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Original Article

Anatomy Section

Radiographic Evaluation of Greater Sciatic Notch for Sex Determination: A Cross-sectional Study from Sri Ganganagar, Rajasthan, India

RASALIKA MIGLANI[1], PARVEEN KUMAR SHARMA[2], VIJAY KUMAR DAYMA[3], NIKHIL SHARMA[4], AAKANKSHA ARORA[5]

ABSTRACT

Introduction: Sex estimation forms a fundamental step in forensic anthropology, bioarchaeology and medicolegal identification. The pelvis is considered the most reliable skeletal element for this purpose, with the Greater Sciatic Notch (GSN) being one of the most sexually dimorphic landmarks. Radiographic evaluation of the GSN offers a non invasive and practical alternative to traditional osteological analysis, particularly when skeletal remains are unavailable.

Aim: To evaluate the morphometric and radiological characteristics of the GSN on plain pelvic radiographs in the population of Sri Ganganagar, Rajasthan and to assess sexual dimorphism in its parameters.

Materials and Methods: A cross-sectional study was conducted at the Department of Radiodiagnosis, Jansewa Hospital, Sri Ganganagar, Rajasthan, India, on 200 Anteroposterior (AP) pelvic radiographs (92 males, 108 females) obtained between August 2024 and July 2025. Radiographs with fractures, deformities, or prior pelvic or hip surgeries were excluded. Bilateral measurements of GSN width, depth, posterior segment, Index I (depth/width×100) and Index II (posterior segment/width×100) were obtained using digital callipers. Data were analysed using Statistical Package for the Social Sciences (SPSS) version 23.0. Sex differences were assessed using the independent samples t-test, with $p<0.05$ considered statistically significant.

Results: All measured parameters exhibited statistically significant sexual dimorphism. Females demonstrated greater mean width (Right: 54.56±2.18 mm; Left: 54.67±2.10 mm), depth (Right: 26.52±1.21 mm; Left: 26.64±1.18 mm) and posterior segment (Right: 28.5±0.98 mm; Left: 28.7±1.06 mm) compared to males. Index I was higher in males (Right: 61.08±3.18; Left: 60.8±2.95), whereas Index II was significantly ($p<0.001$) higher in females (Right: 52.3±2.84; Left: 52.5±2.51).

Conclusion: The GSN showed marked sexual dimorphism in the studied population, with width, depth, posterior segment and Index II being greater in females, while Index I was higher in males. Plain radiography provides a reliable, cost-effective and non invasive method for sex determination and can serve as a valuable adjunct in forensic and anthropological practice.

Keywords: Anthropometry, Forensic anthropology, Pelvis, Radiography, Sex characteristics

INTRODUCTION

Sex estimation is a fundamental aspect of constructing the biological profile in forensic anthropology, bioarchaeology and medicolegal contexts. The pelvis is widely regarded as the most sexually dimorphic skeletal region, shaped by evolutionary pressures of locomotion and obstetrics. These functional demands result in marked morphological differences between male and female pelves, making pelvic traits highly reliable for sex determination [1]. Among these, the GSN has been consistently highlighted due to its strong dimorphism and its preservation in both forensic and archaeological assemblages [2].

The GSN, located on the posterior border of the ilium, is typically wider and shallower in females to accommodate obstetric requirements, while it is narrower and deeper in males [3]. Previous anthropological research has developed both metric and non metric approaches for assessing the notch, reporting classification accuracies of up to 75-90% [4,5]. These methods have established the GSN as a cornerstone of anthropological sex estimation.

Although dry bone analysis remains the classical method for assessing sexual dimorphism, modern research increasingly uses radiographic evaluation as a practical alternative. Plain pelvic radiographs are accessible, inexpensive and non destructive, allowing researchers to study pelvic morphology in living individuals or in situations where skeletal remains are unavailable, incomplete, or cannot be ethically or legally examined [6]. By applying osteometric methods to radiographic images, parameters such as the width, depth, and posterior segment of the greater sciatic notch, along with derived indices, can be accurately measured. These radiographic assessments reliably reflect sexual dimorphism in the pelvis and have proven effective in differentiating male from female hip bones, making them valuable in both forensic and anthropological contexts [7].

