Sexual Dimorphism of Greater Sciatic Notch among Nepalese Population by Three Dimensional CT Images of Pelvis

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ABSTRACT

Background

Sex identification from the skeletal remains, is the first and the foremost step encountered by forensic experts. Hip bone being comparatively robust is resistant to damage and scores even in improperly preserved skeletons. It is also widely agreed that the greater sciatic notch (GSN) holds the greatest degree of sexual dimorphism.

Objective

To study the role of greater Sciatic Notch parameters in sex determination among Nepalese population by means of reconstructed Multi Slice Three-Dimensional Computed Tomography (MDCT) images.

Method

The CT images of individuals who underwent pelvic CT in the Department of Radiology, Dhulikhel Hospital were included in the study. Measurements of width, depth, angles and indices of greater sciatic notch were measured and calculated. Data were entered and analyzed using SPSS (Statistical Package for Social Sciences) version 25.0.

Result

There was a significant difference between means of all greater sciatic notch parameters (p > 0.001) between sex showing sexual dimorphism except depth (p=0.65). By using limiting point, 78.18% male and 83.64% female were correctly classified by using total width. Total angle, Posterior segment and Total width had sensitivity and specificity exceeding 80% and overall accuracy of 87% to 92% in all parameters except depth by receiver-operator characteristic curve analysis.

Conclusion

Application of 3D-CT virtual images in the present study helped us to easily quantify greater sciatic notch parameters. The important greater sciatic notch predictors for sex determination in Nepalese population were determined which would help forensic experts in ascertaining the sex of an unknown individual.

KEY WORDS

Demarking point, Greater sciatic notch, Sex determination, Sexual dimorphism

INTRODUCTION

Early detection of disputed sex of an unknown individual is an important aspect of forensic investigation.[1-7] It is often the first component of biological profile to be assessed because age, stature, and sometimes ancestry are dependent on it.[4,5,8,9] Human skeleton usually demonstrates its sex.[1,7,10] Hence making it interesting from anatomical, forensic, anthropological point of view.[4,9] If the sex is accessed correctly, further investigations are likely to be more accurate allowing removal of opposite sex and hence separate male and female standards may be applied.[11,12]

Availability of simple, economical, quick and accurate modalities can drastically reduce the time taken in identification, thus shortening the legalities associated.[9] Since bones are the hardest and most durable structures, they are commonly used.[9,13,14] Though DNA analysis is more authentic, it is expensive and requires special tools and time.[4,5,15] Hence anthropological preliminary reports can support the primary findings.[15] During mass fatality events, when fragmented bones has to be used, pelvis and hence Greater Sciatic Notch is most accurate which can predict sex with highest accuracy.[1-3,11] It reveals sexual dimorphism due to difference in sex hormones and displays an additional pressure of obstetrics difficulties on women giving birth to large brained infants.[2,3,11,16,17-19] GSN are resilient to damage and its parameters are reliable sex indicators.[2,8,20] Computed Tomography is a noninvasive tool, cost effective and can capture high level details of bone and there is no need to remove soft tissue and come in actual contacts. Several variables can be measured simultaneously and even accuracy can be increased or error reduced.[2,16,21,22]

Different workers have applied different approaches for sex determination from GSN parameters. In the present study a modest effort have been made to assess the role of GSN parameters to determine its accuracy in sex determination among Nepalese population by using 3D images reconstructed by MDCT. We felt the need of this study as much has not been done regarding GSN in our country. Hence, it might be useful for forensic scientist in ascertaining medico-legal cases in our country.

METHODS

A retrospectively cross-sectional study was undertaken in pelvic CT Scans of 110 individuals (55 males and 55 females), above 18 years of age who presented for a radiological investigation at Department of Radiology, Dhulikhel Hospital. An ethical approval was taken from Institutional Review Committee, Kathmandu University School of Medical Sciences (IRC-KUSMS). CT scans with abnormalities like fractures, scoliosis, hip pros¬theses, poor quality studies and those of individuals with any congenital deformity or acquired disease that may affect pelvic dimensions are excluded in the study.

