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ORIGINAL ARTICLE

Anthropometric Analysis of the Greater Sciatic Notch: A Radiographic Study

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Abstract :
The pelvis is a sexually dimorphic bone due to hormonal effects that facilitate its adaptation for parturition in females. This study aimed at determining the radiographic morphometry of the greater sciatic notch (GSN) in a selected Nigerian population. A Tertiary health facility in Delta State Nigeria provided permission to access its radiological database for the pelvic radiographs retrospectively examined in this cross-sectional study. The GSN of 300 patients (154 males and 146 females) were identified and the following measurements taken using digital callipers and protractors; width, depth, posterior segment, total and posterior angles. Statistical Package for Social Sciences version 22 summarised the data in means and further assessed the gender, side and age differences. The association between variables was tested using the Pearson's correlation test. Inferential statistics were deemed significant at $p<5\%$. All variables except the depth and posterior angle were sexually dimorphic ($p<0.05$). The width and posterior angle varied significantly across the age-groups. All variables except the width were asymmetrical ($p<0.05$). All the GSN measurements lacked significant correlation with age ($p>0.05$). The normative values for GSN dimensions in the study population have been provided. Their sexual dimorphism highlights their utility in sex determination of unknown human remains.

Keywords: Greater sciatic notch; Radiographs; Dimension; Index: Forensic.

Introduction :

Body structures exhibit variations in their anthropometric measurements mainly due to the influence of genetics, sex, race, gender and cultural practices. This highlights the need of establishing baseline ranges which forensic experts can use for accurate identification of skeletal relics in mass disasters and medico-legal cases.[1,2] Human identification relies on the comprehensive establishment of an individual's biological profile which consists of sex, stature, age and ethnicity or race.[3-5]

Bones are useful in forensic investigations because of their dense nature that makes them resilient to decay, putrefaction and extreme temperatures.[1,4] Nevertheless, in high-impact catastrophes like plane crashes or explosions, bones are usually fragmented and rarely recovered intact. This makes the forensic identification process challenging.[6,7] Sex differences in the human skeleton are due to trait expression influenced by sex hormones, nutrition and cultural differences that shape gender roles.[3] Sex determination has been conducted using various parts of the human skeleton including the pelvis, skull and long bones. The pelvis provides the highest accuracy for sex determination; approximately 98%.[6, 7] The sexual dimorphism of the hip bone or ossa coxae is attributed to the demands for child bearing and adaptations for bipedalism.[3,8] Despite its susceptibility to damage, the pubic bone is the best sex indicator. Several indices of the pelvis have been used for sex determination namely; the chilotic index, turner pelvic index, ischiopubic (Washburn) index, and sciatic notch index.[1,9] The greater sciatic notch (GSN) is a U-shaped indentation on the posterior aspect of the pelvic bones. It is highly resistant to fragmentation hence, has a high probability of being recovered intact in poorly preserved skeletons.[9-11] The shape and size of the GSN correlate directly with the pelvic inlet.[1] The metric parameters of the GSN show intra and inter-population variations mainly due to racial and ethnic differences.[1,12-14] The GSN displays sexual dimorphism across diverse population groups and this has been linked to sex variances in the development of the hip bone.[1-3,12,13]

For accurate sex prediction in forensic investigations, population-specific standards are required. However, data regarding the radiographic dimensions of the GSN in Delta State, Nigeria is scarce. This research aimed to determine the radiographic measurements of the GSN in adult Nigerians. Furthermore, the association between the metric parameters with age and sex were evaluated to elucidate their role in forensic investigations.

Materials and methods:

This retrospective observational research entailed the analysis of pelvic radiographs stored in the Picture Archiving and Communications System (PACS) software of a Hospital in Delta State, Nigeria. The evaluation began after seeking the Institution's permission (HREC/PAN/2023/020/0559).

Apparently normal antero-posterior pelvic radiographs of patients aged 18-80 years were assessed. The lower age limit of 18 years was chosen to guarantee the evaluation of fully matured pelvises. Excluded radiographs had evidence of previous surgery and visible pelvic pathologies including fractures, osteophytes, tumors, and reduced joint space. Technically inadequate pelvic radiographs with over-penetration, patient rotation or

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Table 1. Age distribution of patients.

Age groups (years)	Total Population	
	N	%
<20	9	3.0
20-29	44	14.7
30-39	59	19.7
40-49	51	17.0
50-59	46	15.3
60-69	59	19.7
>70	32	10.7
Total	300	100

Table 2. Side differences in the metric variables of the GSN.