This also enables the development of population-specific standards, essential for reliable sex determination given the influence of genetic, environmental and functional variation on pelvic morphometry [8]. Anthropological studies have highlighted that both population-specific differences and age-related changes significantly influence the morphometry of the GSN. Ethnic variations necessitate the calibration of discriminant functions to specific groups to ensure accurate sex estimation [9-11]. For instance, research has demonstrated considerable population variation in skeletal sexual dimorphism, emphasising the need for population-specific standards in forensic anthropology [12]. Similarly, studies have shown that age-related changes can affect GSN morphology, with younger individuals tending to have wider, more feminine-appearing sciatic notches compared to older individuals [13,14]. These findings underscore the importance of considering both population and age factors when utilising GSN morphology for sex estimation. Moreover, remodelling processes associated with ageing, particularly in postmenopausal females, may reduce the accuracy of notch-based sex determination. Therefore, contextualising radiographic analyses within the biological background of the studied population is crucial [15].

Plain radiographic evaluation of the GSN offers anthropologists and forensic scientists a reliable, non invasive method for sex determination. It serves as a practical bridge between osteological research and modern imaging, supporting the establishment of comparative databases across populations. Previous studies have highlighted the utility of the GSN for sex estimation in both skeletal and radiographic analyses across various populations [16]. However, most of these studies have focused on non Indian populations or have relied on skeletal remains, limiting their applicability to living individuals in specific regions [17]. There is a paucity of data regarding the morphometric and radiological characteristics of the GSN in the population of Sri Ganganagar, Rajasthan.

The present study aimed to fill this gap by evaluating the GSN on pelvic radiographs of individuals from this region, assessing its reliability for sex determination and establishing population-specific standards. The present research is novel in providing radiographic-based forensic reference data for a region where such information is currently lacking, thereby enhancing the accuracy of anthropological and forensic assessments in the local context.

MATERIALS AND METHODS

The present was a cross-sectional study conducted at the Department of Radiodiagnosis, Jansewa Hospital, Sri Ganganagar, Rajasthan, India, between August 2024 and July 2025. Ethical approval for the study was obtained from the Institutional Ethical Committee (Approval No. TU/EC/NEW/INST/2024/4636-10) and was further endorsed by the Institutional Research Board, Departmental Research Committee and Research Board of Tantia University. All procedures were conducted in accordance with institutional guidelines, ensuring confidentiality and ethical standards.

Inclusion and Exclusion criteria: Adults aged 18-70 years with good-quality AP pelvic radiographs showing complete bilateral visualisation of the GSN were included. Radiographs with fractures, congenital anomalies, bone tumours, infections, deformities, previous pelvic or hip surgeries, or poor image quality were excluded to ensure accurate morphometric assessment.

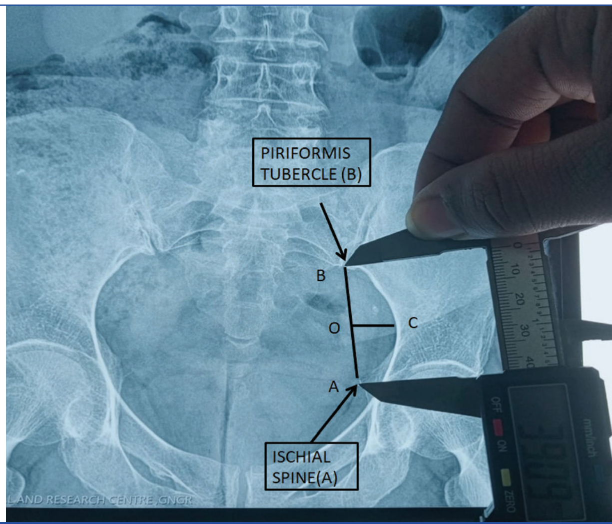
Sample size calculation: The sample size was calculated using a two-sample t-test formula with a significance level (α) of 0.05 and a power (1-β) of 80% (β=0.2). The calculation was based on previously published morphometric measurements of the GSN—specifically, the mean width values in males (μ_2=27.06 mm) and females (μ^1=5.41 mm), with standard deviations of 3.53 and 3.37, respectively [18]. Using these parameters, the minimum required sample size was estimated to be 69 participants per group, resulting in a total of 138 cases for adequate statistical power. To enhance robustness and account for potential exclusions, a total of 200 radiographs were included in the study.

