

## Determination of Sex by Quantitative Analysis of Ischium and Pubis in the Population of Jharkhand

Kumari Sandhya\*, Singh Bhoopendra\*\*, Chanda Camellia\*\*\*, Prasad Renu\*\*\*\*

### Abstract

**Background:** Determination of sex from a small fragment of skeletal remains of human has been frequently a challenge with which a forensic expert comes across in his day to day life. Because of showing sexual dimorphism, hip bone remains to be a favourable part of skeleton for this purpose. Since long it has been proven that hip bone shows racial differences also. **Materials and Methods:** This study was conducted on a set of 41 hip bones, of which 24 belonged to male and 17 belonged to a female. Length of pubic and ischial part was measured and then ischio-pubic index was calculated with the help of formula given by Washburn (1949). **Results:** Ischio-Pubic Index was found to be  $76.72 \pm 0.13$  (Range 65.71-96.08) in males &  $85.87 \pm 2.40$  (Range 73.48-98.42) in females. Ischiopubic index remained in between 73.34 to 80.10 in male and between 78.27 and 93.47 in female with confidence limit of 99%. **Conclusion:** Our study results and its comparison with results of other workers shows that hip bone not shows only dimorphism but its metric values are population specific also.

**Keywords:** Hip Bone; Sex Determination; Pubis; Ischium; Ischio-Pubic Index.

### Introduction

The accurate identification of human skeletal remains crucial in forensic science and physical anthropology, especially because of the escalating crime rates, which have become a worldwide phenomenon. If all soft tissues are absent, identity depends solely on osteological examination and measurements and the recognition of any pathological or anatomical abnormalities in bone. The determination of sex is statistically the most important criterion, as it immediately excludes approximately half the population, whereas age, stature and race each provide points within a wide range of variables. Obvious sex differences do not become apparent until after puberty, usually in the 15-18 year period, though specialized measurements of the pelvis can indicate the sex even in foetal

material. Sex and age are linked, especially where body size and weight are concerned. Similarly, race confuses sexing, for example, the size of the supraorbital ridges in a normal Negroid female may exceed those in the average Caucasian male. The accuracy of sexing is hard to estimate, as various loading factors exist [1]. Krogman's [2] scored 100 per cent accuracy, using the whole skeleton, 95 per cent on pelvis, 92 per cent on skull, 98 per cent on pelvis plus skull, 80 per cent on long bones and 98 per cent on long bones plus pelvis. He admitted, however, that, as most anatomy department material has a sex ratio of about 15:1 in favour of men, marked bias could be introduced by assigning all doubtful bones to the male category.

Apart from above, when bones are incomplete or fragmentary, the problems escalate rapidly. If the ends of long bones are present, then their non-human shape may be more readily determined, but cylindrical segments of the central shaft have little in the way of distinguishing features, apart from size. Burnt bone fragments offer similar problems, added to which is the possibility of heat distortion and shrinkage. The advice of an anatomist is needed in such cases, preferably one with forensic experience and enthusiasm for the project.

**Authors Affiliation:** \*Associate Professor, \*\*\*PG Student, \*\*\*\*Professor and Head, Department of Anatomy, RIMS, Ranchi. \*\*Toxicologist (Associate Professor), RIMS, Ranchi.

**Reprints Requests:** Bhoopendra Singh, Toxicologist (Associate Professor), Dept of Forensic Medicine & Toxicology, Rajendra Institute of Medical Science, Ranchi - 834009 Jharkhand.  
E-mail: [drsinghb@gmail.com](mailto:drsinghb@gmail.com)

