group–Wise Comparison of Radiographic Pelvic Parameters

One-way analysis of variance (ANOVA) was performed to compare pelvic morphometric parameters across different age groups. As shown in Table 2, minor variations were observed in the mean values of ischial length, pubic length, and ischiopubic index across age categories. However, these differences were not statistically significant for ischial length ($F = 0.46$, $p = 0.76$), pubic length ($F = 0.42$, $p = 0.79$), or ischiopubic index ($F = 0.37$, $p = 0.82$). These findings indicate that no significant age-related differences in the measured pelvic parameters were detected within the studied adult population.

Table 2. Comparison of radiographic pelvic parameters across age groups

Parameter	Age group (years)	Mean $\pm$ SD	F-value	p-value
Ischial length (IL), cm	20–30	8.07 $\pm$ 0.79	0.46	0.76
	31–40	7.98 $\pm$ 0.74		
	41–50	8.10 $\pm$ 0.73		
	51–60	7.89 $\pm$ 0.69		
	61–70	7.97 $\pm$ 0.73		
Pubic length (PL), cm	20–30	8.14 $\pm$ 0.62	0.42	0.79
	31–40	8.11 $\pm$ 0.65		
	41–50	8.25 $\pm$ 0.64		
	51–60	8.22 $\pm$ 0.73		
	61–70	8.05 $\pm$ 0.59		
Ischiopubic index (IPI)	20–30	101.64 $\pm$ 11.07	0.37	0.82
	31–40	102.49 $\pm$ 13.40		
	41–50	102.58 $\pm$ 11.69		
	51–60	104.80 $\pm$ 11.99		
	61–70	101.88 $\pm$ 13.57		

Values are presented as mean $\pm$ standard deviation (SD). Differences across age groups were assessed using one-way analysis of variance (ANOVA). A p-value <0.05 was considered statistically significant. IL, ischial length; PL, pubic length; IPI, ischiopubic index.

3.4 Sex-wise Comparison of Radiographic Pelvic Parameters

Independent-samples t-test analysis confirmed that the differences in ischial length ($t = -9.70$), pubic length ($t = 7.05$), and Ischiopubic Index ($t = 15.87$) were all highly significant ($p < 0.001$), demonstrating pronounced sexual dimorphism of the pelvis and supporting the usefulness of the Ischiopubic Index for sex determination. The mean ischial length was greater in males (8.39 ± 0.64) than in females (7.56 ± 0.60). In contrast, the mean pubic length was higher in females (8.47 ± 0.64) than in males (7.90 ± 0.54). Similarly, females exhibited a higher mean ischiopubic index (112.45 ± 9.55) compared to males (94.50 ± 6.98) in **Table 3**.

Table 3: Gender-wise comparison of radiographic pelvic parameters

Parameter	Sex	Mean $\pm$ SD	t-value	p-value
Ischial length (IL), cm	Female	7.56 $\pm$ 0.60	-9.70	<0.001
	Male	8.39 $\pm$ 0.64		
Pubic length (PL), cm	Female	8.47 $\pm$ 0.64	7.05	<0.001
	Male	7.90 $\pm$ 0.54		
Ischiopubic index (IPI)	Female	112.45 $\pm$ 9.55	15.87	<0.001
	Male	94.50 $\pm$ 6.98		

Values are presented as mean $\pm$ standard deviation (SD). Differences between male and female participants were assessed using an independent-samples t-test. A p-value < 0.05 was considered statistically significant. IL, ischial length; PL, pubic length; IPI, ischiopubic index.

3.5 Correlation Analysis among Pelvic Morphometric Parameters

Pearson's correlation analysis was performed to assess the relationships among ischial length (IL), pubic length (PL), and the ischiopubic index (IPI) Table 4. No statistically significant correlation was observed between IL and PL ($r = 0.11$, $p = 0.115$). In contrast, IL showed a strong negative correlation with IPI ($r = -0.72$, $p < 0.001$), indicating that higher ischial length was associated with a lower ischiopubic index. Pubic length demonstrated a moderate-to-strong positive correlation with IPI ($r = 0.60$, $p < 0.001$), indicating that greater pubic length was associated with a higher ischiopubic index. These findings demonstrate that the IPI is strongly related to its constituent pelvic measurements, whereas IL and PL themselves do not show a significant linear relationship.