Study Procedure

Standard AP pelvic radiographs were obtained using a digital X-ray unit operating at 70-80 kVp and 20-30 mAs. Radiographs were taken with patients in the supine position, with both lower limbs internally rotated by approximately 15° for optimal pelvic alignment. The X-ray beam was centered at the midpoint between the anterior superior iliac spines to ensure proper visualisation of the pelvis and the GSN.

The GSN was identified bilaterally on each radiograph. Morphometric parameters were measured using digital callipers with 0.01 mm precision [Table/Fig-1]. The following measurements were obtained:

- **Maximum Width (AB):** Distance between the piriformis tubercle (B) and the ischial spine (A) [10].
- **Maximum Depth (OC):** Perpendicular distance from the deepest point of the GSN (C) to the line of maximum width (AB) [10].



[Table/Fig-1]: Radiographic representation of Greater Sciatic Notch (GSN) measurements with defined anatomical landmarks.

- **Posterior Segment (OB):** Distance between the piriformis tubercle (B) and point O (the intersection of the vertical cross-sectional width and maximum depth) [10].
- **Index I:** (Depth OC ÷ Width AB) × 100 [19].
- **Index II:** (Posterior Segment OB ÷ Width AB) × 100 [19].

Measurements were recorded for both right and left sides and were segregated by sex. To minimise observer bias, two independent trained observers performed the measurements and the mean of their readings was used for statistical analysis [10].

STATISTICAL ANALYSIS

Data were compiled using Microsoft Excel and analysed using the Statistical Package for the Social Sciences (SPSS), version 23.0. Descriptive statistics, including mean, Standard Deviation (SD), minimum and maximum values, were calculated for each parameter. An independent samples t-test was employed to compare the mean values of the GSN parameters between male and female groups for both sides. A p-value less than 0.05 was considered statistically significant. Interobserver variability was minimised by obtaining measurements independently from two observers and calculating the mean of their readings for analysis.

RESULTS

The present study analysed 200 AP pelvic radiographs comprising 92 males and 108 females, with a mean age of 42.78±11.36 years in males and 45.01±13.69 years in females [Table/Fig-2].

Sex	n	Mean	Minimum	Maximum	SD
Male	92	42.7756	21.00	68.00	11.36188
Female	108	45.0081	19.00	70.00	13.69184
Total	200	43.1937	19.00	69.00	13.15782

[Table/Fig-2]: Age and sex distribution of the study population.
*SD: Standard deviation

Width of Greater Sciatic Notch (GSN)

The mean width of the GSN was significantly greater in females than in males. On the right side, females had a mean width of 54.56±2.18 mm, whereas males measured 41.39±1.64 mm (p<0.001). Similarly, on the left side, the mean width was 54.67±2.10 mm in females and 41.54±1.47 mm in males, demonstrating a statistically significant difference (p<0.001) [Table/Fig-3].

Depth of Greater Sciatic Notch (GSN)

Mean depth values of the GSN showed statistically significant sexual dimorphism, with females exhibiting greater depth than males. On the right side, the mean depth was 26.52±1.21 mm in females compared to 25.21±0.64 mm in males. On the left side, females had a mean depth of 26.64±1.18 mm, while males measured 25.25±0.62 mm (p<0.001) [Table/Fig-4].

Parameters	Sex	n	Mean	SD	Min.	Max.	p-value
Right	Male	92	41.39	1.6432	39.1	44.7	<0.001***
	Female	108	54.56	2.1839	48.9	58.5	
Left	Male	92	41.54	1.4680	39.3	44.4	<0.001***
	Female	108	54.67	2.1058	49.9	58.6	

[Table/Fig-3]: Comparison of mean width (mm) of right and left Greater Sciatic Notch (GSN) between males and females
*SD: Standard deviation; Min: Minimum, Max: Maximum; *** p<0.001- Very highly significant.