The literature contains sufficient evidence that metric and morphological biologic differences exist amongst Caucasoid, Mongoloid and Negroid races [3,4]. Measurements of Pubic, ischium and ilium bones and determination of related indices and angles have been very useful in not only forensic science [5], but also in clinical practice, (most especially Obstetrics and Gynaecology) and Physical Anthropology [6]. Davivong [6] and Washburn [7] determined the ischiopubic index obtained by dividing the length of pubis by the length of the ischium. Sexual differences in adult pelvis have been studied and measured extensively. These studies involved metrical and non-metrical characteristics whose range overlap between the sexes. According to Udoaka et al [8], the pubic bone was longer in females while the Ischium was longer in males. They stated that Ischio-pubic index greater than 90 would most probably be that of a female and less than 90 would most probably be that of a male. Similar observation was reported by various other authors those conducted similar study in different parts of the world like Black Malawians [9] - 85 in Male and 104 in Female; France [7]-82 in Male and 94 in Female; Americans [10] - 67.4 in Male and 93.1 in Female; White Americans [10]- 63.4 in Male and 88.4 in Female; Black Americans [10]- 65.8 in Male and 85.2 in Female; Calabar indigenes [11]- 94.2 in Male and 118.8 in Female; and Nigerians in Rivers [12] - 90.88 in Male and 114.8 in Female. In addition to this various studies were conducted in Indian population and findings of few studies were included in this text as in Uttar Pradesh [13] - 89 in Male and 100 in Female; Punjab [14] - 98.2 in Male and 104.24 in Female.

After detailed review and considering the facts that there were many morphologic biologic differences exists amongst population globally. Thus, the present study was carried out to provide reliable data on population in this part of country (Jharkhand).

### Materials and Methods

The study was conducted in the Department of Anatomy, Rajendra Institute of Medical Sciences, Ranchi. Material for the present study comprised of 41 adult hip bones of known sex (M: F =24:17) of Jharkhand population were used for this study. These bones were available in the museum of the department of Anatomy that were supplied from the mortuary of Rajendra Institute of Medical Sciences, Ranchi for routine teaching purpose. The inclusion criteria used were fully ossified, undamaged bones

showing no pathological changes.

At first marking of the junction point of three parts of the hip bone, i.e. pubis, ischium and ilium, on acetabular surface (point J in Figure 1) and inside of the pelvis (point J in Figure 2) were done with the help of Schultz's [5] method. The osteometric measurements for the following two variables were taken with the help of slide callipers, technical quality divider and metallic (steel) graduated scale with readings up to one millimetre.

#### *Pubic Length*

It is a straight line JS as shown in the Figure 2. It is the greatest distance of the junction point on acetabulum (and inside pelvis) from the symphyseal surface of the body of pubis [5] (JS in Figure 2).

#### *Length or Height of Ischium*

It is a straight line JT as shown in the Figure 2. (Length of Ischium term was coined by Davivongs (1963) [6], whereas Seidler (1980) [15] described it as the greatest distance between the central point of acetabulum and the farthest point on inferior aspect of ischial tuberosity which has been named ischial point by Thieme (1957) [16]. It is a straight line JT as shown in the Figure 2. (JT in OB in Figure 2). This length was recorded with the help of slide callipers on both the sides Figure 2)

#### *Ischiopubic Index*

It was calculated with the help of the formula given by Washburn (1949) [17]

$$\text{Ischiopubic index} = \frac{\text{Length of Pubic bone (Fig.1 JS)}}{\text{Length of Ischial bone (Fig. 2 JT)}} \times 100$$

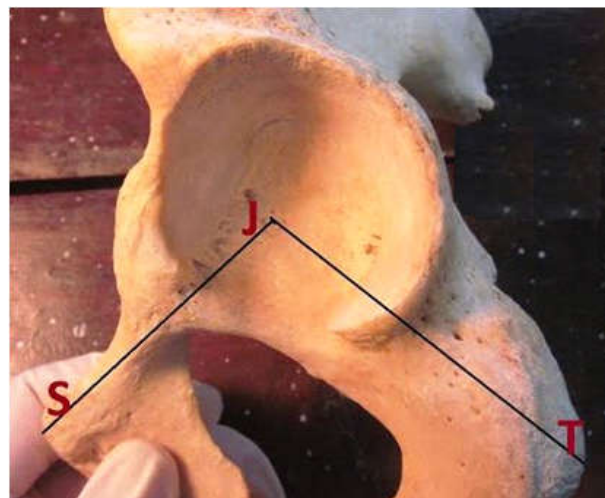


Fig. 1:

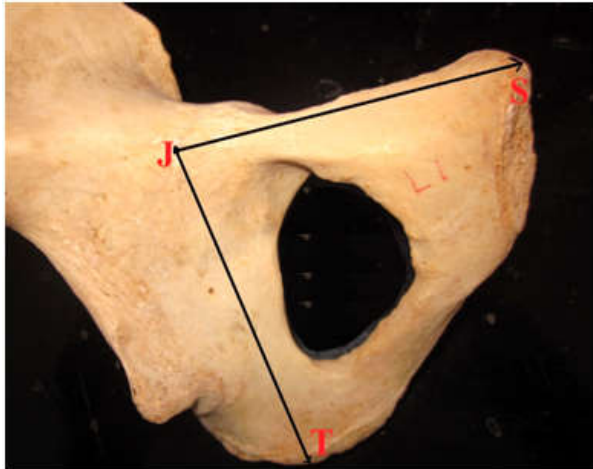


Fig. 2:

*Statistical Analysis*

Data on all the parameters studied were analysed for mean, range and standard deviation using discrete statistics and significant differences using SPSS -16. The actual range of the male and female

sexes was determined from the data. The 99% confidence limits were calculated for the population. The Fisher's t- test was also applied to test the Null hypothesis on the 3 variables (Pubic Length, Ischial length and Ischio-Pubic Index).

H0 - The Mean Length of Pubic Part of Hipbone in Male and Female is equal.

HA - The Mean Length of Pubic Part of Hipbone in Male and Female is not equal.

**Results**

Since, there was no statistically significant difference was observed between right and left sides in both sexes for the two linear measurements, the data for the two sides have been pooled.

The Range, Mean, Standard deviation and Standard Error of the three measurements are shown in Table 1, Table 2 and Table 3.

**Table 1:** Showing Range, Mean, SD and SE of the Length of Pubic Bone in mm

Measurements (in mm)	Male (N=24)	Female (N=17)
Range	54.5-78.2	60.0-74.8
Mean	66.0	66.8
Standard Deviation (SD)	8.6	7.6
Standard Error (SE)	1.76	1.84
99% Confidence Limits	Lower limit -61.06 upper limit -70.94	Lower limit -61.43 upper limit -72.17
t value	0.083	
p value	0.01	

**Table 2:** Showing Range, Mean, SD and SE of the Length of Ischial Length in mm

Ischial Length (in mm)	Male (N=24)	Female (N=17)
Range	71.0-100.0	71.0 - 86.0
Mean	86.6	78.2
Standard Deviation (SD)	0.59	0.71
Standard Error (SE)	0.12	0.17
99% Confidence Limit	86.26 to 86.94	77.70 to 78.70
t value	4.72	
p value	0.01	

**Table 3:** Showing Range, Mean, SD and SE of the Length of Ischio-pubic Index

Measurements and Calculation and calculations	Male Ischiopubic Index	Female Ischiopubic Index
Range	65.71 to 96.08	73.48 to 98.42
Mean	76.72	85.87
Standard Deviation (SD)	6.85	7.58
Standard Error (SE)	1.40	1.84
99% Confidence Limit	72.78 to 80.65	80.5 to 91.24
t value	3.70	
p value	0.01	

