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The sagittal diameter of the lumbar vertebral canal in normal adult Nigerians

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INTRODUCTION

Anatomical narrowing of the lumbar vertebral canal and intervertebral foramina has been reported as a cause of compression of the cauda equina and the emerging nerve roots (Sarpyener, 1945; Schlesinger & Taveras, 1953; Verbiest, 1954; Crock, 1981; Venner & Crock, 1981). The compression is associated with neurological complications, notably pain in the back and lower limbs on walking, weakness and paraesthesiae along the distribution of the affected nerve roots. Classically, the symptoms are relieved by reversing the lumbar lordosis either by bending or crouching. Verbiest (1954, 1955, 1977) called this 'the lumbar spinal stenosis syndrome', and suggested that it could result from congenital or developmental narrowing of the canal. Morphometric studies by Epstein, Epstein & Lavine (1962), Hinck, Hopkins & Clark (1965), Hinck, Clark & Hopkins (1966) and Eisenstein (1977) have established that the abnormality may involve the transverse, sagittal or both diameters of the canal. In a recent review, however, Verbiest (1977) has made it clear that in developmental stenosis, the transverse diameters (interpedicular distances) are normal whereas the sagittal diameters are reduced because of thickened laminae and articular processes, and in some cases also, because of short pedicles. Recognition of the two types of stenosis thus depends, in part, on proof of involvement of the transverse and sagittal diameters. Clearly it is necessary to have baseline values for use in diagnostic work. Tables giving normal values of the sagittal diameter have been compiled by Huizinga, Heiden & Vinken (1951), Hinck *et al.* (1965), Sand (1970), Eisenstein (1977) and by Larsen & Smith (1981) for groups of Caucasian and South African subjects. Age, racial and ethnic variations in the shape and dimensions of the canal are reported, although Eisenstein (1977) cautions that the racial differences are subtle and probably insignificant.

There appears to be no information on the sagittal diameter of the lumbar vertebral canal of Nigerians. The aim of the present study is primarily, to determine the normal ranges of the sagittal diameters of the lumbar vertebral canal in the Nigerian population, and to find out whether they differ from those of other populations.

MATERIALS AND METHODS

Various techniques have been used in morphometric studies of the vertebral canal, reviewed by Amonoo-Kuofi (1982). The method used in the present study was based on a technique of measuring the diameters of osteological specimens (Jones & Thomson, 1968), subsequently adopted by Eisenstein (1977), which gives accurate and reproducible results. Complete sets of lumbar vertebrae (79 male and 43 female)

