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Estimation of Sex Using Demarking Points from Diameters of Lumbar Pedicles in Adult Nigerians

Danladi Sambo Amaza[1*], Aminu Ahmed Rufai[1], Tamunotonye Watson Jacks[1], Joseph Vandi Zirahei[1], Ahidjo Ahmed[2] and Luteino Lorna Hamman[1]

[1]Department of Human Anatomy, College of Medical Sciences, University of Maiduguri, Borno State, Nigeria.
[2]Department of Radiology, University of Maiduguri Teaching Hospital (UMTH), Maiduguri, Borno State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. DSA was involved in conception & design of the study and collection of data. AAR did first manuscript writing, AA managed provision of study materials/Radiographs and selection of normal Radiographs. JVZ did data analysis and interpretation. TWJ did final approval of manuscript and LLH managed the literature searches.

Research Article

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ABSTRACT

Aim: To estimate sex using demarking points and index of sexual dimorphism of horizontal and vertical diameters of lumbar pedicles in male and female Nigerians.
Study Design: Retrospective study.
Place and Duration of Study: Department of Human Anatomy and Department of Radiology (University of Maiduguri Teaching Hospital), University of Maiduguri, Borno State Nigeria between February 2007 and June 2008.
Methodology: Four hundred (400) radiographs of adult Nigerians (200 males and 200 females) were measured. Age range for the individuals was 18-76 years. Radiographs used for this study were obtained from the collection of record unit of the Radiology Department, University of Maiduguri Teaching Hospital (UMTH) in Borno state, Nigeria.Radiographic viewing box, temporary maker, pencil and a meter rule were used for

**Corresponding author: Email: namtadanladi@yahoo.com;*

the measurements.The radiographs for males and females were classified separately into six (6) age groups with ten (10) years interval. Vertical and Horizontal diameters of lumbar pedicle were represented on the radiographs by “h” (taken as the maximum dimension of the pedicle between the upper and lower margins of the pedicles) and by “t” (maximum diameter between the medial and lateral aspect of each pedicle). Distance between upper and lower extremities, as well as that between medial and lateral extremities of each pedicle were marked and measured as vertical and horizontal diameters respectively.

Results: The result of the present study showed that, the vertical and horizontal diameters of the lumbar pedicles in adult Nigerians were all greater in male than in female counterpart. It was also observed that sexual differences in the two parameters were found to be statistically significant ($P<0.001$) in both sexes. Index of sexual dimorphism (ISD) was also calculated and it was observed that all parameters were found to be greater than 100; this showed that male had higher values over female counterpart. Demarking points were also calculated for each parameter, the result also showed similar pattern of increase in male parameters over female counterpart. The result also showed age-related significant ($P<0.001$) variations for the lumbar pedicle diameters, from 18-27 through 38-47 years age groups with a decrease in diameters at the 48-57 through 68-77 years age groups in both sexes.

Conclusion: It was observed that the vertical and horizontal diameters were sexually dimorphic; the demarking points of male diameter were all higher than those of the female counterpart. Index of sexual dimorphism also showed that male vertical and horizontal diameters were all greater than female vertical diameter as the index of sexual dimorphism were all greater than 100 from L1 through L5. This study reconfirms the fact that osteometric assessment is highly population- specific. It may be added that more studies are required in the southern part of Nigerian population to give a better picture of the racial variation that exists there and to offer more osteometric standards for assessing sex for the entire country.

Keywords: Sex determination; demarking point; vertical diameter; horizontal diameter; lumbar pedicles; Nigeria.

1. INTRODUCTION

Anatomists, anthropologists and forensic experts have been called upon to judge the sex of the skeletal material by non-metric observations (Igbigbi and Nanono-Igbibi, 2003). Now sexual divergence was based upon actual measurements in different bones. Metrical study of bones has been done by various authors. Forensic anthropologists and anatomists are often interested in determining the sex of human from their skeletal remains to solve problems of medico-legal system (Kewal, 2007). In forensic anthropology, it is sometimes necessary to determine sex of isolated bones other than those of which sexually dimorphic characters have been well studied (Gumsu and Asala, 2007).

Sexual dimorphism is the systematic difference in form between individuals of different sex in the same species (Marin et al., 2006). Jit and Singh (1966) advocated the demarking point, which identify the sex of the individual with 100% accuracy. Singh and Gangrade (1968) reported that even within the same general population mean value may differ significantly in bone parameters from different zones. Singh and Singh (1972) have shown that demarking point should be calculated separately for different regions of population because the mean of parameter may differ in values. To be certain in identification

calculated ranges has to be considered, which was worked out by adding and subtracting 3X standard deviation (SD) to and from the mean of any parameter. Jit and Singh (1966), have called the limiting point of such calculated range as demarking points which identify sex with 100% accuracy from any given population or region. Sexual dimorphism was observed by the statistically significance difference and the index of sexual dimorphism.