Variables	Side	N	Min	Max	Mean ± SD	P-value
Width (cm)	L	300	3.81	7.01	5.24 ± 0.62	0.100
	R	300	3.67	6.87	5.23 ± 0.61	
Depth (cm)	L	300	1.17	2.85	1.76 ± 0.32	0.001*
	R	300	0.55	2.80	1.71 ± 0.33	
Posterior Segment (cm)	L	300	1.04	3.24	1.82 ± 0.44	0.021*
	R	300	1.02	3.21	1.85 ± 0.43	
Posterior Angle $^{(0)}$	L	300	24.70	76.70	43.59 ± 6.95	0.315
	R	300	21.5	73.9	43.75 ± 7.03	
Total angle $^{(0)}$	L	300	57.9	129.2	105.06 ±11.28	0.001*
	R	300	52.9	132.0	105.84 ±11.74	
Index I	L	300	20.88	61.69	33.90 ± 7.36	0.001*
	R	300	11.85	63.82	33.19 ± 7.41	
Index II	L	300	21.84	59.32	34.77 ± 7.01	0.004*
	R	300	21.47	59.48	35.28 ±6.97	

***- significant difference, SD – standard deviation, R- right, L- left, Min- minimum, Max- maximum**

indistinguishable landmarks were also excluded. Three hundred (300) pelvic radiographs of 154 males and 146 females met the defined selection criteria.

The pelvic radiographs were viewed on a computer desktop and the symmetry verified. Thereafter, the age and gender of the patient was noted and the bilateral GSNs identified. Using a linear digital ruler the depth, width, and posterior segment of the GSN were measured in cm while a digital protractor was used to measure the posterior and total angles in degrees.

The width (AB) of the GSN was defined as the maximum vertical span between the ischial spine (A) and the piriformis tubercle (B) while the depth (CO) was measured as the perpendicular distance from the deepest point of the GSN (C) to where it intersects the line measuring the GSN width (point O). The posterior segment (BO) was the length from the piriformis tubercle (B) to the intersection point (O) of the lines measuring the width and depth of the GSN (Fig 1).[1]

Total angle (ACB) was formed at the deepest point of the GSN (C), from the ischial spine (A) to the piriformis tubercle (B). Posterior angle (BCO) was the deepest point of the GSN (C) formed by the meeting of straight lines from the piriformis tubercle (B) and point O. Index I was calculated as the ratio of depth to width multiplied by 100. Index II was calculated as the ratio of posterior segment to width multiplied by 100 (Fig 1).[1]

Statistical Package for Social Sciences (SPSS) version 22 analyzed the variables considering gender, side and age categories. Means and standard deviations were tabulated and compared across different age and sex groups using the analysis of variance (ANOVA) and independent t-test respectively.

Table 3. Gender differences in the measurements of the GSN.

Variables	Side	Sex	N	Mean ±SD	P-value
Width (cm)	L	M	154	4.99 ± 0.53	0.001*
		F	146	5.51 ± 0.54	
	R	M	154	5.00 ± 0.54	0.001*
		F	146	5.46 ± 0.60	
Depth (cm)	L	M	154	1.75 ± 0.31	0.639
		F	146	1.76 ± 0.34	
	R	M	154	1.71 ± 0.33	0.964
		F	146	1.72 ± 0.32	
Posterior segment (cm)	L	M	154	1.66 ± 0.37	0.001*
		F	146	1.99 ± 0.44	
	R	M	154	1.69 ± 0.39	0.001*
		F	146	2.01 ± 0.43	
Posterior angle $^{(o)}$	L	M	154	43.05 ±7.61	0.165
		F	146	44.17 ± 6.20	
	R	M	154	43.08 ± 7.70	0.089
		F	146	44.46 ± 6.20	
Total angle $^{(o)}$	L	M	154	100.34 ± 10.38	0.001*
		F	146	109.93 ± 10.11	
	R	M	154	101.39 ± 10.87	0.001*
		f	146	110.52 ± 10.79	

***- significant sex differences, SD – standard deviation, R- right, L- left, M- male, F- female.**

Table 4. Gender differences in the measurements of the GSN.