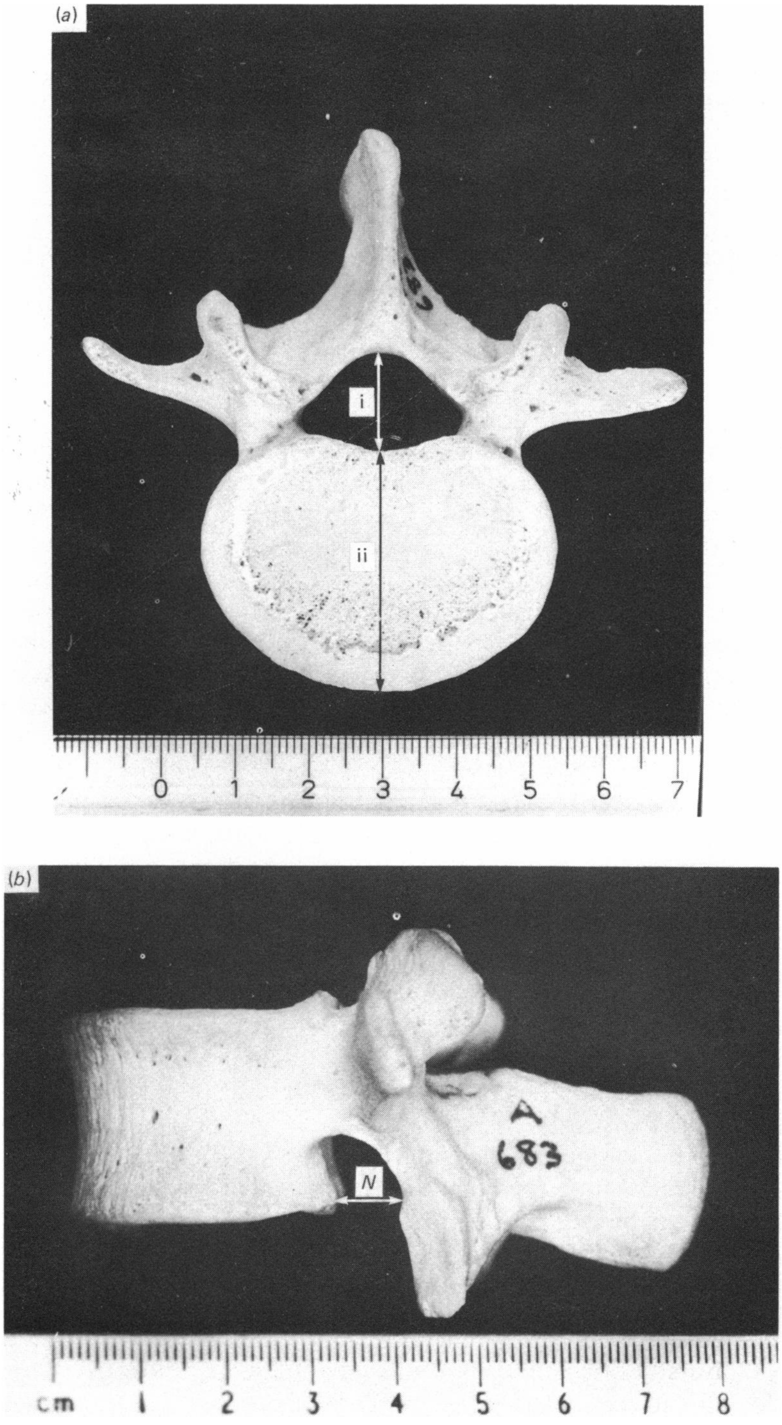

Fig. 1 (*a–b*). (*a*) Photograph of the superior aspect of the third lumbar vertebra showing measurements used to determine the sizes of the lumbar spinal canal and the body. i, midsagittal diameter of the canal; ii, midsagittal diameter of the vertebral body. (*b*) Lateral view of the third lumbar vertebra showing the measurement used to determine the sagittal dimension of the inferior vertebral notch (*N*).

Table 1. *Mean sagittal diameters of the lumbar spinal canal, standard deviations and coefficients of variation in male and female adult Nigerians*

	Males			Females		
	Mean sagittal diameter (mm)	Standard deviation	Coefficient of variation (%)	Mean sàgittal diameter (mm	Standard deviation	Coefficient of variation (%)
L1	16·6	1·0	6·0	15·8	1·2	7·6
L2	15·8	1·0	6·3	15·1	1·1	7·3
L3	14·9	1·0	6·7	14·2	1·1	7·7
L4	15·6	2·0	12·8	14·1	1·3	9·2
L5	16·0	2·4	15·0	14·6	1·2	8·2