Over the recent years many researchers have shown substantial interest in the study of the various features of the vertebral column, and in particular, studies have been conducted on the lumbar vertebrae with reference to the pedicles height and width (Mitral et al., 2002; Singel et al., 2004; Claudia et al., 2002; Karakas et al., 2006; Prakash et al., 2007). According to Singel et al. (2004), there were variations between male and female parameters.

The accurate determination of sex and race are important tools to forensic and physical anthropologists (Igbigbi and Nanono-Igbibi, 2003). According to Frutos (2002), the choice of an appropriate standard for metric determination of sex is of great importance in forensic anthropology. Even within the same population anatomical variations have been reported on the pedicle shape, size and angulations (Weinstein et al., 1992).

The detail measurement of lumbar pedicle is important as it will help in the determination of sex of a given population. Most of the previous studies conducted on the morphometry of pedicle were based on white populations and the vertebrae for male and female were pooled together (Saillant, 1976; Zindrick et al., 1987; Berry et al., 1987; Olsewski et al., 1990) among others. However, Amonoo-Kuofi, 1995 and Arora et al., 2006 reported statistical significant sex differences in lumbar pedicle morphometry.

Determination of sex from skeletal remains is of great importance in medico-legal cases, as well as for anthropological and anatomical importance (Pal et al., 2004). This study will be useful to Anatomists and Physical Anthropologists by providing data of the pedicle diameters (horizontal and vertical) of lumbar vertebrae in both male and female adult Nigerians.

2. MATERIALS AND METHODS

2.1 Materials

This study was a retrospective study, carried out on plain antero-posterior radiographs of the lumbo-sacral region. Four hundred (400) radiographs of adult Nigerians (200 males and 200 females) were measured. The age range for the individuals was 18-77 years. The radiographs for males and females were classified separately into six (6) age groups spanned ten (10) years interval (Table 1). These radiographs were obtained from the collection of record unit of the Radiology Department, University of Maiduguri Teaching Hospital (UMTH) in Borno State, Nigeria. Radiographs used for this study were selected from collections over periods of five (5) years from 2002-2007. Only radiographs that were reported by a consultant radiologist as normal were used for the study.

2.1.1 Other materials

Radiographic viewing box, ink maker, pencil and a meter rule were used for the measurements. The viewing box was connected to a light source which gave illumination for clear view.

Table 1. Distribution of subjects according to age group

Age group (yrs)	Male (mm)	Female (mm)	Total
18 – 27	33	36	69
28 – 37	38	51	89
38 – 47	51	32	83
48 – 57	36	22	58
58 – 67	25	19	44
68 – 77	17	40	57
Total	**200**	**200**	**400**

2.2 Methods

The method adopted for the measurements of the vertical and horizontal diameters of the lumbar pedicles (from L1-L5) were those of Amonoo-kuofi (1995) and Prakash et al. (2007). Radiographs were mounted on surface of an illuminator, a transparent graduated rule in millimeters were used for the measurements. Margins of the pedicles of lumbar vertebrae were well outlined on the plain antero-posterior lumbo-sacral radiographs. On the plain radiographs, outline of the pedicles were somewhat oval, thus accurate measurements were made directly on the radiographs (Senaran et al., 2002; Amonoo-kuofi, 1995).

The measurements were;

1. Vertical (Height) of the pedicles lumbar pedicles measured in millimeters (mm).
2. Horizontal (Width) of the pedicles lumbar pedicles measure in millimeters (mm).

2.2.1 Measurement of the vertical diameter of the lumbar pedicles

The vertical diameter of lumbar pedicle was represented on the radiograph by V as the maximum diameter between the upper and lower margins of each pedicle. Two points were indicated on the upper and lower margins (extremities) of each pedicle in sagittal plane. The distance between the margins was measured as vertical diameter in millimeter. At the lower levels, the plane of the vertical diameter was oblique, with the upper end nearer the midline than the lower end.

2.2.2 Measurement of the horizontal diameter of the lumbar pedicles

The Horizontal (Width) diameter was represented on the radiograph by H as the maximum diameter between the medial and lateral aspect of each pedicle. Two points were indicated on the medial and lateral aspect (extremities) of the pedicle and the distance between them was measured as the horizontal diameter in millimeter.

2.3 Statistical Analysis

Data obtained from the measurements were subjected to statistical analyses. The means of horizontal and vertical diameters were calculated. Standard deviation and standard error of the mean were also calculated. Oneway ANOVA with Dunnett's post test was performed using Graph Pad InStat version 3.00 for window 95 (*http://*www.graphpad.com).

The Index of Sexual dimorphism was calculated as follows:

$$\text{Index of sexual dimorphism (ISD)} = \frac{\text{Mean value of Male}}{\text{Mean value of female}} \times 100.$$

This index indicates the level of difference between sexes; values close to hundred indicate low level of sexual difference and on the other hand the level of sexual difference increases with the increase of the distance from hundred (Marin, 2006).