Parameters	Sex	n	Mean	SD	Min.	Max.	p-value
Right	Male	92	25.21	0.6431	24.1	26.7	<0.001***
	Female	108	26.52	1.2059	23.5	28.7	
Left	Male	92	25.25	0.6239	24.2	26.7	<0.001***
	Female	108	26.64	1.1786	23.8	28.8	

[Table/Fig-4]: Comparison of mean depth (mm) of right and left Greater Sciatic Notch (GSN) between males and females.
*SD: Standard deviation; Min: Minimum; Max: Maximum; *** p<0.001 - Very highly significant.

Posterior Segment

Females demonstrated significantly higher posterior segment values compared to males. On the right side, the mean posterior segment was 28.5±0.98 mm in females and 15.2±1.16 mm in males. On the left side, females measured 28.7±1.06 mm, whereas males had 15.3±1.17 mm, showing a statistically significant difference (p<0.001) [Table/Fig-5].

Parameters	Sex	n	Mean	SD	Min.	Max.	p-value
Right	Male	92	15.2	1.1632	10.4	19.8	<0.001***
	Female	108	28.5	0.9762	26.3	30.2	
Left	Male	92	15.3	1.1763	10.4	19.2	<0.001***
	Female	108	28.7	1.0582	26.7	31.2	

[Table/Fig-5]: Comparison of mean posterior segment (mm) of right and left Greater Sciatic Notch (GSN) between males and females.
*SD: Standard deviation; Min: Minimum, Max: Maximum; *** p<0.001 - Very highly significant.

Index I and Index II

Index I was significantly higher in males (Right: 61.08±3.17; Left: 60.8±2.95) compared to females (Right: 48.6±3.06; Left: 48.8±2.91) (p<0.001) [Table/Fig-6].

Parameters	Sex	n	Mean	SD	Min.	Max.	p-value
Right	Male	92	61.08	3.1768	55.2	66.5	<0.001***
	Female	108	48.6	3.0658	41.12	55.68	
Left	Male	92	60.8	2.9468	55.2	65.9	<0.001***
	Female	108	48.8	2.9132	40.9	55.6	

[Table/Fig-6]: Comparison of mean index - I of right and left Greater Sciatic Notch (GSN) between males and females.
*SD: Standard deviation; Min: Minimum, Max: Maximum; *** p<0.001 - Very highly significant.

Conversely, Index II was significantly higher in females (Right: 52.3±2.84; Left: 52.5±2.51) than in males (Right: 36.7±2.75; Left: 36.9±2.71) (p<0.001) [Table/Fig-7].

Parameters	Sex	n	Mean	SD	Min.	Max.	p-value
Right	Male	92	36.7	2.7568	26.4	43.8	<0.001***
	Female	108	52.3	2.836	47.8	60.9	
Left	Male	92	36.9	2.7168	26.5	44.1	<0.001***
	Female	108	52.5	2.5128	47.8	60.20	

[Table/Fig-7]: Comparison of mean index - II of right and left Greater Sciatic Notch (GSN) between males and females.
*SD: Standard deviation; Min: Minimum, Max: Maximum; ***p<0.001-Very highly significant.

Overall Comparison

When bilateral values were combined, females consistently showed greater width, depth and posterior segment measurements, whereas males demonstrated higher Index I. Index II predominated in females [Table/Fig-8].