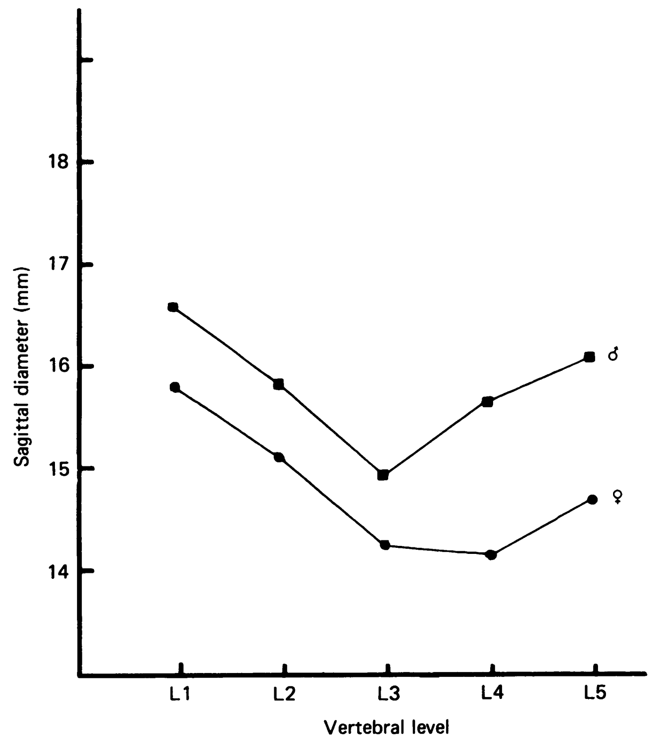

Fig. 2. Mean midsagittal diameters of the lumbar vertebral canal in males (♂) and females (♀).

aged between 23 and 60 years, from the osteological collection of the Department of Anatomy, University of Ibadan, were studied. The full medical histories were not obtained for all subjects but it was ensured as far as possible that material from persons who had died of chronic skeletal disorders or related causes were not included. Care was also taken to exclude specimens showing osteophytes or other evidence of bone disease.

The neural canal of each vertebra was examined and the shapes of the canal, the groove for the spinal nerve and the intervertebral foramen were noted. Direct

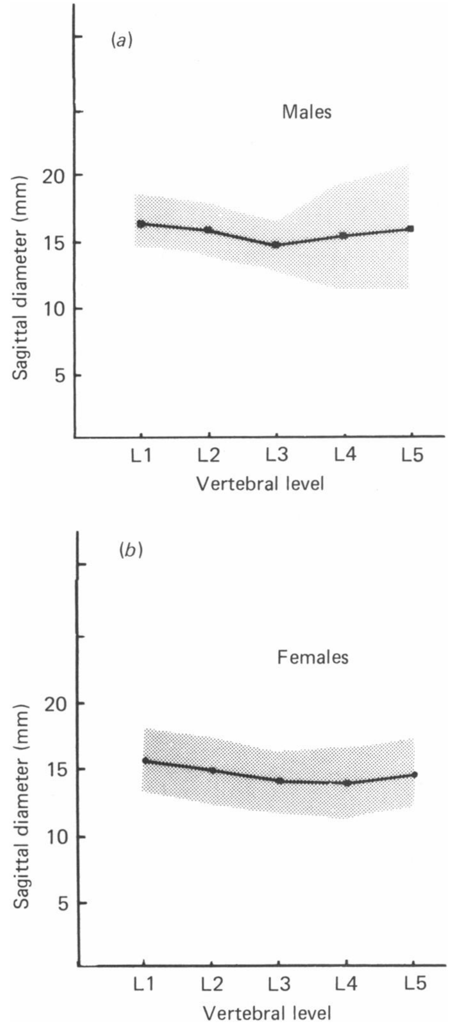

Fig. 3 (*a*–*b*). Maximum and minimum limits (shaded) of lumbar midsagittal diameters in normal adults: (*a*) males; (*b*) females. The solid line represents the mean midsagittal diameter.

measurements of the midsagittal diameter of the canal, the maximum anteroposterior diameter of the vertebral body (Fig. 1 *a*), and the maximum anteroposterior diameter of the inferior vertebral notch (Fig. 1 *b*) were made using a sliding Vernier caliper, and recorded to the nearest tenth of a millimetre. The midsagittal diameter of the canal was measured at the point where the canal was narrowest: near the upper border, at the level of a slight anterior bulge in the deep surface of the posterior wall of the canal. Use of this landmark was found to give reproducible results by Verbiest (1977). The anteroposterior diameter of the vertebral body was measured at mid-waist level where it was narrowest; whilst the maximum anteroposterior diameter of the inferior vertebral notch was taken as the maximum horizontal distance between the posterior surface of the lower part of the vertebral body and the deep surface of the lamina.