Mean ± 3 x standard deviation (S.D) was used to calculate the ranges from which demarking points (DP) were determined (Singh and Gangrade, 1968).

A probability level of P<0.001 was considered extremely significant, p<0.01 very significant, p < 0.05 significant, while probability level of P>0.05 was considered not significant.

3. RESULTS

3.1 Vertical Diameter of the Lumbar Pedicles

Table 2. Descriptive statistic for vertical diameter in males and females at L1 vertebra

Age GP (in yrs.)	Males			Females			P value
	Mean ± S.D (in mm) of V.D	S.E	95% CL (in mm)	mean ± S.D (in mm) of V.D	S.E	95% CL (in mm)	
18 – 27	16.6±1.5	0.3	16.1-17.1	15.4±1.4	0.2	15.0-15.9	P< 0.05
28 – 37	17.2±1.7	0.3	16.7-17.8	16.1±1.5	0.2	15.6-16.5	P< 0.05
38 – 47	18.1±1.3	0.2	17.8-18.5	16.6±1.3	0.2	16.2-17.1	P< 0.01
48 – 57	17.0±1.7	0.3	16.9-17.5	16.8±1.4	0.3	16.1-17.4	NS
58 – 67	18.1±0.6	0.1	17.8-18.3	17.1±1.2	0.3	15.8-17.6	P< 0.01
68 – 77	17.6±0.7	0.2	17.2-18.0	16.6±1.7	0.3	16.1-17.2	NS

GP=Group; yrs.=years; S.D=Standard Deviation; V.D=Vertical Diameter; S.E= Standard Error; NS= Not Significant;95%CL=95% Confidence Limit; P value=level of significance between male and female.

In Table 2 it was observed that male mean vertical diameter ranged from 16.6mm at 18-27 years age group to 18.1mm at 58-67years age group, while female mean vertical diameter ranged from 15.4mm to 17.1mm at the same age group of the male counterpart respectively.

Table 3. Descriptive statistic for vertical diameter in males and females at L2 vertebra

Age GP (yrs.)	Males			Females			P value
	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	
18 – 27	16.8 ± 1.5	0.3	16.1-17.1	15.7 ± 1.4	0.2	15.0 -15.9	P< 0.05
28 – 37	17.2 ± 1.7	0.3	17.1-18.2	16.3 ± 1.5	0.2	15.6-16.5	P< 0.05
38 – 47	18.1 ± 1.3	0.2	17.8-18.5	16.5 ± 1.3	0.2	16.2-17.1	P< 0.01
48 – 57	17.0 ± 1.7	0.3	16.4-17.6	16.8 ± 1.4	0.3	16.1-17.4	NS
58 – 67	18.4 ± 0.6	0.1	17.8-18.3	17.5 ± 1.2	0.3	15.8-17.6	P< 0.01
68 – 77	17.8 ± 0.7	0.2	17.2-18.0	16.7±1.7	0.3	16.1-17.2	NS

GP=Group; yrs.=years;S.D=Standard Deviation; V.D=Vertical Diameter; S.E= Standard Error; NS= Not Significant;95%CL=95% Confidence Limit; P value=level of significance between male and female.

In Table 3 male mean vertical diameter ranged from 16.8mm at 18-27 years age group to 18.4mm at 58-67years age group, while female mean vertical diameter ranged from 15.7mm to 17.5mm at the same age group of the male counterpart respectively.

Table 4. Descriptive statistic for vertical diameter in males and females at L3 vertebra

Age GP (yrs.)	Males			Females			P value
	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	
18 – 27	16.2 ± 1.6	0.3	15.6-16.7	14.8 ± 1.8	0.3	14.1-15.4	P< 0.05
28 – 37	17.6± 1.7	0.3	17.1-18.2	16.1 ± 1.6	0.2	15.6-16.5	P< 0.01
38 – 47	17.8 ± 2.1	0.3	17.2-18.4	16.5 ± 1.1	0.2	16.1-16.9	P< 0.05
48 – 57	17.5 ± 1.9	0.3	16.8-18.1	16.2 ± 1.1	0.2	15.7-16.7	P<0.05
58 – 67	18.9 ± 1.0	0.2	18.5-19.3	17.1 ± 1.2	0.3	16.5-17.6	P< 0.001
68 – 77	18.7 ± 0.8	0.2	18.3-19.1	16.3 ± 0.9	0.1	16.0-16.6	P< 0.001

GP=Group; yrs. =years; S.D=Standard Deviation; V.D=Vertical Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit; P value=level of significance between male and female.

The male vertical diameter ranged from 16.2mm at 18-27 years age group to 18.9mm at 58-67years age group, while female mean vertical diameter ranged from 14.8mm to 17.1mm at the same age groups of the male counterpart respectively (Table 4).