S. No.	Parameters	Sex	Mean	SD	Min.	Max.	p-value
1	Width	M	41.02	1.2351	39.1	44.7	<0.001***
		F	54.17	2.1650	48.9	58.6	
2	Depth	M	25.09	0.6439	24.1	26.7	<0.001***
		F	26.27	1.2086	23.5	28.8	
3	Posterior segment	M	15.4	1.1520	10.4	19.8	<0.001***
		F	28.6	1.0254	26.3	31.2	
4	Index-I	M	61.01	2.9965	55.2	65.9	<0.001***
		F	48.7	2.9020	40.9	55.6	
5	Index-II	M	36.8	2.7350	26.4	44.1	<0.001***
		F	52.4	2.6252	47.8	60.9	

[Table/Fig-8]: Mean and standard deviation of Greater Sciatic Notch (GSN) parameters in males and females.
*SD: Standard deviation; Min: Minimum; Max: Maximum; *** p<0.001 - Very highly significant

DISCUSSION

Sex determination is a crucial component in establishing a biological profile during forensic, anthropological and medicolegal investigations. The pelvis, being the most sexually dimorphic skeletal region, provides highly dependable features for this purpose. Among these, the GSN holds particular significance due to its clear sexual dimorphism and visibility in both skeletal and radiological examinations. The present study analysed the morphometric characteristics of the GSN in a North Indian population (Sri Ganganagar, Rajasthan) using plain pelvic radiographs to assess its role in sex determination.

In the present study, the mean width of the GSN was significantly higher in females (54.17 mm) than in males (41.02 mm), supporting the established concept of a wider, shallower notch in females to facilitate childbirth. Although this trend agrees with previous research by Alizadeh Z et al., (M: 56.18 mm; F: 62.62 mm), Kumari R et al., (M: 46.2 mm; F: 53.1 mm) and Mostafa E et al., (M: 68.9 mm; F: 80.9 mm), the absolute values in the present study were comparatively lower [6,10,17]. These differences may stem from variations in imaging modality {Computed Tomography (CT) scan vs. radiograph}, differences in measurement landmarks, magnification errors and population-based pelvic morphology.

Similarly, the mean depth of the GSN was slightly greater in females (26.27 mm) than in males (25.09 mm), indicating a shallower notch in males. While Karki RK et al., and Kumari S and Sukdev O observed comparable values [20,21], Alizadeh Z et al., reported lower mean depths (M: 20.94 mm; F: 23.13 mm) [6]. Such variation could be attributed to ethnic differences, radiographic positioning and methodological diversity among studies—particularly the use of CT scans, dry bone samples, or plain radiographs.

A marked difference was noted in the posterior segment length, where females (28.6 mm) showed nearly twice the values of males (15.4 mm). This finding aligns with the results of Kim DH et al., (M: 11.3 mm; F: 25.45 mm) and Soltani S et al., (M: 9.4 mm; F: 20.4 mm), reinforcing that posterior segment expansion reflects the broader pelvic outlet in females, which is related to obstetric adaptation [11,19].

For the derived indices, Index I (depth/width×100) was higher in males (61.01) than in females (48.7), signifying a relatively deeper and narrower notch in males. This is consistent with observations by Karki RK et al., and Kumari S and Sukdev O [20,21]. Conversely, Index II (posterior segment/width×100) was higher in females (52.4) than in males (36.8), corroborating trends reported by Alizadeh Z et al., and Karki RK et al., [6,20].

Overall, the marked differences in numerical values compared with other authors [Table/Fig-9] [6,10,11,19-22] likely arise from several factors, including ethnic and genetic variation, age distribution,

Authors with year	Ethnicity	Material	N	Width of GSN		Depth of GSN		Posterior segment		Index- I		Index- II	
				Male mean	Female mean	Male mean	Female mean	Male mean	Female mean	Male mean	Female mean	Male mean	Female mean
Alizadeh Z et al., (2013) [6]	Iranian	X-ray	64	56.18	62.62	20.94	23.13	22.78	28.53	32.74	37.12	40.87	45.97
Okoseimie-ma S and Udoaka A (2013) [22]	Nigeria	X-ray	518	42.24	50.73	15.60	14.91	14.65	21.39	38.81	30.10	34.55	42.18
Mostafa E et al., (2016) [17]	Egyptian	CT-scan	141	68.9	80.9	-	-	-	-	-	-	-	-
Kim DH et al., (2018) [11]	Korean	3D Model	202	45.8	56.2	34.7	32.1	11.3	25.45	17.4	38.2	-	-
Soltani S et al. (2018) [19]	Iranian	3D CT scan of pelvis	237	44.9	52.9	30.2	30.0	9.4	20.4	16.6	32.9	20.79	37.8
Kumari S and Sukdev O (2019) [21]	Indian	X-ray	33	41.2	43.4	34.4	26.1			84.49	61.22		
Karki RK (2020) [20]	Nepalese	CT-scan	110	40.31	45.85	25.13	24.75	11.12	16.65	62.79	49.48	27.77	33.06
Kumari R et al., (2024) [10]	North Indian	PMCT of pelvis	408	46.2	53.1	31.6	30.3	9.4	20.0	15.7	32.4	73.30	81.03
Present study 2025	Rajasthan (India)	X-ray	200	41.02	54.17	25.09	26.27	15.4	28.6	61.01	48.7	36.8	52.4