Table 2. *Sagittal diameter of each lumbar vertebra in adult males and females*: 95 % *tolerance range*

Level	Male range (mm)	Female range (mm)
L1	14·6–18·6	13·4–18·2
L2	13·8–17·8	12·9–17·2
L3	12·9–16·9	12·0–16·4
L4	11·6–19·6	11·5–16·7
L5	11·2–20·8	12·2–17·0

Table 3. *Comparison between mean measurements of lumbar sagittal diameters* (*in males and females*) *in the present study, and the study of Eisenstein* (1977). *Values are given in millimetres*

	Males			Females		
	Present study (n = 79)	Eisenstein (1977): Zulus (n = 108)	Eisenstein (1977): Sotho (n = 106)	Present study (n = 43)	Eistenstein (1977): Zulus (n = 54)	Eisenstein (1977): Sotho (n = 62)
L1	16·6	16	16	15·8	17	16
L2	15·8	15	15	15·1	16	16
L3	14·9	15	14	14·2	15	15
L4	15·6	15	15	14·1	16	15
L5	16·0	16	16	14·6	16	16

OBSERVATIONS

Midsagittal diameter of the canal

The results of measurements of the midsagittal diameter of the vertebral canal in both males and females are presented in Table 1. The mean values, standard deviations and coefficients of variation were calculated for both sexes. In the male subjects, a steady narrowing of the sagittal diameter from the level of the first lumbar (L1) to the third lumbar (L3) vertebrae was followed by widening at L4 and L5 (Fig. 2). The range of diameters for the female canals followed a similar pattern except that, at all levels, the mean diameters were narrower than in the male and, whereas from L1 to L3 the difference did not exceed 0·8 mm, it was of the order of 1·5 mm at L4 and L5 levels. In both sexes, the midsagittal profile of the vertebral canal was wider at the cephalic end than it was at the caudal end, and showed a midlumbar narrowing. This 'hour-glass' shape of the canal has been observed in other populations. In the present study, the narrowest part of the female canal was at L4. In males and females, the intersegmental difference in midsagittal diameter between L1/L2, L2 and L3 was nearly 1 mm, whilst the difference between L4 and L5 was about 0·5 mm in males and females.

At L1, L2 and L3, the female canal showed slightly more variation as compared to the male canal, perhaps due to greater differences in general somatic size in women; but at L4 and L5 striking variation was noted in the male.

The upper and lower 95 % limits of the normal values were worked out for males and for females (Table 2) using the formula given by Bradford Hill (1977). These ranges, which varied narrowly especially at L4 and L5, are illustrated in Figure 3.

In order to correlate the size of the vertebral canal in this population with those

Table 4. *Ratio of mean sagittal diameter of lumbar spinal canal to the mean anteroposterior (AP) diameter of vertebral bodies in males and females*

	Males			Females		
	Mean sagittal diameter of canal (mm)	Mean AP diameter of body (mm)	Ratio	Mean sagittal diameter of canal (mm)	Mean AP diameter of body (mm)	Ratio
L1	16·6	29·2	0·6	15·8	26·1	0·6
L2	15·8	30·6	0·5	15·1	27·6	0·5
L3	14·9	32·2	0·5	14·2	29·1	0·5
L4	15·6	34·0	0·5	14·1	31·1	0·5
L5	16·0	32·2	0·5	14·6	31·3	0·5

Table 5. *Mean anteroposterior diameters of the inferior vertebral notches, standard deviations and coefficients of variation in males and females*

	Males			Females		
	Mean antero-posterior diameter (mm)	Standard deviation	Coefficient of variation (%)	Mean antero-posterior diameter (mm)	Standard deviation	Coefficient of variation (%)
L1	8·8	1·2	13·6	8·1	0·9	11·1
L2	8·4	1·3	15·5	7·8	0·7	9·0
L3	7·5	1·3	17·3	7·5	1·1	14·7
L4	7·6	1·1	14·5	7·4	1·2	16·2
L5	7·0	0·9	12·9	7·3	1·0	13·7

of other black populations, the mean midsagittal diameters obtained in the present study were compared with those of two different populations of black South Africans studied by Eisenstein (1977). Because Eisenstein's report did not give standard deviations of the diameters from the mean values, firm deductions could not be made. But it was broadly inferred from the data available (Table 3) that the mean midsagittal diameter of the lumbar canal was greater in the Nigerian male subject as compared to the black South African male subject, whilst among females the black South African subjects seemed to have wider mean sagittal diameters.