The CT scans were reconstructed to produce 3D-CT pelvic images. At first, the GSN landmarks, most anterior part of Posterior Inferior Iliac spine (PIIS), Ischial Spine and the deepest point of the GSN) were determined as shown in figure 1. The following parameters from right side were then measured and calculated. All linear measurements were taken in millimeters, angles were measured in degrees. Each measurement was taken by two observers twice each and was averaged to reduce measurement errors.

1. Maximum width (AB) = Distance between the PIIS (A) and Ischial spine (B).

2. Maximum depth (OC) = Perpendicular distance between the deepest point of the GSN (O) to the maximum width AB

3. Posterior segment (AC) = Distance between PIIS (A) and the point where perpendicular line drawn from the deepest point touches the maximum width (C)

4. OA = Distance between PIIS (A)and deepest point (O)

5. OB = Distance between IS (B) and deepest point (O)

6. Angle AOB = Total angle of GSN

7. Angle AOC = Posterior angle of GSN

8. Index I = (Depth OC / width AB) X 100

9. Index II = (Posterior segment AC / Width AB) X 100

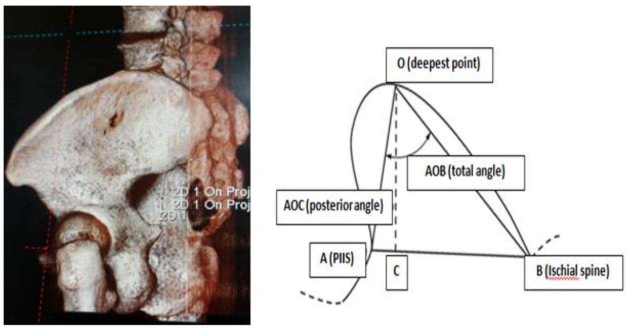

Figure 1. 3D CT (128 slice) pelvic image showing GSN with its diagrammatic representation

The identification points (IP) were determined by the lowest value of a parameter in females and highest value for the same in males.[7,23-26] All the values less than the minimum value for the females were treated as male bone for width, posterior segment, total angle, posterior angle and Index II and the bones having values more than maximum value of males were treated as female bones as females have greater measurement than male for these parameters. Similarly for Index I and depth, maximum value of female was IP for male and minimum value of male was IP for female as males have greater measurement than female in these parameters. The range between these two values is known as overlapping zone. Parameter having a broader overlapping zone is thought to be a bad estimator. The demarking point (DP) was calculated by using ± 3 SD in mean.[7,23-26] Mean ± 3 SD ensured that > 99% of the value fall within the range calculated. The minimum value in females will be taken as demarking point for male i.e. the value less than this point falls in male category for width, posterior segment, Total angle, Posterior angle and Index II and reverse for Depth and Index I. The limiting point (LP) was calculated by dividing the sum of male and female identification points by two.[24]

Descriptive analysis for age and various parameters of GSN were summarized as Mean ± SD (standard deviation), range (min to max). Student's Independent sample t test, was performed to assess the significance of difference of means of variables between male and female. Differences were considered significant at P < 0.05. Pearson-moment correlation was performed separately for male and female to determine the strength of correlation between various GSN parameters with age. The receiver-operating characteristics (ROC) curve analysis was performed to determine the cut-off values of parameters of GSN at optimum sensitivity and specificity for age estimation. The area under the curve was also determined to find out overall accuracy of a variable and its sex discriminating performance The data were analyzed using IBM SPSS Statistics for Windows software package version 25.0 (IBM Corp., NY, USA).