**Table 4:** Mean Ischiopubic indices of various populations

Population	Sex	Mean $\pm$ SD	N	P	Authors
Black Malawians	Male	85.0 $\pm$ 15.7	120	<0.05	Igbigbi and Msamati <sup>9</sup>
	Female	104.6 $\pm$ 15.7	135		
France	Male	82.0 $\pm$ 7.2	93	<0.05	Wasburn <sup>7</sup>
	Female	94.5 $\pm$ 3.1	61		
Americans	Female	71.3 $\pm$ 3.1	253	<0.05	Tague <sup>10</sup>
	Male	67.4 $\pm$ 8.1	212		
White American	Female	93.1 $\pm$ 10.4	50	<0.05	Tague <sup>10</sup>
	Male	63.7 $\pm$ 7.8	50		
Black Americans	Female	88.4 $\pm$ 8.5	50	<0.05	Tague <sup>10</sup>
	Male	65.8 $\pm$ 8.7	49		
Caucasians	Female	85.2 $\pm$ 8.5	-	<0.05	Caldwell and Moley <sup>16</sup>
	Male	<60	-		
South-South Nigerians	Female	<90	30	<0.05	Oladipo et al. <sup>3</sup>
Middle Belt Nigerians	Female	81.4 $\pm$ 6.4	40	<0.05	Oladipo et al. <sup>3</sup>
	Male	104.2 $\pm$ 11.1	20		
Eastern Nigeria	Female	83.1 $\pm$ 5.8	30	<0.05	Oladipo et al. <sup>3</sup>
	Male	101.7 $\pm$ 11.3	100		
Port Harcourt, Nigeria	Female	84.0 $\pm$ 10.4	100	<0.05	Udoaka et al. <sup>3</sup>
	Male	102.6 $\pm$ 11.7	54		
Calabar indigenes	Female	81.0 $\pm$ 5.70	114	<0.001	Ekanem et al. <sup>12</sup>
	Male	102.7 $\pm$ 9.20	100		
Nigerians in Rivers State	Female	94.2 $\pm$ 9.9	268	<0.05	Udoaka et al. <sup>4</sup>
	Male	118.8 $\pm$ 12.8	406		
Present study	Female	90.88 $\pm$ 5.52	24	<0.05	Present study
	Male	114.87 $\pm$ 8.08	17		

#### *Length of Pubic*

The mean of pubic length was 66.0 $\pm$ 8.6 mm in males and 66.8 $\pm$ 7.6 mm in females. The 99% confidence limit was between 61.06 mm and 70.94 mm in males and between 61.43 mm to 72.17 mm in females (Table 1). The Fisher's t-test was applied to test the Null Hypothesis for pubic length. The 't' value was found as 0.083 (non significant) so Null Hypothesis may be true that there was no significant difference in the pubic length among the male and female in the studied group.

#### *Length of Ischial*

The mean Ischial length of males and females hipbones were 86.6 $\pm$ 0.59 mm (Ranged 71.00-100.00 mm) and 78.2 $\pm$ 0.71 mm (Ranged 71.00 - 86.00 mm), respectively. The 99% confidence limit was between 86.26 and 86.94 mm in males and 77.70 and 78.70 mm in female. The Fisher's t-test was applied to test the Null Hypothesis for the Length of Ischial. The 't' value was found as 4.72 and thus Null Hypothesis was rejected ; it showed that there was a significant difference in the Ischial length of male and female in the studied group.

#### *Ischiopubic Indices*

The mean Ischio-pubic Indices in both males and

females bones were 76.72 $\pm$ 6.85 (Range - 65.71 - 96.08) and 85.87 $\pm$ 7.58 (Range - 73.48 - 98.42), respectively. The 99%, confidence limit was between 72.78 to 80.65 in males and from 80.5 and 91.24 in females (Table 3). The Cochran's t test was applied to test the Null Hypothesis for Ischiopubic indices. The 't' value was found as of 3.70 which was significant showing that the null hypothesis is not true while alternative hypothesis is true. It showed that there was a significant difference in the Ischio-Pubic Index of hipbone amongst the male and female in the studied group.

#### **Discussion**

Sex differences in the human pelvis are well defined in different literature and contributions from anatomists, anthropologists, and obstetrician all are there on this topic. The action of oestrogens on osteoblastic activity is a well-known fact, today leading to its differential growth according to reproductive requirement [18].