Canal/body ratio

Theoretically, it was expected that the size of the vertebral body should vary proportionately with the build of the individual. This meant that there would be corresponding variations of the height of the pedicles and the width of the laminae (factors which determine the sagittal diameter of the canal and also of the intervertebral foramen). In order to find out the relationship between the canal and body size, a comparison was made by finding the ratio between the mean sagittal diameter of the canal and the mean anteroposterior diameter of the vertebral body at the various vertebral levels. The results showed that as the size of the vertebral body changed, the sagittal diameter of the canal also varied, maintaining a ratio of 0·6 at L1 and 0·5 at L2, L3, L4 and L5 levels in both sexes (Table 4). This confirmed that

Table 6. *Ratio of anteroposterior diameter of inferior vertebral notch to the anteroposterior diameter of the vertebral body in males and females*

	Males			Females		
	Diameter of inferior vertebral notch (mm)	Diameter of vertebral body (mm)	Ratio	Diameter of inferior vertebral notch (mm)	Diameter of vertebral body (mm)	Ratio
L1	8·8	29·2	0·3	8·1	26·1	0·3
L2	8·4	30·6	0·3	7·8	27·6	0·3
L3	7·6	32·2	0·2	7·5	29·1	0·3
L4	7·5	34·0	0·2	7·4	31·1	0·2
L5	7·0	34·2	0·2	7·3	31·3	0·2

the lumbar canal in this population is more capacious at L1 in both males and females than at lower levels. These ratios could be of practical importance in the clinical appraisal of lateral radiographs of the lumbar spine and in forensic work.

Anteroposterior diameter of the inferior vertebral notch

The inferior vertebral notch forms the cephalic boundary and the anterior and posterior walls of the intervertebral foramen. In isolated vertebrae, therefore, measurements of the maximum horizontal anteroposterior width of the notch could be used as an index to assess the size of the intervertebral foramen. The mean distances measured to the nearest tenth of a millimetre are given in Table 5. It was observed that the inferior vertebral notch showed a slight but steady decrease in diameter in both males and females, with a high degree of variation. The trend of variation in the diameter of the inferior vertebral notch was clearly different from that of the midsagittal diameter of the vertebral canal and yet the height of the pedicle was a common factor to the two parameters. Because of the observed differences in the relationship of the vertebral canal and the inferior vertebral notch to a given pedicle height, an attempt was made to find out whether the inferior vertebral notch bore any fixed relationship to the vertebra, by calculating the ratio between the diameter of the notch and the anteroposterior diameter of the vertebral body (Table 6). It was evident from the results that, in the male subjects, the inferior vertebral notch maintained ratios of 0·3 at L1 and L2 and 0·2 at L3, L4 and L5; the values for females were similar to those of males, differing only at L3, where a ratio of 0·3 was noted.

DISCUSSION

Morphometric studies of the lumbar vertebral canal report age, sex, racial and ethnic differences in the size of the canal (Huizinga *et al.* 1951; Hinck *et al.* 1965, 1966; Eisenstein, 1977; Amonoo-Kuofi, 1982) but, in a recent reappraisal of the sagittal diameter, Larsen & Smith (1981) are unable to confirm the observation of Hinck *et al.* (1965, 1966) that it varies in different age groups. The present results confirm, nevertheless, that there are differences in the size of the adult canal between Nigerian subjects and the sample populations of Hinck *et al.* (1966) and Eisenstein (1977); and it is noteworthy that, in both males and females, there are differences in the shape and size of the canal between the South African black population (Eisenstein, 1977) and the present sample. The 'hour-glass' shape of the sagittal profile of the canal reported by Huizinga *et al.* (1951), Hinck *et al.* (1965), Sand (1970) and Larsen & Smith (1981) is also seen in the Nigerian subjects in whom the narrowest diameter is found at L3 in the male and at L4 in the female.