Table 4. Correlation among pelvic morphometric parameters

Parameter	Ischial Length (IL), cm	Pubic Length (PL), cm	Ischiopubic Index (IPI)
Ischial Length (IL), cm	1.00	0.11 ($p = 0.115$)	-0.72 ($p < 0.001$)
Pubic Length (PL), cm	0.11 ($p = 0.115$)	1.00	0.60 ($p < 0.001$)
Ischiopubic Index (IPI)	-0.72 ($p < 0.001$)	0.60 ($p < 0.001$)	1.00

Values represent Pearson's correlation coefficients (r). A p-value < 0.05 was considered statistically significant.

3.6 Diagnostic Performance of the Ischiopubic Index for Sex Classification

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the discriminatory performance of the IPI for sex classification. As shown in Figure 1, the IPI demonstrated an area under the curve (AUC) of 0.941, indicating excellent discriminatory ability for differentiating male and female pelvis in the studied sample. These findings suggest that the IPI has strong potential as a morphometric parameter for sex estimation based on pelvic measurements.

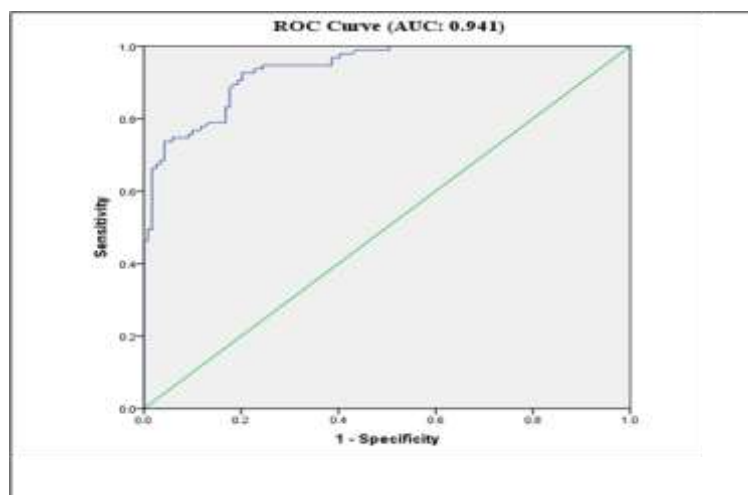


Figure 1. Receiver operating characteristic (ROC) curve illustrating the discriminatory performance of the ischiopubic index (IPI) for sex classification. The area under the curve (AUC = 0.941) indicates excellent ability of the IPI to discriminate between male and female pelvis in the studied sample. The diagonal reference line represents performance expected by chance (AUC = 0.50).

4. DISCUSSION

The present study evaluated sexual dimorphism in radiographic pelvic morphology using ischial length (IL), pubic length (PL), and the ischiopubic index (IPI) in 214 adults from the western Uttar Pradesh population. Significant differences were observed