Variables	Side	Sex	N	Mean ±SD	P-value
Index I	L	M	154	35.37 ± 7.41	0.001*
		F	146	32.35 ± 7.01	
	R	M	154	34.60 ±7.64	0.001*
		F	146	31.71 ± 6.89	
Index II	L	M	154	33.44 ±6.90	0.001*
		F	146	36.16 ± 6.89	
	R	M	154	33.93 ± 7.17	0.001*
		F	146	36.70 ± 6.49	

***- significant sex differences, SD – standard deviation, R- right, L- left, M- male, F- female.**

Laterality was investigated using paired t-test and Pearson's correlation test determined the relationship between age and the variables. Significance was considered at probability level of less than 5%.

Results:

Out of the 300 pelvic radiographs, 146 (48.7%) belonged to female patients, while 154 (51.3%) were from males. The sample's average age was 47.26 ± 16.89 years, ranging from 18 to 80 years. The 30-39 years' and 60-69 years' age-groups had the maximum frequencies, each accounting for 20% while the < 20 years age group had the lowest frequency (9, 3%) of patients (Table 1).

Significant side differences in the depth, posterior segment, total angle and both indices were observed ($p<0.05$). The left side exhibited larger depth and index I while the right side had larger total angle, posterior segment and index II ($p<0.05$). The side variations in the width and posterior angle were however not statistically significant ($p>0.05$) (Table 2).

Females displayed significantly larger GSN width, index II, posterior segment, and total angle while the index I was larger in males ($p<0.05$). The GSN depth or posterior angle didn't show any sex variances ($p>0.05$) (Tables 3 and 4).

Table 5. Difference in mean variables of the GSN within the age groups.

		Age Groups (Years)							
Variables	Side	<20	20-29	30-39	40-49	50-59	60-69	>70	P-value
Width (cm)	L	5.10 ± 0.77	4.98 ±0.63	5.34 ±0.54	5.29 ±0.56	5.21 ±0.56	5.38 ±0.68	5.18 ±0.65	0.034*
	R	4.99 ±0.71	4.98 ±0.61	5.33 ±0.55	5.26 ±0.56	5.23 ±0.53	5.33 ±0.70	5.18 ±0.62	0.051
Depth (cm)	L	1.73 ± 0.45	1.70 ±0.31	1.83 ±0.35	1.72 ±0.28	1.70 ±0.32	1.76 ±0.31	1.84 ±0.33	0.203
	R	1.65 ±0.40	1.67 ±0.29	1.78 ±0.35	1.67 ±0.26	1.68 ±0.33	1.73 ±0.34	1.77 ±0.39	0.451
Posterior segment (CM)	L	1.68 ±0.40	1.72 ±0.40	1.94 ±0.51	1.80 ±0.36	1.85 ±0.37	1.84 ±0.43	1.76 ±0.53	0.200
	R	1.75 ± 0.50	1.77 ±0.44	1.95 ±0.48	1.82 ±0.38	1.85 ±0.39	1.86 ±0.43	1.79 ±0.50	0.429
Posterior angle (0)	L	37.32 ±6.12	42.43 ±8.22	44.96 ±9.00	43.82 ±5.77	44.65 ±4.48	43.82 ±6.21	42.13 ±6.13	0.035*
	R	36.68 ±6.80	41.59 ±7.67	45.80 ±9.08	43.96 ±6.29	44.62 ±4.97	44.08 ±5.60	42.73 ±5.90	0.002*
Total angle(0)	L	97.31 ±10.87	102.77 ±12.50	106.11 ±10.07	105.87 ±10.97	107.11 ±11.06	105.84 ±12.43	102.80 ±9.47	0.127
	R	98.12 ±12.09	102.97 ±12.01	107.32 ±11.14	107.21 ±11.74	106.95 ±11.00	106.54 ±13.05	104.14 ±10.01	0.148
Index I	L	34.42 ±10.11	34.62 ±7.34	34.53 ±6.94	32.83 ±6.77	32.96 ±7.66	33.31 ±7.74	35.77 ±7.17	0.525
	R	33.68 ±9.44	33.88 ±6.75	33.54 ±7.04	32.19 ±6.85	32.35 ±7.28	33.12 ±8.28	34.41 ±8.06	0.818
Index II	L	33.14 ±7.19	34.53 ±6.46	36.25 ±8.26	34.20 ±6.78	35.57 ±6.22	34.11 ±6.18	33.78 ±8.09	0.516
	R	34.81 ±7.11	35.37 ±6.95	36.53 ±7.89	34.78 ±7.07	35.39 ±6.67	34.90 ±6.01	34.32 ±7.44	0.816

*** significant age difference, SD – standard deviation, R- right, L- left.**

Table 6. Correlation between the GSN variables and age.