Comparison of the mean midsagittal diameters obtained in the present study with measurements of two different populations of black South Africans, reported in the osteometric study of Eisenstein (1977), shows that, although the mean diameters of the various groups fall within the same range, they differ in two morphological aspects:

(1) the 'hour-glass' shape of the lumbar canal noted in other studies and confirmed in the present investigation is only vaguely demonstrated in the South African population;

(2) whilst in the Nigerian population the diameters of male canals are larger than female canals, it was noted that among the South African group female canals were wider than male canals. Thus, Nigerian females appear to have markedly narrower lumbar canals than their South African counterparts. The males do not show appreciable differences.

As in the other populations studied, the widest anteroposterior diameter measured in the present study is at L1 level. Davis (1955) notes that in most individuals the first lumbar level coincides with the region of functional transition between the relatively immobile thoracic spine and the mobile lumbar segment. In addition, this level houses the lower end of the lumbar enlargement of the spinal cord and the conus medullaris. Hence, the width of the canal at this level may be a reflection not only of the size of its contents, but also of an adaptation to ensure protection of those contents during complex movements of this transitional region. At this level also, there is a change in the curvature of the spine from the thoracic convexity to the lumbar concavity. The effect is that the lower end of the spinal cord would tend to be displaced dorsally in the erect posture, and therefore the sagittal diameter has to be capacious enough to accommodate it.

At the lower lumbar levels (L4 and L5), there is greater variability than is observed at higher levels, with the male showing a wider spread from the diameter mean than the female. These observations, which confirm the findings of Larsen & Smith (1981), are similar to those reported by Amonoo-Kuofi (1982) on interpedicular distances and suggest that in a few cases the male canal is actually smaller at lower lumbar levels than the female canal. The reason for such wide variations in sagittal diameter especially at the fifth lumbar level is unclear. But since this is the site of the lumbosacral angulation, it is suggested that the tendency for an increase in this dimension at L5 is an adaptation to accommodate the sacral nerve roots; these would bowstring during angular movement between the mobile lumbar segment and the immobile sacrum at the lumbosacral junction.

Intervertebral foramen

Since the height of the pedicle contributes to the sagittal diameters of both the canal and the intervertebral foramen, it is tempting to conclude that, in the normal individual, the sagittal diameter of the intervertebral foramen and of the canal should show the same pattern of variation with given segmental levels. The experience of this study shows that, whilst the maximum sagittal diameter of the intervertebral foramen decreases steadily from L1 to L5, the diameter of the canal presents an 'hour-glass' contour, indicating that other factors, most probably the laminae, play a significant part in determining the dimensions of these two parameters. Verbiest (1977) stated that "developmental stenosis of the lumbar vertebral canal was due to disturbances of growth in the pedicles, laminae and articular processes". The present findings amplify Verbiest's observation, and it may be suggested that the angle of inclination of the lamina, interlaminar angle and differences in thickness of the lamina are probably more important determinants of the sagittal diameter than the height of the pedicle. This would be in accord with the findings of Chynn, Altman, Shaw & Finby (1978) that in spinal stenosis (*a*) there are distinct deviations from normal in the form and orientation of the superior articular process, (*b*) there is overgrowth of the inferior articular process and (*c*) the laminae are bulky.

SUMMARY

An osteometric study of the anteroposterior diameter of the lumbar vertebral canal and intervertebral foramina of normal adult Nigerians is reported. The results show that the midsagittal diameter of the canal is subject to racial variations, and is determined primarily by the thickness and orientation of the lamina and to a lesser extent by the height of the pedicle. The significance of the findings is discussed.

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