Table 5. Descriptive statistic for vertical diameter in males and females at L4 vertebra

Age GP (yrs.)	Male			Female			P value
	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	
18 – 27	17.7 ± 1.7	0.3	17.1-18.3	16.1 ± 1.8	0.3	15.4-16.7	P< 0.01
28 – 37	17.8 ± 1.7	0.3	17.2-18.3	15.8 ± 1.6	0.2	15.4-16.3	P< 0.01
38 – 47	17.7 ± 1.5	0.2	17.3-18.1	17.4 ± 1.3	0.2	16.9-17.9	NS
48 – 57	18.2 ± 1.7	0.3	17.6-18.8	17.5 ± 2.0	0.4	16.4-18.2	NS
58 – 67	18.2 ± 0.9	0.3	17.8-18.6	16.6 ± 1.3	0.3	15.9-17.2	P< 0.001
68 – 77	18.0 ± 0.8	0.2	17.6-18.4	16.0± 1.3	0.2	15.6-16.4	P< 0.001

GP=Group; yrs.=years; S.D=Standard Deviation; V.D=Vertical Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit; P value=level of significance between male and female.

Male vertical diameter ranged from 17.7mm at 18-27 years age group to 18.2mm at 58-67 years age group, while female mean vertical diameter ranged from 15.8mm at 28-37 years age group to 17.5mm at 48-57 years age group (Table 5).

Table 6. Descriptive statistic for vertical diameter in males and females at L5 vertebra

Age GP (yrs.)	Males			Females			P value
	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	Mean ± S.D (mm) of V.D	S.E	95% CL (mm)	
18 – 27	18.0 ± 2.2	0.4	17.2-18.8	16.8 ± 1.9	0.3	16.1-17.4	P< 0.05
28 – 37	18.3 ± 2.3	0.4	17.5-19.0	15.6 ± 2.1	0.3	14.9-16.1	P< 0.001
38 – 47	18.4 ± 1.8	0.2	17.9-18.9	18.1 ± 2.1	0.4	17.3-18.8	P< 0.001
48 – 57	19.3 ± 2.0	0.3	18.6-19.9	18.1 ± 1.5	0.3	17.4-18.7	P<0.05
58 – 67	19.3 ± 1.2	0.2	18.8-19.8	18.1 ± 1.3	0.3	17.4-18.7	P< 0.05
68 – 77	19.2 ± 1.3	0.3	18.6-19.9	17.8 ± 0.8	0.1	17.5-18.0	P< 0.001

GP=Group; yrs.=years; S.D=Standard Deviation; V.D=Vertical Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit; P value=level of significance between male and female.

Male vertical diameter ranged from 18.0mm at 18-27 years age group to 19.3mm at 58-67 years age group, while female mean vertical diameter ranged from 15.6mm at 28-37 years age group to 18.1mm at 58-67 years age group (Table 6).

Table 7. Descriptive statistic for vertical diameter for male and female from L1-L5

Vertebral Level	Males			Females			P value
	Mean±S.D of V.D	S.E	95% CL	Mean ±S.D of V.D	S.E	95% CL	
L1	17.4 ± 1.3	0.1	17.2 - 17.6	15.7 ± 1.4	0.1	15.5 -15.9	P < 0.001
L2	17.5 ± 1.5	0.1	17.2 - 17.7	16.3 ± 1.6	0.1	16.0 - 16.5	P < 0.001
L3	17.6 ± 1.9	0.1	17.4 - 17.9	16.1 ± 1.5	0.1	15.9 - 16.3	P < 0.001
L4	17.9 ± 1.5	0.1	17.7 - 18.1	16.4 ± 1.7	0.1	16.2 - 16.6	P < 0.001
L5	18.7 ± 2.0	0.1	18.4 - 18.9	17.1 ± 2.0	0.1	16.8 - 17.4	P < 0.001

S.D=Standard Deviation; V.D=Vertical Diameter; S.E= Standard Error; 95%CL=95% Confidence Limit; P value=level of significance between male and female.

In Table 7 it was observed that, male mean vertical diameter ranged from 17.4mm at L1 to 18.7mm at L5, while female mean vertical diameter ranged from 15.1mm to 16.0mm at the same vertebral level as the male counterpart respectively.

Table 8. Demarking point and index of sexual dimorphism for vertical diameter for male and female from L1-L5

Vertebral level	Males			Females			ISD
	Mean±S.D of V.D	Calculated range	D.P	Mean±S.D of V.D	Calculated range	D.P	
L1	17.4 ± 1.3	13.5 - 21.3	>19.9	15.7 ± 1.4	11.5 - 19.9	<13.5	110.8
L2	17.5 ± 1.5	13.0 - 22.0	>21.1	16.3 ± 1.6	11.5 - 21.1	<13.0	107.3
L3	17.6 ± 1.9	11.9 - 23.3	>20.6	16.1 ± 1.5	11.6 - 20.6	<11.9	109.3
L4	17.9 ± 1.5	12.2 - 22.4	>21.5	16.4 ± 1.7	11.3 - 21.5	<12.2	109.1
L5	18.7 ± 2.0	12.7 - 24.7	>23.1	17.1 ± 2.0	11.1 - 23.1	<12.7	109.4

S.D = Standard Deviation; ISD= Index of Sexual Dimorphism; S.E = Standard Error of the mean; D.P = Demarking Pointand V.D.= Vertical diameter

Demarking points (DP) for male ranged from >19.9mm at L1 to >23.1mm at L5 while female DP decreased from <13.5mm at L1 to <11.9mm at L3. Index for sexual dimorphism at L1 through L5 were, 110.8, 107.3, 109.3, 109.1 and 109.4 respectively (Table 8).