According to Washburn SL [19] the pubic region is most responsive to sex hormones; therefore the pubic structure is best indicator of sex determination of a skeleton. He has also expressed that the pubis is more reliable than any other bone, because female

sex hormone responsible for causes sex differences in these dimensions.

The Ischio-pubic index was observed to be a very useful index in sex differentiation. In this present study, the identification point for female was  $>85.87$  whereas that of males was  $<76.72$ . The mean values of this index were observed to be statistically significant.

It is observed from the findings of various different studies that the pubic length, ischial length and ischiopubic index differ in different races. A comparative data of these parameters in different races are shown in Table 4.

In this present study, the mean length of pubic bone was found  $66.00 \pm 8.6$  mm (Range 54.50 - 78.20 mm) in males and  $66.80 \pm 7.6$  mm (Range 60.00 - 74.80 mm) in females. This was justified the dimorphic character and showed that pubic length was more in females than in males. The similar observation was reported by Sachdeva et al [14] in Punjabies populations that mean was  $85.60 \pm 0.47$  mm (Range 77.50 - 95.30 mm) in females and  $79.20 \pm 0.71$  mm (Range 56.30- 93.40 mm) in males. An another study was conducted by Parija et al [20] in Odisha (South East India) they reported that the mean was 70.50mm (Range 49-84 mm) in females and 69.00 mm (Range 51-74 mm) in males.

When these results were compared with other races, there were racial differences. The Washburn (1948) [7] was conducted a study amongst White American and Negroes population. His study found that the mean value of pubic length was 77.90 mm in Females and 73.80 mm in males of White American's [7] while 73.50 mm in females and 69.20 mm in males of Negroes [7]. Further another study was conducted by Washburn [17] in 1949 in the population of Bantu and Bushman race. Where he found that the mean value of pubic length was 73.20 mm in females and 66.20 mm in males of Bantu race and it was found 66.80 mm in females and 60.40 mm in males of Bushman race.

Davivongs (1963) [6] was conducted a study in Australian Aborigines and found that the mean of Pubic length was 69.20 mm in female and 63.30 mm in males, which is comparable to the measurement value of present study. Urhobo males were having pubic length as  $78.51 \pm 12.4$  mm, whereas in their females pubic length was  $92.39 \pm 7.08$  mm. Itsekiri population had the mean values for pubic length, as  $82.20 \pm 10.62$  mm in males, and in females mean pubic length was  $92.05 \pm 6.36$  mm.

Pubis was significantly longer in females as compared with males in the North Indian population.

It can be observed from the Table 1 and 4 that when compared between the two sexes, pubic length is always more in females as compared to males in all the races. However, amongst different races, it was observed that the maximum in French & Belgian and minimum in Bushman [17]. It was also observed that the East Indian values are closest to the South East Indian population, which may be due to similar ethnicity; comparable values were reported among other races like Australian Aborigines [6], Bushman [17] and American Negroes [7] races (Table 4).

Ischium was significantly longer in males as compared to females in the North Indian population (Table 1). As it is evident in Table 4, the height of Ischium is universally more in males than in females in all the races. The findings of the present study are comparable with the races of Bantu [17] and Australian Aborigines [6].

The Washburn (1948), [6] who first put forward the view that the Ischial's height is proportional to the overall body size and reflects robusticity of male skeleton. Later, Leuteneggar (1970) [22] demonstrated a significant correlation between Ischial length and body size. Recently working further on the same subject, Rissech & Malgosa (2007) [23] not only supported the earlier workers, but also revealed that the significant sexual dimorphism in Ischial height appears at the age of 20 years due to longer growth period in males i.e. 25 years as compared with 20 years for females.

