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Morphometric study of sciatic nerve and its topographic anatomical variations in relation to landmark structures around pelvis: a Nigerian population study

Sciatic nerve anatomical variations

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Abstract

Background: Sciatic nerve presents significant variations that pertain to its topography and divisions. The topographic variation shows sex effect due to differences in the dimension of pelvis that makes for the adaptability of female pelvis for pregnancy and childbirth. The objective therefore was to evaluate the sciatic nerve morphology and its topographical variations in relation to landmark structures in the pelvis of both sexes.

Materials and methods: Ninety-eight lower limb adult cadavers, sixty-six males and thirty-two females devoid of any gross pathology from Nigerian were used for the study. The cadavers were dissected to expose the sciatic nerves and the variations recorded. Anthropological measurements were taken and analysed using a Spearman's rank-order correlation model.

Results and Conclusions: The relationships between sciatic nerve and the piriformis muscle shows five varied types with the typical type comprising 83.0%. The largest thickness of SN in males and females were 18.5 cm and 17.3 cm respectively while the smallest thickness were 8.6 cm and 11.9 cm respectively. The dimensions between posterior superior iliac spine and greater trochanter (PSIS-GT) and between lateral edges of sciatic nerve intersection with piriformis to the tip of greater trochanter (LESN-GT) shows inverse correlation relationship between the two sexes. In males, there was a weak positive correlation (r_s = 0.165) between LESN-GT (4.75 ± 1.52) and PSIS-GT (15.3 ± 2.90) which was not statistically significant at 0.01 level (p = 0.989). In females, the relationship between LESN-GT (6.39 ± 0.59) and PSIS-GT (12.2 ± 3.70) shows moderate negative correlation (r_s = -0.476) which was not statistically significant at 0.01 level (p = 0.195). The dimension of LESN-GT which was observed to be longer in females was deemed to account for the deviation of sciatic nerve of females from the males' topographic anatomical relations.

Key words: sciatic nerve, morphometry, topography, variations

INTRODUCTION

The word sciatic has Greek origin. Sciatic nerve (SN) is unique because it is not only the longest but also the thickest nerve in the body [1, 2]. It has an extensive origin from lumbosacral plexus formed by the ventral rami of L4-S3 spinal nerves in the pelvic region. It has two components, the tibia and common peroneal. The tibia component is formed from the ventral branches of ventral rami of L4-S3 spinal nerves, while the common peroneal component is formed from the dorsal branches of ventral rami of L4-S2 spinal nerves [3]. Usually the nerve enters the gluteal region by passing through the greater sciatic foramen beneath the piriformis. In the gluteal region it lies beneath gluteal maximus muscle descending downward between ischial tuberosity and greater trochanter of femur to reach the back of thigh. More often the nerve terminates by dividing into two branches, tibial nerve and common peroneal nerve usually at the superior angle of popliteal fossa [2, 4]. SN is essentially the nerve supply to the muscles of the leg, foot and back of the thigh. It also provides cutaneous innervation to nearly the entire skin of the leg [1, 3].

The understanding of the course of SN is important because it presents significant variations that pertains to its topography and divisions. More so large number of invasive procedures are performed in the gluteal region. Therefore, the knowledge of the typical and variant anatomical patterns in relation to landmark structures is crucial to avoid accidental iatrogenic injuries during surgical procedures. Piriformis is a key muscle of the gluteal region that has remarkable landmark relations with SN [5]. The high bifurcation of SN in the pelvis with the varied exit of its component parts through greater sciatic notch in relation to piriformis might lead to the compression of the nerve or nerves which could also result to piriformis syndrome [6]. There are reports on varied anatomical relations with piriformis where the undivided nerve may emerge above or through the muscle while other variables include the division of the nerve which may lie above or partly demarcated by the muscle [7, 8, 9]. These variable relationships different from what is considered the normal with piriformis have been suggested to increase the chances of the nerve entrapment at the location [10].