		Age	Width		Depth		Posterior Segment		Posterior Angle		Total Angle		Index I		Index II	
Side			L	R	L	R	L	R	L	R	L	R	L	R	L	R
Age	r	1	0.096	0.096	0.040	0.048	0.013	0.000	0.035	0.068	0.056	0.058	-0.013	-0.007	-0.044	-0.058
	p		0.098	0.096	0.486	0.403	0.817	0.997	0.540	0.242	0.337	0.318	0.821	0.909	0.445	0.320

L- left, R- right, r- Pearson's Correlation, p- Sig. (p-value).

A significant variance in the width and posterior angle were noted across the age-groups (Table 5). However, age lacked significant correlation with all the GSN parameters investigated ($p < 0.05$) Table 6. Table 7 compares the findings of different studies on GSN, highlighting the population differences.

Discussion:

The GSN width in this study surpassed the mean value documented in several earlier reports.[1,2,12,14] It was however smaller than the width reported by Alizadeh et al.[3] and Sarac-Hadžihalilović et al.[13] The depth was smaller than the research findings in India, Iran, and Bosnia.[1,3,13,14] The posterior segment was larger than the values reported by Karki et al.[1] and Shangloo et al.,[2] but smaller than reports by Sarac-Hadzihalilovic et al.,[13] Jain and Choudhary,[12] and Alizadeh et al.[3] (Table 7). The GSN angles (posterior and total angles) were larger than the measurements by Shangloo et al.,[2] Sharma et al.[14] and Karki et al.[1] Index I was lower than the findings by Jain and Choudhary,[12] Karki et al.,[1] and Shangloo et al.[2] Index II was lower than the results by Jain and Choudhary.[12] and Alizadeh et al.[3] and higher

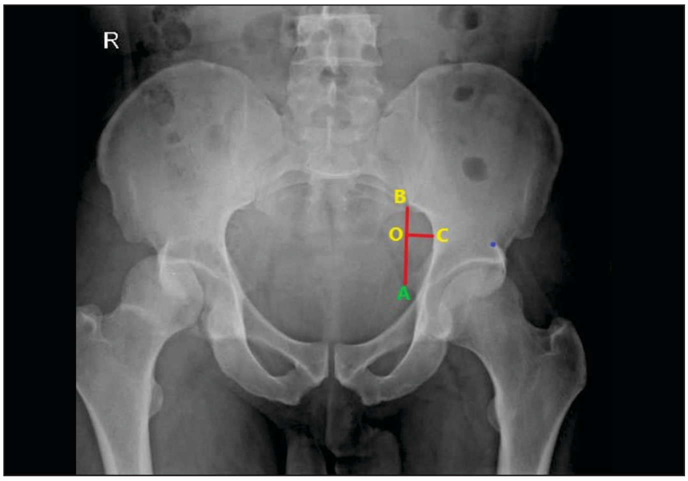

Figure 1. Antero-posterior pelvic radiograph showing measurement of GSN. A – tip of the ischial spine, B – Piriformis tubercle, AB –Width, OC- Depth, C- deepest point of the GSN, OB- posterior segment.

than the studies by Shangloo et al.[2] and Karki et al.[1] The population differences in Index II could be ascribed to the variant influence by the posterior segment, sacrum development, piriform tubercle, and ischial spine.[1]

These measurements varied across many studies due to different ethnic, cultural, genetic, racial and environmental factors like occupation, nutrition, climate and physical activity.[1,4,7,15] Variations in sample size, sample composition, and data collection tools; ranging from traditional rulers and goniometers to digital substitutes, may also explain the observed differences.[7,16] Disparities in sample types namely; dry bones, radiographs, or computed tomography scans, can influence the GSN measurements in diverse populations.[7] The accuracy of the morphometry in radiography could be influenced by superimposition of structures and inherent magnification that varies in studies.[1]

We report asymmetry in the GSN depth, indices, total angle and posterior segment, corresponding with Alizadeh et al.[3] and Shangloo et al.[2] Consistent with Alizadeh et al.,[3] the left GSN was deeper than the right. This contradicted Shangloo et al.,[2] who observed a deeper right GSN. Bilateral asymmetry may distort, delay, or speed up the skeletal markers used in estimating the indicators of biological profile. Many factors are responsible for GSN asymmetry including; handedness, genetics, biomechanical and environmental factors.[11,15,16]