3.2 Horizontal Diameter of Lumbar Pedicles

Male horizontal diameter decreased from 9.6mm at 18-27 years age group to 8.7mm at 68-77 years age group, while female mean horizontal diameter ranged from 8.3mm at 18-27 years age group to 8.5mm at 68-77 years age group (Table 9).

Table 9. Descriptive statistic for horizontal diameter in both males and females at L1 vertebra

Age GP (yrs.)	Males			Females			P value
	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	
18 – 27	9.6 ± 1.3	0.2	9.1-10.1	8.3 ± 1.4	0.2	7.7-8.7	P<0.01
28 – 37	9.5 ± 1.0	0.2	9.2-9.8	8.4 ± 1.4	0.2	8.0-8.8	P<0.05
38 – 47	9.6 ± 1.8	0.3	9.1-10.1	8.4 ± 1.2	0.2	7.9-8.8	P<0.01
48 – 57	9.3 ± 1.3	0.2	8.9-9.8	8.3 ± 1.4	0.2	7.7-8.9	P<0.01
58 – 67	8.8 ± 1.0	0.2	8.4-9.2	8.2 ± 1.0	0.2	8.0-9.0	NS
68 – 77	8.7 ± 1.0	0.2	8.3-9.3	8.5 ± 1.0	0.2	8.2-8.9	NS

GP=Group; yrs.=years; S.D=Standard Deviation; H.D=Horizontal Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit, P value=level of significance between male and female

Table 10. Descriptive statistic for horizontal diameter in both males and females at L2 vertebra

Age GP (inyrs.)	Males			Females			P value
	Mean ±S.D (in mm) of H.D	S.E	95% CL (in mm)	Mean ± S.D (in mm) of H.D	S.E	95% CL (in mm)	
18 – 27	9.7 ± 1.5	0.3	9.2-10.2	8.7 ± 1.3	0.2	8.2-9.1	P<0.05
28 – 37	9.7 ± 1.2	0.2	9.3-10.1	8.4 ± 1.4	0.2	8.0-8.8	P<0.01
38 – 47	9.3 ± 1.2	0.2	8.9-9.6	8.9± 1.2	0.2	8.4-9.3	P<0.01
48 – 57	9.2 ± 1.4	0.2	8.9-9.9	8.7 ± 1.4	0.3	8.1-9.3	P<0.05
58 – 67	10.4 ± 0.4	0.1	9.9-10.3	9.0 ± 1.0	0.2	8.5-9.5	P<0.05
68 – 77	10.1± 2.1	0.5	9.3-11.5	7.8 ± 0.9	0.1	7.5-8.1	P<0.001

GP=Group; yrs.=years; S.D=Standard Deviation; H.D=Horizontal Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit, P value=level of significance between male and female

Male horizontal diameter decreased from 9.7mm at 18-27 years age group to 9.2mm at 48-57 years age group, while female mean horizontal diameter fluctuated but distinction between males and females (Table 10).

Table 11. Descriptive statistic for horizontal diameter in both males and females at L3 vertebra

Age GP (in yrs.)	Males			Females			P value
	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	Mean ±S.D (mm) of H.D	S.E	95% CL (mm)	
18 – 27	11.5 ± 1.8	0.2	11.2-11.7	9.8 ± 1.5	0.1	9.6-10.0	P<0.001
28 – 37	10.8 ± 1.8	0.3	10.2-11.5	9.1 ± 1.0	0.3	8.8-9.5	P<0.001
38 – 47	11.1 ± 2.1	0.3	11.5-12.7	10.4± 1.0	0.2	10.1-10.8	P<0.001
48 – 57	11.2 ± 1.5	0.2	10.7-11.7	9.9 ± 1.4	0.3	9.2-10.5	P<0.001
58 – 67	11.0 ±1.6	0.3	10.4-11.7	10.1 ± 1.3	0.3	9.4-10.7	P<0.01
68 – 77	12.4± 0.5	0.1	12.1-12.6	9.9 ± 0.7	0.1	8.7-9.1	P<0.001

GP=Group; yrs.=years; S.D=Standard Deviation; H.D=Horizontal Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit, P value=level of significance between male and female

Male horizontal diameter ranged from 10.8mm at 28-37 years age group to 12.4mm at 68-77 years age group, while female mean horizontal diameter ranged from 9.1mm at 28-37 years age group to 10.4mm at the 38-47 years age group (Table 11).