At the lower part of gluteal region, the land mark structures of SN are the ischial tuberosity and greater trochanter of femur where the nerve location corresponds to a line drawn slightly medial to the midpoint between ischial tuberosity and the greater trochanter to the apex of popliteal fossa. In between the two bony tuberosities the nerve crosses posterior to obturator internus, gameli and quadratus femoris muscles that form its muscular bed [11]. The SN descends to the back of thigh and it is commonly reported to bifurcate into tibial and common peroneal nerves at the superior angle of popliteal fossa [1]. Its bifurcation however has shown wide topographic variations [3, 12, 13].

This study was designed to evaluate the sciatic nerve morphology and its topographical variations in relation to landmark structures in the pelvis of both sexes in adults with the view to establishing sexual differences in its orientation.

MATERIALS AND METHODS

Ninety-eight lower limb adult cadavers, 66 males and 32 females devoid of any gross pathology were used for the study. The cadavers were formalin-fixed in the Anatomy Department of three Medical Schools in Nigeria. The fixation was carried out by pouring the prepared formalin solution into the embalming pressure cylinder fitted with a pipe with a pair of cannulas attached to its end. Each of the cadavers was transfused with formalin solution through the femoral artery. Some quantity was also conveyed through the carotid artery for the brain tissues to be adequately fixed. After the embalmment, the cadavers were kept in the storage tanks containing formalin solution for three weeks before the dissections. The gluteus maximus was cut midway with each half reflected medially and laterally to expose the underlying sciatic nerve partially covered at the lower part of gluteal region. The biceps femoris was also cut and retracted to expose the nerve at the upper part of the thigh. The fatty and connective tissues were removed for the nerve to be fully appreciated. SN was followed down to its point of bifurcation. The emergence of the nerve from the greater sciatic foramen and its relations to the piriformis was recorded. Also images of anatomical variations of SN were captured with digital camera and documented. Illustrations were also made to further elucidate the variations. The following measurements were made in accordance with an established guidelines [14] with modifications using digital calliper and stainless meter rule: 1. Width of SN at the lower margin of the piriformis (WSN-LMP); 2. The width of SN at the level of lesser trochanter (WSN-LLT); 3. The vertical distance between medial edge of SN intersection with PM to ischial tuberosity (MESN-IT); 4. The vertical distance between lateral edge of SN intersection with PM to the tip of greater trochanter (LESN-GT); 5. The length of SN from the lower edge of piriformis to the point of its bifurcation (LSNLP-SNB); 6. The width of common peroneal nerve at SN bifurcation (WCP-SNB); 7. The width of tibia nerve at SN bifurcation (WTN-SNB); 8. The vertical distance between the lateral edge of SN intersection with piriformis to the posterior superior iliac spine (LSN-PPSS); 9. The thigh length from the tip of greater trochanter to knee joint fusion (TL). 10. Distance between apex of ischial tuberosity and greater trochanter (IT-GT); 11. Distance between posterior superior iliac spine and greater trochanter (PSIS-GT); 12. Distance between posterior superior iliac spine and ischial tuberosity (PSIS-IT); 13. Length of the lower extremity (LLE).

S/N	**Measured parameters**	**Abbreviations**
1.	Width of SN at the lower margin of the piriformis	WSN-LMP
2.	The width of SN at the level of lesser trochanter	WSN-LLT
3.	The vertical distance between medial edge of SN intersection with piriformis to ischial tuberosity	MESN-IT
4.	The vertical distance between lateral edge of SN intersection with piriformis to the tip of greater trochanter	LESN-GT
5.	The length of SN from the lower edge of piriformis to the point of its bifurcation	LSNLP-SNB
6.	The width of common peroneal nerve at SN bifurcation	WCP-SNB
7.	The width of tibia nerve at SN bifurcation	WTN-SNB
8.	The vertical distance between the lateral edge of SN intersection with piriformis to the posterior superior iliac spine	LSN-PPSS
9.	The thigh length from the tip of greater trochanter to knee joint fusion	TL
10.	Distance between apex of ischial tuberosity and greater trochanter	IT-GT
11.	Distance between posterior superior iliac spine and greater trochanter	PSIS-GT
12.	Distance between posterior superior iliac spine and ischial tuberosity	PSIS-IT
13.	Length of the lower extremity	LLE

The data collected was analyzed using STATA software version 14.0. A Spearman's rank-order correlation model was used in assessing the statistical significance of associations at 0.05 and 0.01 confidence levels. The rationale for correlation coefficient analytical model in this study was to ascertain parameters positively and negatively correlated with connection to sexual dimorphism of adult human pelvis.