Table 1. Descriptive statistics of various GSN parameters

Sex		AB	OC	AC	<AOB	<AOC	Index I	Index II
Male	Mean	40.31	25.13	11.12	65.11	25.47	62.79	27.77
	SD	4.07	4.18	2.84	11.69	7.03	11.30	7.22
	SE Mean	0.55	0.56	0.38	1.58	0.95	1.52	0.97
	Min	29.9	17.2	7	43.23	16.65	45.20	15.18
	Max	47.7	33.7	18.5	105.26	52.79	97.53	46.75
Female	Mean	50.28	24.75	16.65	84.94	35.02	49.48	33.06
	SD	6.11	4.29	4.12	10.33	6.59	7.73	6.76
	SE Mean	0.82	0.58	0.56	1.39	0.89	1.04	0.91
	Min	40.6	17	10.4	65.38	21.77	33.83	18.62
	Max	64	40	25.1	115.56	48.59	67.09	50.1
Mean difference		-9.97	0.38	-5.54	-19.82	-9.56	13.31	-5.28
SE of difference		0.99	0.81	0.67	2.1	1.3	1.85	1.33
t-value		-10.08	0.47	-8.21	-9.421	-7.35	7.21	-3.96
p-value		0.000	0.63	0.000	0.000	0.000	0.000	0.000

(AB=Total width (mm); OC=Maximum depth (mm); AC= Posterior segment(mm); <AOB=Total angle(degree); <AOC=posterior angle(degree);SD=standard deviation; SE=Standard error)

RESULTS

The statistical descriptive which includes mean, standard deviation, minimum, maximum, difference in means of male and female measurements and the calculated indices and their respective significance by students t- test of the current study are presented in Table 1. The mean age of male was 41.94 ± 16.66, minimum being 19 and maximum being 85 while the mean age of female was 45.85 ± 17.39, minimum being 18 and maximum being 87. The result of the present study showed that Total width (AB) and Posterior segment (AC) of Greater Sciatic notch was found be significantly greater in female than in male (p < 0.001). However the depth of sciatic notch (OC) was found to be greater in male but the mean difference by independent sample t-test was not found to be statistically significant (p > 0.05). Hence, the depth of the sciatic notch was not used for calculation of Identification Point, Demarking Point and Limiting Points. Table 1 also showed high sexual dimorphism in Total angle and Posterior angle (p < 0.001). Index I was significantly greater in male and Index II was greater in female (p < 0.001).

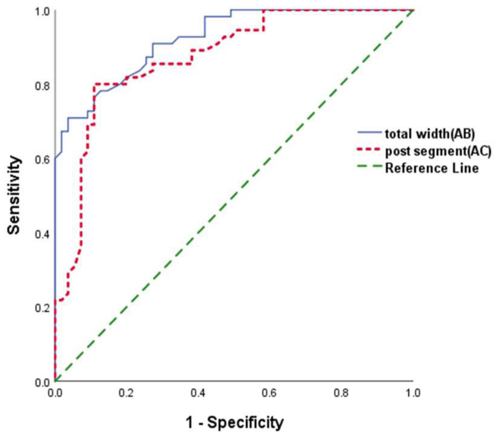

Figure 2. Receiver-operating characteristics (ROC) curves of GSN width and post segment for sex determination

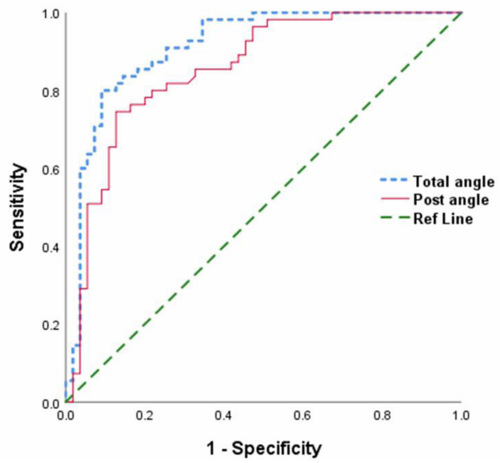

Figure 3. Receiver-operating characteristics (ROC) curves of GSN angles for sex determination

A receiver-operator characteristic (ROC) curve analysis suggested the optimal cutoff value for different GSN parameters. The effective parameters for sex estimation were found to be Total angle, Posterior segment and Total width with sensitivity and specificity exceeding 80% and overall accuracy of 87% to 92%. However the poorest indicator of sex on the basis of all criteria was found to be depth. The best cutoff points with optimal sensitivity,