between male and female participants for all three parameters. Males had a greater mean ischial length than females (8.39 ± 0.64 vs. 7.56 ± 0.60 cm), whereas females demonstrated a greater mean pubic length (8.47 ± 0.64 vs. 7.90 ± 0.54 cm). Consequently, the mean IPI was substantially higher in females (112.45 ± 9.55) than in males (94.50 ± 6.98), with all sex-based differences reaching statistical significance ($p < 0.001$). These findings demonstrate clear sexual dimorphism in pelvic morphology and support the utility of radiographic pelvic measurements for sex estimation and align with Jaji Sulaimon et al. study (16). **Danfulani et al.** reported a mean IPI of 89.31 ± 4.84 in males and 111.49 ± 6.66 in females in a Nigerian population, closely resembling the direction and magnitude of the sex difference observed in the present study (2). Similarly, **Adhvaryu et al.** reported higher IPI values among females than males in an Indian skeletal sample, with mean values of 115.88 ± 10.07 and 100.52 ± 6.33 , respectively (11). **Joshi et al.** also demonstrated marked sexual dimorphism in a Nepalese population, reporting an IPI of 91.73 ± 5.0 in males and 110.9 ± 7.0 in females (1). Collectively, these studies indicate a consistent tendency for females to exhibit a higher ischiopubic index than males despite differences in geographic origin, sample characteristics, and measurement methodology. The findings of **Jaji Sulaimon et al.** also demonstrated a statistically significant difference in the ischiopubic index between male and female hip bones in a Nigerian population (16). Their study, based on 89 hip bones, further supports the usefulness of pelvic morphometry for sex estimation. However, differences in the absolute values reported across previous investigations and the present study may be attributable to population-specific skeletal morphology, genetic and environmental influences, sampling characteristics, age distribution, and differences between measurements obtained from dry bones and those obtained from radiographic images. Therefore, population-specific reference values remain important when applying pelvic morphometry in forensic and medico-legal practice. An additional finding of the present study was the absence of a statistically significant influence of age on the measured pelvic parameters. One-way ANOVA demonstrated no significant differences across the 20–70-year age groups for IL ($F = 0.46$, $p = 0.76$), PL ($F = 0.42$, $p = 0.79$), or IPI ($F = 0.37$, $p = 0.82$). Although small variations in mean values were observed among age groups, none reached statistical significance. This suggests that, within the studied adult population, the evaluated pelvic measurements remained relatively stable across the examined age range. Nevertheless, the absence of a significant age-group effect should not be interpreted as proof that these parameters are completely unaffected by ageing in all populations. Correlation analysis further demonstrated distinct relationships among the pelvic measurements. Ischial length showed a strong negative correlation with IPI ($r = -0.72$, $p < 0.001$), whereas pubic length showed a positive correlation with IPI ($r = 0.60$, $p < 0.001$). In contrast, the correlation between IL and PL was weak and statistically non-significant ($r = 0.11$, $p = 0.115$). These relationships are expected in part because the IPI is mathematically derived from pubic and ischial lengths; therefore, correlations involving IPI should be interpreted as structural relationships rather than independent biological associations. The discriminatory performance of the IPI was further supported by receiver operating characteristic analysis. An AUC of 0.941 demonstrated excellent discrimination between male and female pelves in the studied sample. This result complements the highly significant difference in mean IPI between the sexes and indicates that the index may have substantial value as a radiographic parameter for sex classification. However, the AUC represents performance within the present study population, and validation in independent and geographically diverse populations would be necessary before adopting a universal diagnostic threshold. Overall, the present findings reinforce previous evidence that pelvic morphology exhibits marked sexual dimorphism, particularly in the relative proportions of the pubic and ischial components.

5. CONCLUSION

This study evaluates the morphometric characteristics of the pelvis using the ischiopubic index for sex determination. It demonstrates clear sexual dimorphism in pelvic measurements, particularly in Ischial length (IL), Pubic length (PL), and the Ischiopubic index (IPI). Males exhibited greater ischial length, whereas females showed higher pubic length and ischiopubic index values. No significant age-related differences were observed, indicating the stability of these parameters across adult age groups. The ischiopubic index showed excellent discriminative ability and emerged as a simple, reliable, and effective parameter for sex determination. These findings have important applications in forensic anthropology, medico-legal investigations, and anatomical research.

6. DECLARATION

Ethical approval: The study protocol was reviewed and approved by the Institutional Ethics Committee, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India (Approval No. TMU/IEC/2024-25/046). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Consent to participate: Written informed consent was obtained from all participants prior to their inclusion in the study.

Consent for publication: Not applicable. The manuscript does not contain any identifiable personal information or images requiring separate consent for publication.

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Conflicts of interest: The authors declare that they have no conflicts of interest.

Data availability: The data supporting the findings of this study are available from the corresponding author on reasonable request, subject to institutional and ethical requirements and protection of participant confidentiality.

Authors' contributions: All authors contributed to the conception and design of the study, data acquisition, analysis and interpretation of the findings, and preparation of the manuscript. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

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