RESULTS

A total of five varied types of SN relationships with piriformis was observed in this study. The summary is shown in table 1. Type A is the most frequently occurring and it is the typical type. Besides type A, four (4) variable types were observed. The total number of the variable types were not significant compared to the typical type (type A).

In Figure 1A, SN gains access into the gluteal region beneath the lower border of piriformis as an undivided nerve which was the most common type showing a prevalence of 81 (83.0%). In males the incidence was 54 (55.1%) while in females, 27 (27.6%). Figure 1B shows a bifurcated nerve entering the gluteal region comprising 7 (7.1%) cases. In males the occurrence was 5 (5.1%) and in females, 2 (2.0%). This variation shows the common peroneal nerve piercing the piriformis while the tibial nerve emerging at the lower border of piriformis with both uniting inferiorly. Figure 1C was observed in 2 (2.0%) cases all in males. The pattern shows two divisions from sacral plexus emerging above and below the piriformis muscle respectively in the gluteal region which united into a common trunk at the inferior part of the muscle. In Figure 1D, the bifurcated nerves separately entered the gluteal region below the piriformis muscle and continuing separately throughout their course. This variation comprises 6 (6.0%) cases. In males it had incidence of 4 (4.1%) whereas in females the incidence was 2 (2.0%). Figure 1E shows a bifurcated nerve with the common peroneal component piercing the piriformis while the tibial component emerging at the lower border of the piriformis muscle with both continuing separately throughout their course. The variation had a prevalence of 2 (2.0%) cases with one (1.0%) each in male and female respectively. Apart from the pictures, the five varied types were also illustrated as depicted in Figures 1b-5b.

Table 1. Relationship between sciatic nerve and the piriformis

Types	Description	Percentage Proportion
A	Sciatic nerve emerging below piriformis (common type)	83.0% (81)
B	Sciatic nerve divisions passing through and below piriformis uniting inferior	7.1% (7)
C	Sciatic nerve divisions emerging above and below piriformis uniting inferior	2.0% (2)
D	Two sciatic nerve divisions emerging below piriformis not uniting inferior	6.0% (6)
E	Sciatic nerve divisions passing through and below piriformis not uniting inferior	2.0% (2)