Table 2. Statistics derived from ROC curve analysis of GSN Parameters

Parameters	Cut-off	Sensitivity	Specificity	AUC	Std Err
Total Width	44.45	81.8	80	0.922	0.023
Post segment	13.55	80	89.1	0.872	0.034
Total angle	74.64	85.5	81.8	0.912	0.029
Post angle	28.87	80	78.2	0.854	0.037
Depth	24.75	49.1	47.3	0.534	0.055
Index I	53.08	74.5	74.5	0.834	0.037
Index II	28.71	74.5	63	0.714	0.049

specificity and overall accuracy for all parameters are tabulated in Table 2 and depicted figure 2 and 3. Cut off point for Total width, Post segment, Total angle, Post angle, Index II are 44.45 mm, 13.55 mm, 74.64, 28.87 and 28.71 respectively, the value greater than this are classified as female and values lower than these are classified as male. However for depth and Index I, the cutoff points are 24.75 and 53.08, the value greater than these are considered as male and values smaller are considered as female.

Table 3. IP, DP and LP of GSN parameters and percentage classified

Parameters	Cut-off	Sensitivity	Specificity	AUC	Std Err
Total Width	44.45	81.8	80	0.922	0.023
Post segment	13.55	80	89.1	0.872	0.034
Total angle	74.64	85.5	81.8	0.912	0.029
Post angle	28.87	80	78.2	0.854	0.037
Depth	24.75	49.1	47.3	0.534	0.055
Index I	53.08	74.5	74.5	0.834	0.037
Index II	28.71	74.5	63	0.714	0.049

Table 3 presents the Identification Point, Demarking Point and Limiting point calculated for the various parameters of GSN. By using Identification Point, 50.91% male and 61.82% female were correctly classified from Total width. The remaining lied in the overlapping zone. Similarly by using demarking point 12.73% male and 9.09% female were correctly classified. The rest of the parameters could not be satisfactorily classified by demarking point. However the values above and below DP are bound to be male or female as it is said to provide 100% accuracy. Similarly by using Limiting Point, 78.18% male and 83.64% female were correctly classified. Hence, like the cutoff point given by ROC curve, Limiting point could also be used as the indicator in sex determination.

DISCUSSION

The techniques and standards used for identification of individuals are varied and depend upon the circumstances of each particular case.[24] Skeletal sexing can be achieved using morphological (visual) or metric (quantitative) methods of forensic anthropology.[1,5,27] Both have their strength and weakness.[24] The visual method is based on observation of morphological sex-linked patterns of growth and development, is easy to assess, and does not require measuring tools. Nonetheless, it is highly subjective and depends on the skill of the anthropologist.[5,27] They are based on almost stereotypic male and female and are for ultra-masculine and ultra-feminine pelves.[16] In contrary, osteometric measurement require a specific tool for measurement, but is simple, reliable and decreases the problem of observer's subjectivity.[7,10,16,19,27] On the other hand, metric method is also subjected to greater intra- and inter-population variability.[16,19] Various metric studies have been applied using dry bones, X-rays and CT-scan image by various workers around the world.[2,4,10,11,12,18,20,21] However, only those procedures which define a precise and unambiguous methodology leading to an accurate diagnosis of sex should be employed.[28]

In certain situations when only fragmented bones are present, experts have to extract information from limited and fragmentary skeletal remains, usually in mass disasters.[24] GSN being the densest in the innominate, is one of survivable structures in the badly damaged and poorly preserved skeleton.[1,9,12] Due to its direct implication in reproduction, it shows different characteristic in either sex.[19] Hence, morphometric GSN parameters have been utilized in this endeavor. CT scan images are beneficial for the countries where there is limited access to documented skeletal collections.[16,29] Investigations by CT images are repeatable and verifiable at any time.[22] Results of some previous research have even shown that there were no significant differences between real bones or 3D CT models.[21,27,30] Hence it may be an alternative way to study semi-fleshed bodies as in mass disaster consisting of comingled and charred bodies allowing the visualization of the bones independently of the state of theremains.[16,21,30] It also avoids the necessity to prepare and deflesh bones.[15] Nonetheless, the interchangeability of forensic anthropological methods and virtual bone models needs to be tested further.[5]