Table 12. Descriptive statistic for horizontal diameter in both males and females at L4 vertebra

Age GP (in yrs.)	Males			Females			P value
	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	
18 – 27	12.1 ± 1.7	0.3	11.5-12.7	10.8 ± 1.5	0.2	10.3-11.3	P<0.01
28 – 37	12.6 ± 1.8	0.3	12.0-13.1	11.0 ± 1.2	0.2	10.7-11.4	P<0.001
38 – 47	12.2 ± 1.4	0.2	11.8-12.6	11.4 ± 1.4	0.2	10.9-11.9	NS
48 – 57	13.1 ± 1.4	0.2	12.6-13.6	11.9 ± 1.0	0.2	11.2-12.1	P<0.01
58 – 67	12.2 ±0.7	0.1	11.9-12.5	11.9 ± 1.0	0.2	11.5-12.4	NS
68 – 77	12.5 ± 1.0	0.2	12.0-13.0	11.4 ± 1.1	0.2	11.0-11.7	P<0.05

GP=Group; yrs.=years; S.D=Standard Deviation; H.D=Horizontal Diameter; S.E= Standard Error; NS= Not Significant95%CL=95% Confidence Limit, P value=level of significance between male and female

Male horizontal diameter ranged from 12.1mm at 18-27 years age group to 13.1mm at 38-47 years age group, while female mean horizontal diameter ranged from10.1mm at 18-27 years age group to 11.9mm at the 48-57 and 58-67 years age groups (Table 12).

Table 13. Descriptive statistic for horizontal diameter in both males and females at L5 vertebra

Age GP (yrs.)	Males			Females			P value
	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	Mean ± S.D (mm) of H.D	S.E	95% CL (mm)	
18 – 27	12.6 ± 1.6	0.3	12.0-13.2	11.6 ± 1.1	0.2	11.5-12.2	P<0.01
28 – 37	13.1 ± 1.1	0.2	12.7-13.5	12.2 ± 1.6	0.2	11.7-12.6	P<0.01
38 – 47	13.3 ± 1.1	0.2	12.9-13.6	12.3 ± 1.6	0.3	11.8-12.9	P<0.001
48 – 57	13.9 ±1.2	0.2	12.9-13.8	12.9 ± 1.0	0.2	12.5-13.4	P<0.01
58 – 67	13.6 ±1.3	0.3	13.0-14.0	12.2 ± 1.1	0.2	11.712.7	P<0.01
68 – 77	13.8 ± 0.9	0.2	13.4-14.3	11.9 ± 1.0	0.2	11.5-12.2	P<0.001

GP=Group; yrs.=years; S.D=Standard Deviation; H.D=Horizontal Diameter; S.E= Standard Error; NS= Not Significant; 95%CL=95% Confidence Limit, P value=level of significance between male and female

Male horizontal diameter ranged from 12.6mm at 18-27 years age group to 13.9mm at 48-57 years age group, while female mean horizontal diameter ranged from11.6mm at 18-27 years age group to 12.9mm at the 48-57 years age group (Table 13).

Table 14. Descriptive statistic for horizontal diameter in males and females, from L1-L5

Vertebral level	Males			Females			P value
	Mean±S.D (mm) of H.D	S.E	95% CL	Mean±S.D (mm) of H.D	S.E	95% CL	
L1	9.4 ± 1.4	0.1	9.2 - 9.7	8.4 ± 1.2	0.1	8.2 - 9.6	P < 0.001
L2	9.7 ± 1.4	0.1	9.5 - 9.8	8.5 ± 1.3	0.1	8.3 - 8.7	P < 0.001
L3	11.5 ± 1.8	0.1	11.2 - 11.7	9.8 ± 1.5	0.1	9.6 - 10.0	P < 0.001
L4	12.4 ± 1.5	0.1	12.2 - 12.7	11.3 ± 1.3	0.1	11.1 - 11.5	P < 0.001
L5	13.2 ± 1.3	0.1	13.1 - 13.4	12.2 ± 1.3	0.1	12.0 - 12.4	P < 0.001

S.D=Standard Deviation; H.D=Horizontal Diameter; S.E= Standard Error, 95%CL=95% Confidence Limit; P value=level of significance between male and female

In Table 14, the horizontal diameter of the lumbar pedicles for male ranged from 9.4mm at L1 to 13.2mm at L5 while female mean horizontal diameter ranged from 8.4mm at L1 to 12.2mm at L5 Significance difference between male mean and female mean were all found to be extremely significant (P<0.001)

Table 15. Demarking point and index of sexual dimorphism for horizontal diameter for males and females