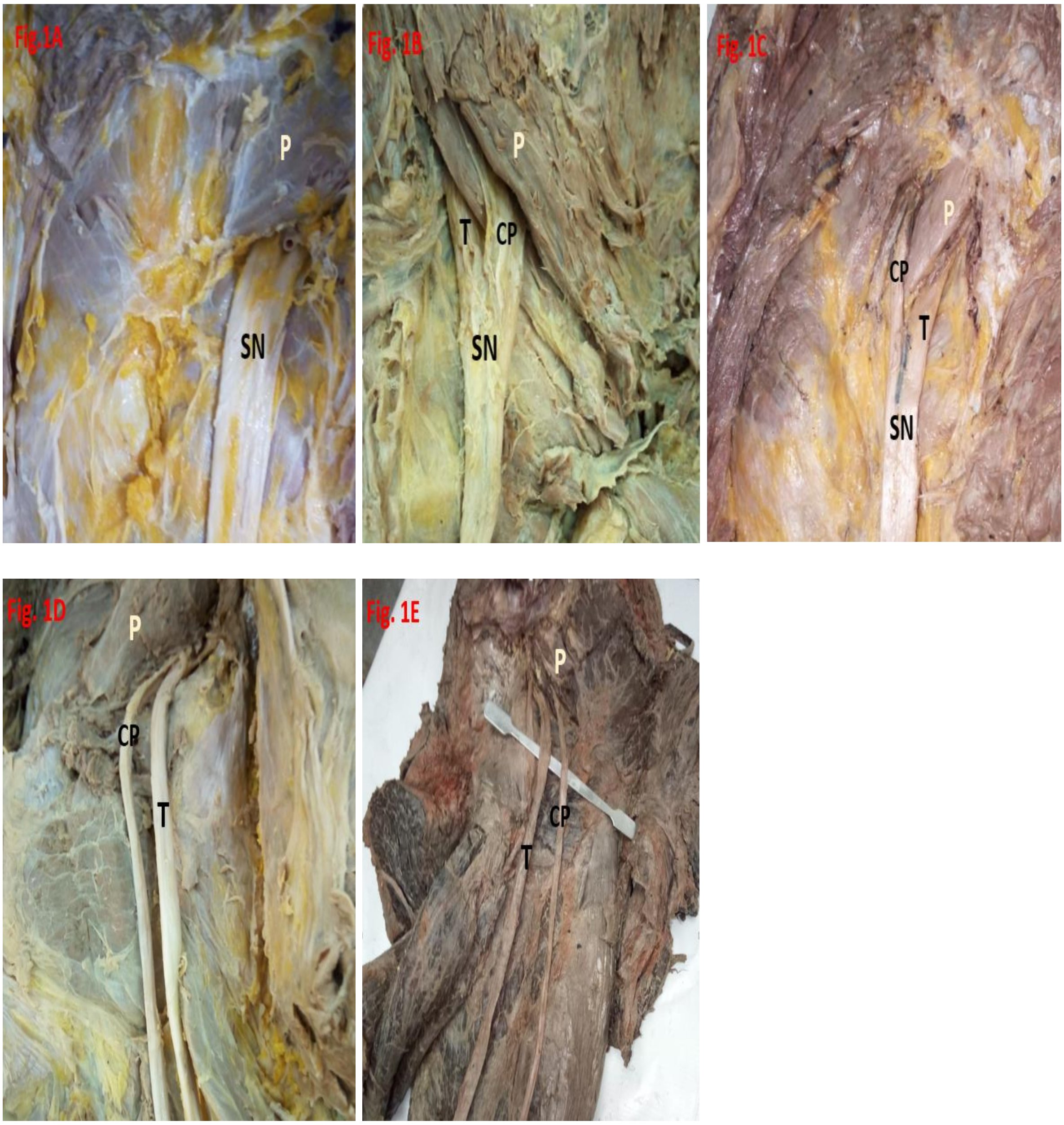
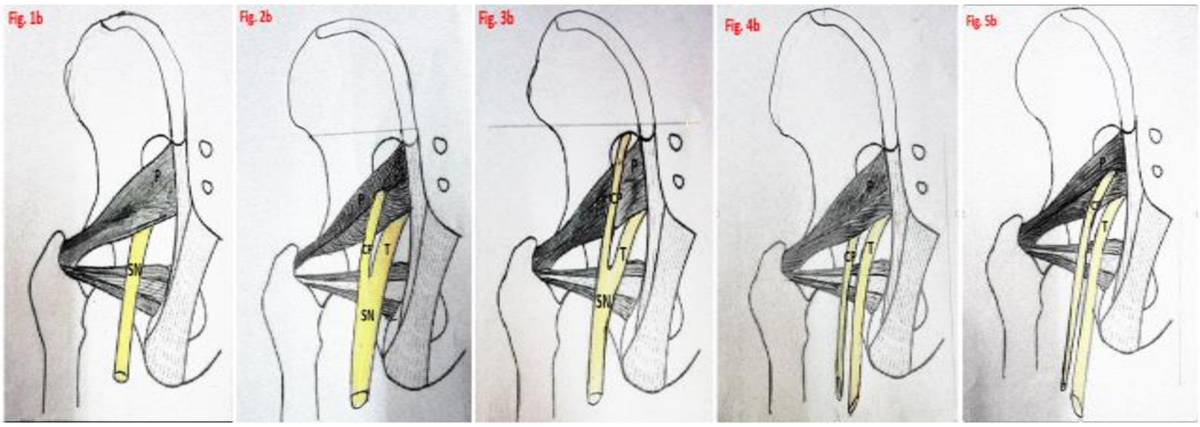