The GSN was wider in females and this was congruent with other literature reports that highlight the GSN's significance in forensics.[1,3,14] Parallel with several reports, the GSN depth lacked significant sex variation.[1,3,13,14] However, this differed from studies by Jain and Choudhary.[12] and Shangloo et al.[2] These disparities exist because of varying magnitude of sexual dimorphism of bones in different populace. Aligning with several studies, females had larger posterior segment of GSN which could be utilized as a good sex indicator.[1-3,13,14] The posterior angle lacked sexual dimorphism, contradicting with the findings of some studies.[1,2,14] Corresponding with previous reports, the total angle was significantly larger in females hence relevant in forensic investigations.[1,2]

Table 7. Comparison between the GSN morphometry in this study and other studies.

Author		Karki et al.[1]		Shangloo et al.[2]		Alizadeh et al.[3]		Jain and Choudry,[12]		Sarac- Hadžihalilović et al.[13]		Sharma et al.[14]		Current study	
Country		Nepal		India		Iran		India		Bosnia		India		Delta, Nigeria	
Modality		Radiographs		Dry bones		Radiographs		Dry bone		Dry bones		Dry bone		Radiographs	
Population		64		68		98		46		98		100		300	
Unit		cm		cm		cm		mm		mm		mm		cm	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F
Width	L	40.31	50.28	4.11	5.18	5.58	6.3	34.1	43.3	53.93	60.65	39.11	41.36	4.99	5.51
	R			4.36	5.16			33.8	45					5	5.46
Depth	L	25.13	24.75	2.66	1.88			26.5	24.2	33.47	33.55	28.26	28.22	1.75	1.76
	R			2.75	2.36			25.6	24.7					1.71	1.72
Posterior segment	L	11.12	16.65	1.24	1.3			28	22	19.57	28.85	12.16	21.68	1.66	1.99
	R			1.65	1.64			28.9	24.7					1.69	2.01
Posterior angle (o)	L	25.47		22.08	26.09							22.44	29.7	43.05	44.17
	R			30.79	33.78									43.08	44.46
Total angle (o)	L			67.69	70.52							59.58	71.77	100.34	109.93
	R			63.74	73.06									101.39	110.52
Index I	L			66.19	64.12	41.96	39.98	78	57					35.37	32.35
	R			63.74	66.46	32.74	37.12	74	55					34.6	31.71
Index II	L			29.7	26.65	40.5	47.26	82	50	0.58	0.86			33.44	36.16
	R			37.6	39.52	40.87	45.98	85	55					33.93	36.7

M- male, F- female, L- left, R-right, mm- millimeters, cm- centimeters.

Indices I and II exhibited population diversity due to racial disparities and different measuring methods used. These indices were sexually dimorphic mainly due to hormonal effects on the pelvic growth. The indices can therefore be useful in sex determination of skeletal relics during forensic investigations.[1,4,16] The GSN morphometry lacked significant association with age, hence, they aren't reliable age indicators in the study population. Nevertheless, this warrants further investigation using a larger sample size consisting of an even age distribution. On the contrary, DesMarais et al.[11] noted that the GSN becomes narrower with advancing age mainly due to the effects of hormones on bone metabolism.

Following the comparison of GSN morphometry in different studies, this research emphasizes on the need for population-specific normative values for accurate identification during forensic investigations. Sexual dimorphism due to hormonal effects and pelvic adaptations for childbirth make the GSN significant in forensics.[1,10] The presence of the GSN in any human remains recovered from our study population can therefore be utilized in the prediction of sex of the individual. Misinterpretation of sex may occur if the values applied are not from the population the bone originated from.

Conclusion:

The normative values for GSN dimensions in the study population have been provided. Their sexual dimorphism highlights their utility in sex determination of unknown human remains.

Limitations of Study: The sample size was limited to radiographs from radiological database of a single hospital hence findings can not he generalised to the broader population. Inherent limitations of radiographs such as magnification and superimposition could have affected the precision of the morphometry.

Future Research Directions: The morphometry of the GSN can be evaluated using a larger sample of radiographs from many hospitals thus ensuring diverse age, regional and ethnic representation. Advanced imaging modalities like computed tomography can be utilised for precise morphometry. Formulas for accurate sex determination using GSN morphometry can be derived.

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