Vertebral Level	Males			Females			ISD
	Mean±S.D (mm) of H.D	Calculated Range	D.P	Mean±S.D (mm) of H.D	Calculated Range	D.P	
L1	9.4 ± 1.4	5.2-13.6	>12.6	8.4 ± 1.2	4.2-12.6	<5.2	111.9
L2	9.7 ± 1.4	5.3-13.9	>12.4	8.5 ± 1.3	4.6-12.4	<5.3	114.1
L3	11.5 ± 1.8	6.9-16.1	>14.3	9.8 ± 1.5	5.3-14.3	<6.9	117.3
L4	12.4 ± 1.5	7.9-16.9	>15.2	11.3 ± 1.3	7.4-15.2	<7.9	109.7
L5	13.2 ± 1.3	9.3-17.1	>16.1	12.2 ± 1.3	8.3-16.1	<9.3	108.2

H.D=Horizontal Diameter; ISD= Index of Sexual Dimorphism; D.P =Demarking Point; S.D = Standard Deviation.

Demarking points for the male mean ranged from >12.6mm at L1 to >13.2mm at L5 while the female mean ranged from <5.2mm at L1 to <9.3mm at L5. Index for sexual dimorphism at L1 through L5 was, 110.8, 107.3, 109.3, 109.1 and 109.4 respectively (Table 15).

4. DISCUSSION

4.1 Vertical Diameter of Lumbar Pedicles

The present study showed that the vertical diameter of the lumbar pedicles of male subjects were significantly greater than female counterpart at all vertebral segments from LI to L5 and in adult age group (18-27 through 38-47 years) in Tables 2-6. However Prakash et al. (2007) observed contrary pattern of increase, they observed that the mean vertical diameter for female were higher than the mean vertical diameter for male, their observations correlated with early pubertal growth increase in females than in males. Male mean vertical diameter ranged from 17.4mm at L1 to 18.7mm at L5 (Table 7), while female mean vertical diameter increased from15.7mm to 16.0mm at the same age groups of the male counterpart

respectively with slight decrease at L3 (Table 7). Arora et al. (2006), observed the mean vertical diameter also increased from 14 to 21mm in male and from 14 to 29mm in female, and was contrary with the present study. Amonoo-kuofi (1995), observed a cephalo-caudal increase in mean vertical diameter, which also support the present study by showing that male mean vertical diameter were mostly higher than those of the female counterpart at the same age group and the same vertebral level. Contrast was however observed in the present study of the mean vertical diameter in elder (48-57 through 67-77 years) age group, which showed a tendency to decrease in both the sexes. Hence it can be hypothesized that age related osteoporosis along with wear and tear processes were responsible for decreasing mean vertical diameter in the X-ray. Study by Singel et al. (2004), reveals that the mean vertical diameter of the lumbar pedicles was greater at L1, L2 & L3 levels after which it goes on decreasing at L4 & L5 levels for both males & females and this was in conformity with the present study which observed possible cause of the decrease in the lower lumbar vertebrae as osteoporosis. The present study reveals different trend of increase as observed by Singel et al. (2004), because they did not observed significant differences between male and female mean vertical diameter of the lumbar pedicles. The maximum mean vertical diameter of the lumbar pedicles in the present study from the radiographs of male subjects were significantly greater than the female counterpart at all vertebral level from L1 to L5 in the age groups (18-27 through 68-77 years). Amonoo-kuofi (1995), did not observed any significant differences between right and left lumbar pedicles and this was also noted in the present study, he also observed that the gender differences were not significant in majority of the elder (greater than 50 years) age groups. Amonoo-kuofi (1995) related the larger mean vertical diameter of the second and third lumbar pedicles to the weight bearing functions and concluded that the mean vertical diameter with its larger dimension and the wider variations with age, contributes more to the weight-bearing function than the horizontal diameter. He opined that after the fifth decade of life the horizontal and vertical diameters of the lumbar pedicles in females showed a tendency to increase, while male diameters decreased. On the contrary in the present study the aforementioned diameters in elder (48-57 through 67-77 years) age group showed a tendency to decrease in both the sexes. The study by Amonoo-kuofi (1995) also reflects that the vertical diameter of the lumbar pedicles in male and female were greater at L5 with 20.7mm and 17.5mm respectively. On the contrary study by Singel et al. (2004) reveals that, the vertical diameter was maximum at L1, L2 and L3 levels, after which it goes on decreasing at L4 and L5 levels for both male and female. It was also observed that the vertical diameter was sexually dimorphic, since the demarking points (DP) of male vertical diameter were all higher than those of the female. Male DP ranged from >19.9mm at L1 to >23.1 at L5 while female DP decreased from <13.5mm at L1 to <11.9mm at L3 (Table 8) Index of sexual dimorphism confirms that male vertical diameter were all greater than female vertical diameter as the index of sexual dimorphism were all greater than 100 from L1-L5 (Table 8).