Figure 1A-E: Variations in SN divisions into TN and CPN: **A**. SN passes beneath the lower border of piriformis into the gluteal region as an undivided nerve; **B**. CPN entered gluteal region by piercing the piriformis while the TN emerged at the lower border of piriformis with both uniting inferiorly; **C.** CPN entered the gluteal region above the piriformis while TN emerged below the piriformis into gluteal region with both uniting inferiorly; **D**. CPN and TN separately entered the gluteal region below the piriformis muscle and continuing separately throughout their course; **E**. CPN pierced the piriformis while the TN emerged at the lower border of piriformis with both continuing separately throughout their course.



Figs. 1b-5b: Illustration of the variations in SN divisions into TN and CPN

The statistical data in tables 2 and 3 did not vary markedly in their mean probably because most of the parameters considered were not affected by the anomalous types or due to their insignificant number. Further analysis on the data was conducted to identify the parameters positively and negatively correlated with connection to sexual dimorphism of human pelvis.

A Spearman's rank-order correlation was run to determine the relationship between WSN-LMP in males and in females respectively (Table 4). There was a moderate, positive correlation between WSN-LMP in males and in females which was not statistically significant $r_s = -0.465$, $p = 0.052$.

Table 5 presents a Spearman's correlation that was run to assess the relationship between LESN-GT and IT-GT in the examined male and female cadavers. In the males, there was a very weak positive correlation ($r_s = 0.005$) between LESN-GT and IT-GT. However, there was no statistically significant correlation between them at 0.01 level ($p = 0.989$). In females, the relationship between LESN-GT and IT-GT shows moderate positive correlation ($r_s = 0.399$) which was not statistically significant at 0.01 level ($p = 0.302$).

Spearman's correlation was run to assess the relationship between LESN-GT and PSIS-GT in male and female cadavers as presented in Table 6. In males, there was a weak positive correlation ($r_s = 0.165$) between LESN-GT and PSIS-GT which was not statistically significant at 0.01 level ($p = 0.989$). In females, the relationship between LESN-GT and PSIS-GT shows moderate negative correlation ($r_s = -0.476$) which was not statistically significant at 0.01 level ($p = 0.195$).

Table 2. Basic descriptive statistics for the analysed variables in males

N	Abbreviations	Mean (cm)	Median (cm)	Max (cm)	Min (cm)	SD (cm)
1	WSN-LMP	15.20	13.55	18.50	8.60	±2.93
2	WSN-LLT	13.32	13.10	18.10	8.09	±3.07
3	MESN-IT	4.55	4.33	6.60	2.06	±1.18
4	LESN-GT	4.75	5.15	7.00	2.50	±1.52
5	LSNLP-SNB	37.58	35.50	44.00	27.00	±5.26
6	WCP-SNB	3.69	3.67	5.08	2.25	±0.86
7	WTN-SNB	6.42	6.58	8.66	4.50	±1.49
8	LSN-PPSS	7.15	7.25	9.00	5.50	±1.22
9	TL	39.72	37.50	45.00	30.00	±3.11
10	IT-GT	6.50	7.00	7.50	5.00	±0.60
11	PSIS-GT	15.30	14.00	16.50	12.50	±2.90
12	PSIS-IT	28.20	12.00	14.50	10.00	±2.73
13	LLE	82.72	82.00	93.00	70.00	±3.20