[Table/Fig-9]: Comparison of the variables of Greater Sciatic Notch (GSN) in different studies [6,10,11,19-22].
Min: Minimum; Max: Maximum; *GSN: Greater sciatic notch

differences between skeletal and radiological methods, imaging magnification, observer bias and variations in defining anatomical landmarks. The use of plain radiographs in the present study, unlike CT or 3D reconstructions in others, may also contribute to lower absolute values due to projectional limitations.

Therefore, the present study highlights the necessity of establishing population- and modality-specific standards for morphometric assessment. Despite the variability, the consistent pattern of sexual dimorphism across studies confirms the reliability of the GSN as a useful parameter for forensic sex determination. Plain radiography, being inexpensive, non invasive and widely available, remains a practical and effective tool for anthropological and medicolegal applications.

Limitation(s)

The present study was limited to a specific regional population, which may restrict the generalisability of the findings to other ethnic groups. Only AP pelvic radiographs were analysed, whereas three-dimensional imaging modalities such as CT or Magnetic Resonance Imaging (MRI)—which provide more precise morphometric data—were not utilised. The study was cross-sectional and factors such as age-related changes or pathological alterations in pelvic morphology were not explored. Furthermore, manual measurements using digital callipers may have introduced minimal observer variability despite standardised protocols.

CONCLUSION(S)

The present radiographic study of the GSN in a North Indian population (Sri Ganganagar, Rajasthan) demonstrated significant sexual dimorphism across all measured parameters, including width, depth, posterior segment length, Index I and Index II ($p<0.001$). Females exhibited greater mean width, depth and posterior segment values, whereas males showed higher Index I, indicating a narrower and deeper notch. These findings are consistent with most previous studies, although variations were observed due to ethnicity, imaging modalities and sample sizes. Radiographic morphometric analysis of the GSN provides a non invasive, cost-effective and reliable method for sex estimation, making it a valuable adjunct in forensic anthropology, medicolegal investigations and archaeological research. Establishing population-specific reference values is essential to enhance the accuracy of biological profile reconstruction. The present study contributes baseline data for the North Indian population and supports the use of plain pelvic radiographs in routine forensic practice.

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PARTICULARS OF CONTRIBUTORS:

1. Research Scholar, Department of Anatomy, Dr. S.S. Tantia M.C.H. and R.C. Sri Ganganagar, Sri Ganganagar, Rajasthan, India.
2. Associate Professor/Director Academic and Research, Department of Anatomy, Dr. S.S. Tantia M.C.H. and R.C. Sri Ganganagar, Sri Ganganagar, Rajasthan, India.
3 Research Scholar, Department of Anatomy, Dr. S.S. Tantia M.C.H. and R.C. Sri Ganganagar, Sri Ganganagar, Rajasthan, India.
4 Research Scholar, Department of Anatomy, Pacific Medical University, Udaipur, Rajasthan, India.
5 Research Scholar, Department of Anatomy, Dr. S.S. Tantia M.C.H. and R.C. Sri Ganganagar, Sri Ganganagar, Rajasthan, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Rasalika Miglani,
27, Vinayak Vihar, Sri Ganganagar-335001, Rajasthan, India.
E-mail: rasalikamiglani@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Sep 18, 2025
- Manual Googling: Nov 12, 2025
- iThenticate Software: Nov 14, 2025 (8%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

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