In our study, the mean length of Ischial bone was  $86.60 \pm 0.59$  mm (Range 71.00-100.00 mm) in males &  $78.20 \pm 0.71$  mm (Range 71.00-86.00 mm) in females. This justifies the dimorphic character and showed that the Ischial length is more in male than in female. The similar observation was found as having a mean value of  $73.10 \pm 0.78$  (Range 60.20 - 87.70 mm) in female and  $80.70 \pm 0.57$  mm (Range (70.40 - 94.00 mm) in male in the study done by Sachdeva et al [14] in Punjab (North India). An another study was done by Parija et al [20] in Odisha ( South East India ) they reported that the mean length of Ischial bone was 69.00 mm (Range 59.00- 80.00 mm) in females and 71.00 mm (Range 61.0 -81.0 mm) in males; these findings are closely match with the results of the present study.

Washburn (1948) [7] in his study found, the mean value of Ischial length was 78.30 mm in white American Females and 88.40mm in males. In case of Negroes he got these values as 77.50 mm in females and 86.60 mm in males. Similar study he had conducted in 1949 [17] in another population; he observed that in the Bantu race the mean of Ischial length was 74.80 mm in females and 80.30 mm in

males. The Urhobo males were having mean Ischial length of  $85.58 \pm 11.6$  mm and their females were having it as  $81.97 \pm 12.00$  mm. Itsekiri males were found to have Ischial length  $83.84 \pm 10.82$  mm and females were found to have Ischial length  $85.03 \pm 14.59$  mm. Male of South Nigerians were having Ischial length mean of  $85.03$  mm and females were having Ischial length mean  $79.52$  mm. Further evidence that human populations vary in sexual dimorphism in the pelvis as a whole can be found by looking at the Ischiopubic index (Table 3). This is a much more consistently defined measurement and shows that the Ischio-pubic index is universally more in females as compared to males. The same was true for present study also where it was significantly more in females (Table 3).

Washburn (1948) [7] named this index as "Washburn Index" and gave the reason for using it for sexual dimorphism that the difference in the length of ischium is roughly proportional to the difference in size but the pubic bone is proportionately longer in females as it is most responsive to female sex hormones. Washburn (1949) [17] claimed 84% male and 100% female American skeletons could be identified by using the ischio-pubic index. He demonstrated that the cut-off between males and females varies from one population to another. Conclusions from these studies most often note that the main population component of pelvic variation is size related; however these studies have not systematically examined population variability in sexual dimorphism in pelvic morphology.

Table 4 shows that in our study Mean Ischio-pubic Index was found to be  $76.72 \pm 6.85$  (Range 65.71-96.08) in males &  $85.87 \pm 7.58$  (Range 73.48 - 98.42) in females. Here it is evident that the ischio-pubic index is greater in female than in male. The same parameter was found as having mean value of  $117.97 \pm 12.32$  SD (Range 92.13-139.18) in female and  $98.27 \pm 7.33$  (Range 70.11-122.71) in male in the study done by Sachdeva et al [14] in Punjab (North India)

Study done by Parija et al [20] in Odisha (South East India) these values came as Mean  $-100.06$  (Range 59 - 80) in Female and Mean  $85.60$  (61.0 - 81.0) in Male; our results match to a great extent with the results found in this study. Pal et al [24] in their study in Madhya Pradesh (Central India) found this index having mean value 100 in females and 89 Males.

Washburn (1948) [7] in his study found these values as  $-99.5$  in white American Females and  $83.6$  cm in males. In case of Negroes he got this value as  $95.0$  in females and  $79.9$  in males. Again in 1949 he found this parameter in the Bantu race as the mean

having  $98.1$  in Female and  $-82.5$  in male. In Bushman population this index was  $83.7$  for Males and  $100.0$  for females. The Davivongs (1963) [6] worked on Aborigines race in Australia and found this Index as  $77.98$  Male and  $92.72$  in Females.

## Conclusion

Our study results and it's comparison with results of other workers shows that hip bone not shows only dimorphism but it's metric values are population specific also.