Table 3. Basic descriptive statistics for the analysed variables in females

N	Abbreviations	Mean (cm)	Median (cm)	Max (cm)	Min (cm)	SD (cm)
1	WSN-LMP	14.05	14.60	17.30	11.90	±1.60
2	WSN-LLT	9.88	11.38	16.40	6.36	±3.64
3	MESN-IT	5.48	5.45	5.90	5.00	±0.32
4	LESN-GT	6.39	6.60	7.70	5.50	±0.59
5	LSNLP-SNB	31.50	32.75	38.50	27.00	±3.37
6	WCP-SNB	3.12	2.66	3.59	1.72	±0.54
7	WTN-SNB	4.78	5.63	7.07	4.19	±0.84
8	LSN-PPSS	6.91	7.30	8.50	6.10	±0.78
9	TL	34.52	35.00	39.00	31.00	±2.50
10	IT-GT	11.10	11.00	7.00	6.00	±0.30
11	PSIS-GT	12.20	12.00	15.00	10.00	±3.70
12	PSIS-IT	11.10	11.00	14.00	10.00	±1.90
13	LLE	72.10	70.00	80.00	65.00	±4.10

Table 4. Correlation between WSN-LMP in male and in female cadavers. Correlation is significant at the 0.01 level (2-tailed)

			WSN-LMP (male)	WSN-LMP (female)
Spearman's rho	WSN-LMP (male)	Correlation Coefficient	1.000	-0.465
		Sig. (2-tailed)	.	0.052
		N	60	30
Spearman's rho	WSN-LMP (female)	Correlation Coefficient	-0.465	1.000
		Sig. (2-tailed)	0.052	.
		N	60	30

Table 5. Correlation between LESN-GT and IT-GT in male and female cadavers. Correlation is significant at the 0.01 level (2-tailed)

			LESN-GT		IT-GT	
			males	females	Males	females
Spearman's rho	LESN-GT	Correlation Coefficient	1.000	1.000	0.005	0.388
		Sig. (2-tailed)	.	.	0.989	0.302
		N	66	32	66	32
Spearman's rho	IT-GT	Correlation Coefficient	0.005	0.388	1.000	1.000
		Sig. (2-tailed)	0.989	0.302	.	.
		N	66	32	66	32

Table 6. Correlation between LESN-GT and PSIS-GT in male female cadavers. Correlation is significant at the 0.01 level (2-tailed)

			LESN-GT		PSIS-GT	
			Males	females	males	females
Spearman's rho	LESN-GT	Correlation Coefficient	1.000	1.000	0.165	-0.476
		Sig. (2-tailed)	.	.	0.628	0.195
		N	66	32	66	32
Spearman's rho	PSIS-GT	Correlation Coefficient	0.165	-0.476	1.000	1.000
		Sig. (2-tailed)	0.628	0.195	.	.
		N	66	32	66	32

DISCUSSION

Sciatic nerve shows substantial variations with landmark structures in the gluteal region. Different population studies have highlighted some of these variations most of which are variations in relation with piriformis [15, 16, 17]. The major interest with the variations is because of the clinical event associated with the abnormalities. More often, variation in the exit of SN in relation to piriformis may cause its compression resulting to piriformis syndrome [16, 18]. The variable relations of SN to piriformis was also noted as the probable cause of nondiscogenic sciatica and other pain etiologies [19]. Variations such as high division of SN can lead to nerve injury during deep intramuscular injections. It is also the major factor responsible for the failure of SN block when performing popliteal block anesthesia [4]. Nonetheless, each of the anatomical variations may reflect a different and specific clinical presentation. In this study five types of relationship of SN with piriformis was recorded. The typical type (type A) shows very high prevalence constituting 83% of the population examined. Other population reports corroborated with similar high frequency [4, 11, 20]. In the other observed variable types, SN exhibited high bifurcation with its component parts having varied relations with piriformis muscle. However, they constituted a small fraction of the overall number examined. They formed 17% cumulative of the entire population. None of the unusual types was unique compared to other population studies. The most prevalent of the variations was type B. The high prevalence shows consistency with the report of many population studies [6, 20, 21, 22]. Type C and Type E were the least occurring variables, each accounting for 2% of cases. Type C was also shown as least frequently occurring in many population studies [4, 20, 23]. It is pertinent to establish the prevalence rate of SN variable types because more often they lead to inadvertent injury during surgical procedures in the gluteal region. Besides they are often exposed to compression resulting to 'piriformis syndrome'.