The results of our study demonstrate a significant sexual dimorphism in most of the parameters of GSN. The highly significant variation was observed in Total width, Posterior segment, Total angle, Posterior angle, Index I and Index I. This result was in accordance with all the workers around the world who conducted study either on dry bones or their images.[2-4,6,11,18,20,21] Concerning GSN width, significantly higher mean was observed in female which became wider at its posterior part. This was concurrent with many workers.[2,4,10,18,20,21] However it disagreed with Jain et al., who found no significant difference in the width of right side of GSN.[12] In our study we found maximum depth to be the poorest estimator of sex as the difference between the male and female was not significant (p=0.63). This finding was not in line with other studies conducted by Shah et al., Manoj et al., Singh et al. and Kumari, et al. who

Table 4. Comparison of present work with the mean values of parameters with different workers

Authors		Singh[18]	Shah[4]	Alizadeh[10]	Dnyanesh[11]	Mostafa[21]	Soltani[2]	Manoj[6]	Kumari[20]	Present study
		1978	2011	2013	2013	2017	2018	2019	2019	2020
Population		Indian	Indian	Iranian	Indian	Egyptian	Iranian	Indian	Indian	Nepalese
Method		Dry bones	Dry bones	X-ray	Dry bones	CT-scan	CT-scan	Dry bones	X-ray	CT-scan
Width	M	44.3*	38.5*	56.18*	40.11*	68.9*	44.93*	36.74*	41.2*	40.31*
	F	48.27	42.7	62.62	47	80.9	52.93	43.42	43.4	45.85
Depth	M	25.93*	24.14*	20.94 NS	32.34 NS	-	30.18 NS	26.75*	34.4*	25.13NS
	F	25.86	22.27	23.13	31.28	-	30.02	24.94	26.1	24.75
Post segment	M	6.06*	6.83*	22.78*	11.4*	-	9.4*	8.51*		11.12*
	F	16.39	12.48	28.53	21.92	-	20.39	17.6		16.65
Total angle	M	65.31*	69.45*		60.94*	-	66.31*	64.3*		65.11*
	F	82.76	82.85		73	-	80.91	80.84		84.94
Post angle	M	12.78*	16.63*		19.17*	-	16.64*	17.73*		25.47*
	F	32.42	29.93		34.32	-	32.95	35.36		35.02
Index I	M	62.12*	63.48*	32.74 NS	80.93*	-	68.22*	73.68*	84.49*	62.79*
	F	53.69	52.54	37.12	67.14	-	57.66	58.27	61.22	49.48
Index II	M	14.61*	17.52*	40.87*	28.9*	-	20.79*	23.04*		27.77*
	F	33.7	29.14	45.97	46.64	-	37.8	39.92		33.06

(Significance of difference of means of male vs female : *:Highly significant; NS:Not significant)

found significant difference in the depth of male.[4,6,18,20] And female however matched with the finding of Soltani et al., Dnyanesh et al. and Raut et al.[2,11,25] In contrast to most of the studies, notch was found to be deep in women in the study by Alizadeh et al. and Ram et al.[10,31] The two studies done in Iran by different authors showed great difference in their measurements which suggest that major variation can be seen even amongst the close population.[2,10,12] These variations among population are affected by multiple factors like cultural, environmental, geographical, ancestry, nutrition, climate, labors and genetic elements hence emphasizing the need for population-specific osteometric standards.[7,11,13,29] To add up, with racial differences, it is difficult to implement a uniform method for sex determination.[3,7] The result of our study also demonstrated post segment, total angle, post angle to be significantly greater in female than male. This was similar to the finding of various other authors.[2,4,6,8,10,11,18,20,21] The reason for this is attributed to the special adaptation of female bone for child bearing.[4,10,19] In line many studies, Index I and Index II also showed high sexual dimorphism. Index II can be influenced not only by the posterior segment but also by the development of surrounding structures like the ischial spine, piriform tubercle and sacrum.[31]