## References

1. Pekka Saukko, Bernard Knight. Knight's Forensic Pathology. Third Edition; published Hodder Arnold. 2004: 98-130.
2. Krogman WCA, Iscan MY. The human skeleton in forensic medicine, 2nd edn. Thomas, Springfield. 1986.
3. Oladipo GS. The Sub-pubic angle in adult indigenous Nigerians. Tropical journal of medical research. 2006; 10(1): 15-19.
4. Oladipo GS, Ugboma HAA, Suleiman YA. Comparative study of sub-pubic angles in adult Ijaws and Igbo's. Asia J. med. Sci. 2009a; 1(2): 26-29.
5. Schultz AH. The skeleton of the trunk and limbs of higher primates. Human Biol. 1930; 2: 303-438.
6. Davivong V. The pelvic girdle of the Australian Aborigines, sex differences, sex determination. AM. J. of Phys. Anthropol. 1963; 21: 443-455.
7. Washburn S. L. Sex differences in pubic bone. Am. J. Phys. Anthropol. 1948; 6:199-207.
8. Udoaka et al Udoaka, A.I., E.J. Olotu and C.E. Ikheloa. Determination of Ischiopubic index in adult Nigerians in Port Harcourt, Rivers State. Port Harcourt Med. J. 2009; 23(3): 318-321.
9. Igbigbi, P.S. and B.C. Msamati. Ischiopubic index in black Malawians. East Afr. Med. J. 2000; 77(9): 514-516.
10. Tague, R.G. Variations in pelvic size between males and females. Am. J. Phys. Anthropol. 1989; 80: 59-71.
11. Ekanem, T., A. Udongwu and S. Singh. Radiographic determination of sex differences in ischiopubic index of a Nigerian population. Int. J. Biol. Anthropol. 2009; 3: 2.
12. G. Sunday Oladipo<sup>1</sup>, K. C. Anugweje, Emoefe Oghenekevwe Rosemary and C. Uzomba Godwin. Radiologic Study of Ischiopubic Index of Urhobos and Itsekiris of Nigeria. British Journal of Medicine & Medical Research. 2015; 5(9): 1114-1120.

13. Pal GP, Bose S and Choudhary S. Reliability of criteria used for sexing of hip bones. *J Anat Soc Ind.* 2004; 53(2): 58-60.
  14. Kanika Sachdeva, Rajan Kumar Singla, Gurdeep Kalsey. Role of ischio-pubic index in sex identification from innominate bones in north indian population. *Int j anat res.* 2014; 2(3): 515-20.
  15. Seidler H. Sex-diagnosis of isolated oscoxae by discriminant functions. *J Human Evol.* 1980; 9: 597-600.
  16. Thieme FP. Sex in Negro skeletons. *J Forensic Med.* 1957; 4(2): 72-84.
  17. Washburn SL. Sex differences in the pubic bone of Bantu and Bushman. *Am J Phys Anthropol.* 194 ; 7: 425-432.
  18. Jordaan HVF. The differential development of the hominid pelvis. *S Afr Med J.* 1976; 50: 744-748.
  19. Washburn SL. Skeletal proportions of adult langurs and macaques. *Human Biol.* 1942; 14: 444-472.
  20. Bijaylaxmi Parija, Biswa Bhusan Mohanty, Sitansu Kumar Panda, Divya Agrawal, Ischio Pubic Index, A Reliable Parameter For Sexing Of Human Hipbones. *International Journal of Review in Life Sciences.* 2(3): 95-97.
  21. Orban RS. An evaluation of the sexual dimorphism of the human innominate bone. *J Human Evol.* 1980; 9: 601-607.
  22. Leutenegger W. Newborn size and pelvic dimensions of Australopithecus. *Nature.* 1972; 240: 568-569.
  23. Rissech C and Malgosa A. Pubis growth study: applicability in sexual age diagnosis. *Forensic Sci Int.* 2007; 173(2-3): 137-145.
  24. Pal GP, Bose S and Choudhary S. Reliability of criteria used for sexing of hip bones. *J Anat Soc Ind.* 2004; 53(2): 58-60.
-