It is observed that limited number of articles centred on the morphometric analysis of SN structure as well as its relations with some landmark structures [24, 25]. Its morphometric studies that relates to sex dimension began to emerge just in the recent past [14, 26, 27]. There has been an increase in curiosity due to diversity in topographic anatomical relations of the nerve in the females which is of clinical concern.

The width of SN that was assessed at the lower margin of piriformis muscle shows values that did not vary markedly between the two sexes. In both legs of each specimen, the values were not varied, however it only applied to cases where the nerve emerges as a single trunk beneath the lower border of piriformis muscle. Nonetheless, a population study in Brazil has documented a significant difference in the width size of SN between both legs of the same spacemen [28]. In a correlation coefficient analysis between the two sexes, a moderate, positive correlation was observed between WSN-LMP in males and in females. The analysis was indicative that sex variation showed cumulatively very little differential in the nerve width of the two sexes. The sizes of WSN-LMP and WSN-LLT in each specimen varied considerably with WSN-LLT showing reduction in size that was more remarkable in females.

The relationship of SN with piriformis muscle and also with selected bony landmarks in the pelvis was examined in both sexes. In typical anatomical relations between SN and piriformis and selected bony landmarks, certain regularities can be established in the two sexes. The relationship between LESN-GT and IT-GT in both sexes shows positive correlation nonetheless in males it exhibited weak correlation (r_s = 0.005) whereas in females it was moderately correlated (r_s = 0.399).

The female's pelvis serves multiple roles that include providing support, locomotion, childbirth, *etc.* [27]. The adaptability to these multiple roles is responsible for its sexual dimorphism. Pelvis dimorphism has been used variably for sex determination in various anthropological contexts [29, 30]. The path of SN has been described in relation to ischial tuberosity (IT), greater trochanter (GT) and PSIS [12, 31]. The information provided was a clear guide in this contextual view of SN topography in the two sexes. It is noted in a recent study that the sexual differences in distances and angulation between clinically relevant pelvis and hip bone landmark show that only the angle at PSIS and GT are significantly larger in males [32]. Huseynov *et al.*, [26] had earlier reported that the obstetric adaptation of female pelvis makes for wider pelvic cavity influenced by hormonal changes at puberty. Apparently, the sexual dimorphism is viewed as the major factor responsible for topographic variation of SN in females. Pregnancy also constitutes a key consideration in this regard which however borders outside this investigation. In this study however, the angulation between LESN-GT and PSIS-GT were ascertained and analysed. The analysis of relationship between LESN-GT and PSIS-GT in male cadavers shows weak positive correlation (r_s = 0.165). However In females the relationship between LESN-GT and PSIS-GT exhibited moderate negative correlation (r_s = -0.476). Between the two sexes the correlation analysis indicated inverse relationship between LESN-GT and PSIS-GT in males and in females. The negative correlation of LESN-GT and PSIS-GT recorded in females has a strong bearing to obstetric adaptation of pelvis for child birth. The result of the morphometric analysis buttresses orientation alteration of ileum in females in which there is a considerable reduction in angulation between PSIS and GT. Based on this study findings, the authors strongly agree with the report that the angle at PSIS and GT are significantly larger in males [32]. However, the remark [32] that there are no sex differences in the orientation of the ileum is not in tandem with our findings. The dimension of LESN-GT in both sexes show considerable variations. LESN-GT is longer (significantly) in females than in males thus accounting in part to SN varied topographic relations and to a larger extent deemed to be responsible for inverse correlation between LESN-GT and PSIS-GT in the two sexes. The considerable deviation of SN of females from the males' topographic anatomical relations is of clinical concern because of the sexual dimorphism of the pelvis. The implications in females include greater risk of SN injury during intramuscular injections and during invasive medical procedures at the gluteal region [14, 32].

CONCLUSIONS

The morphometric analysis of the anatomical relationships between SN and the landmark structures of the hip bone shows variations due to the sexual differences in the dimension of the pelvis. The deviation of SN of females from the males' topographic anatomical relations is of clinical concern requiring for diligence during surgical procedures in the gluteal region to avoid damage to the nerve.

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