4.2 Horizontal Diameter of Lumbar Pedicles

The present study observed that, the mean horizontal diameter of the lumbar pedicles were also significantly greater in male than female counterpart at all the vertebral levels (L1-L5) and in adolescent age group (18-27 through 38-47 years) as seen in Tables 9-13, this findings was in agreement with studies conducted by Amonoo-kuofi (1995) and Prakash et al. (2007) but contrary to the result presented by Singel et al. (2004) and Zindrick et al. (1998), where it was observed that female and male parameter fluctuate, in most cases female mean horizontal diameter were higher than male mean horizontal diameter. The contrast could be due to racial variations. According to the present study, the horizontal

diameter in male and female were greatest at L5, 13.2mm and 12.2mm respectively (Table 14). Male horizontal diameter ranged from 9.4mm at L1 to 13.2mm at L5, while female mean horizontal diameter ranged from 8.4mm to 12.2mm at the same age groups of the male counterpart respectively (Table 14). Amonoo-kuofi (1995) observed variations in different age groups and at different vertebral levels, 40-49.9 years age group reveals that the mean horizontal diameter in male and female were greatest at L5 with 14.2mm and 12.5 respectively. Similarly the mean horizontal diameter of the lumbar pedicles in male and female according to Singel et al. (2004) was maximum at L5 with 18.2mm and 19.5mm respectively. Arora et al. (2006) observed that there were significant differences between male and female and that male mean horizontal diameter were greater than the female mean horizontal diameter at the same vertebral level and age groups. Arora et al. (2006), also observed that, the horizontal diameter increased from L1 to L5 with male having greater diameter than female. It was also observed that the horizontal diameter was sexually dimorphic, since the demarking points of male horizontal diameter were all higher than those of the female. Male DP ranged from >12.6mm at L1 to >16.1 at L5, while female DP increased from <5.2mm at L1 to <9.3mm at L5 (Table 15). Index of sexual dimorphism confirms that male horizontal diameter were all greater than female horizontal diameter as the index of sexual dimorphism were all greater than 100 from L1-L5 (Table 15).

Factors contributing to the measured differences between bone specimen and the X-rays can be hypothesized as due to partial volume effects may be responsible for the differences which resulted to greater values in the radiological study than the direct bone measurement. In plain radiographs, magnification factor can only be roughly estimated, besides, X-ray measurements had the common limitation of the two dimensional structures. Bone specimen observations had the usual benefit of the three dimensional structures; on the other hand, the fact that some dry bone properties differ from the in vivo bones was the main limitation. It is known that the average male skeleton is longer and more robust than the average female, although the magnitude of the difference varies from population to population. The sex differences may be result of genetic factors, environmental factors affecting growth and development (nutrition, physical activity and pathologies), or the interaction of these factors Trancho et al. (1997).

5. CONCLUSION

The result of the present study showed that, the vertical and horizontal diameters of the lumbar pedicles in adult Nigerians were all greater in male than in female counterparts. It was also observed that sexual differences in the two parameters were found to be statistically significant ($P<0.001$) in both sexes. Index of sexual dimorphism (ISD) was also calculated, and it was observed that all parameters were found to be greater than 100; this showed that male had higher values over female counterparts. Demarking points also showed similar trend of increase in male parameters over female counterpart. The result also showed age-related significant ($P<0.001$) variations for the lumbar pedicle diameters with increase from 18-27 through 38-47 years age groups with a decrease in diameters at the 48-57 through 68-77 years age groups in both sexes. This evidence suggests that pedicles diameters undergoes continuous change throughout the age ranged studied. It was also observed that radiographic measurements from Nigerian population was found to be higher than the morphometric study using lumbar bones from other parts of the world.

The three parameters placed the lumbar vertebrae as a useful bone in sex determination among adult Nigerians, particularly where other bones commonly used for sex determination of individual from skeletal remains such as pelvic and skull are not found.

The conclusion drawn from the measurement of the lumbar pedicles for identification of sex by several researchers is not applicable to all races, because of variations in diet, heredity, climate and other geographical conditions as reported by Trancho (1997). Asala et al. (1998) also stated that the human body dimension can be affected by racial, geographical, gender and age factors; hence the study of bones morphology is useful from region to region, because of these numerous factors in sex determination.

6. RECOMMENDATION

This study reconfirms the fact that osteometric assessment is highly population- specific. It may be added that more studies are required in the southern part of Nigerian population to give a better picture of the racial variation that exists there and to offer more osteo-metric standards for assessing sex for the entire country, this is because different cultures exhibit different patterns of occupational stress and this may be the reason why population specific standards must be developed for sex differentiation.

CONSENT

All authors declare that 'written informed consent was obtained from the University of Maiduguri Teaching Hospital (UMTH) for publication of this case report.

ETHICAL APPROVAL

All authors hereby declare that all radiographs and measurement protocol have been examined and approved by the ethical committee of the University of Maiduguri Teaching Hospital (UMTH) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki."

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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