The comparison of various measurements and calculated indices of various studies with the current study are presented in Table 4. It shows similarity and variations in the dimensions among different and close population. Hence, the sexual dimorphism standards of specific populations cannot be applicable for all as skeletal size differs considerably across populations and the use of inappropriate method can result in misinterpretation of sex especially when a population origin is unknown.[2,18,23,27]

To assess the sex discriminating power of various parameters of GSN, ROC curve analysis was performed. The most effective parameters for sex estimation were found to be total angle, posterior segment, total width which provided the best balance between sensitivity and specificity exceeding 80% and overall accuracy of 87% to 92%. This result was concurrent with the study of Solatni, et al.[2] Our finding of depth was again similar to Soltani, et al., who found it to be unsatisfactory estimator of sex (overall accuracy < 50%).[2] Index I gave overall accuracy of 83.4% in our study which differed with Soltani et al. who found 20.7% overall accuracy by the same.[2]

The Identification, Demarking and Limiting points of different parameters of GSN were worked out in our study. By applying the IP, total width had most accurate discriminating capacity for male. It could classify about 50% males and only 5% of females, which disagreed with Singh et al. where > 60% male and female could be classified.[18] Raut et al. could classify 12.8% male and 31.03% females bone accurately by using IP of width which was not concurrent with our study.[25] Remaining of the population fell in overlapping zone. Hence many authors find it of doubtful value as it is very crude and shows significant overlapping.[7,16,18,23-26] And does not always represent a condition for belonging to one sex or other.[7] Raut et al. has reasoned for this overlapping to hypo masculinity in male and hypo femininity in female.[25] Raut classified 22.41% females by DP which was only 9.1% in our study.[25] Demarking points could classify satisfactory number of male and female by using total angle in the current study which was not in agreement with Singh et al., however agreed with Raut et al.[18,25] Singh and Raut found posterior angle to be the good estimator of sex.[18,25] However, in our study demarking point could classify only 12.7% male and 9.1% female by posterior angle. Demarking Point of Index I could classify none of the females in our study which was close to Singh et al.[18] However, Index II was found to be the good estimator by some but could classify none of the male and females in current study.[18,25] Though the percentage classified by DP is very minimal, in medico-legal cases where 100% accuracy is demanded, demarking points rather than identification point is preferred.[18,23,24] Nonetheless, it is not necessary in a given bone for all the parameters to cross the demarking point to assign a sex. If a single demarking point of any parameter is crossed, it would identify bone with 100% accuracy.[18,25] The calculated Limiting Points gave the cutoff points which could classify most of the sex accurately. Like any other bone, pelvic bone too isn't free of debate as measurements always may not represent a condition for belonging to certain sex.[3,19] This variation in the findings again highlight and warrant the development of population specific standards.

The reconstructed images are used in the current study due to lack of sufficient bones. It is currently unknown whether morphological sex estimation traits are accurately portrayed on virtual bone model, however many studies have claimed that they can be accurately portrayed and accurately scored on reconstructed virtual 3D bone elements.[5]

Hence, the author would prescribe for performing the population based studies by using larger samples from virtual images to determine own population specific cutoff points as it cannot be assumed that the methods and results of one population to yield equally high success rates in all.

CONCLUSION

The morphometric study of greater sciatic notch parameters in Nepalese population concluded that it is significantly sexually dimorphic. The satisfactory sex allocation accuracy could be obtained from the cutoff points of Total angle, Total width, Posterior angle, posterior segment and Index I. However population specific aspects of sexual dimorphism should be taken into consideration when applying these values, hence it should be applied for Nepalese population only. We also could not deny the fact that most of the parameters fall in the overlapping zone of the opposite sex. So, authors advocate for the use of the parameters which show optimal sensitivity, specificity and maximum overall accuracy. Larger study groups and comprehensive assessment of various other parameters related to greater sciatic notch are required to further substantiate the results in Nepalese population.

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