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" NORMAL INTERPEDICULATE DISTANCES AND
MID-SAGITTAL DIAMETERS OF THE LUMBAR SPINAL
CANAL IN ADULT KENYAN AFRICANS "

A dissertation submitted in part-fulfilment for the
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BY

DR. MUSHTAQ I. ANWARY
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DECLARATION

CANDIDATE:

This dissertation is my original work and has not been submitted for a degree in any other University.

SIGNED: *M Anwary*
DR. MUSHTAQ I. ANWARY

SUPERVISOR:

This dissertation has been submitted for examination with my approval as the University Supervisor.

SIGNED: *M Wambugu*
DR.(MRS.) M.N. WAMBUGU M.B.Ch.B, M.Med.
Lecturer,
Dept. of Diagnostic Radiology,
University of Nairobi.

(iii)

DEDICATION

To my wife, MUMTAZ
For her patience and understanding
during the preparation of this
dissertation.

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SUMMARY

Interpediculate distances of lumbar spinal canal were measured on normal, plain, antero-posterior radiographs of lumbar spine in 185 male and 185 female adult Kenyan Africans.

Mid-sagittal diameters (Antero-Posterior diameters) of lumbar spinal canal were measured on normal, plain lateral radiographs of the lumbar spine in 180 male and 180 female adult Kenyan Africans.

Mean, standard deviation and 90% tolerance range of interpediculate and mid-sagittal diameters were calculated at each lumbar vertebral body level, in both sexes separately. The results were compared with those of other authors.

A normal range of 17mm to 25mm for mid-sagittal diameter is established in both sexes. A graphic representation of 90% tolerance range of interpediculate distances is given separately for both sexes.

Finally a recommendation is made to use these ranges in the assesement of lumbar spinal canal pathology, especially in cases of suspected spinal canal stenosis.

INTRODUCTION

The purpose of this study is to establish the range of normal values of the lumbar spinal canal mid-sagittal diameters and interpediculate distances in Kenyan, adult male and female Africans in the interest of facilitating investigation of lumbar spinal canal pathology.

The spinal canal is bounded anteriorly, by the vertebral bodies and intervertebral discs backed by the posterior longitudinal ligament. Posterolaterally the canal is formed by the pedicles and laminae lined by the ligamenta-flava. The cross-sectional shape of the canal is triangular at L₅ and roundish to oval at upper lumbar levels (11).

According to the type of pathology, there is either increase or decrease in the canal dimensions. Tumours arising from the spinal cord, the meninges and other space occupying lesions of the spinal cord may cause focal or generalised increase in the canal size, which is assessed by measuring interpediculate distances on a plain radiograph. There may be other radiological changes on plain radiographs, which include:-

- (a) Flattening of the medial surface of the pedicles.
- (b) Enlarged intervertebral foramina.
- (c) Flattening or scalloping of the posterior surface of the vertebral bodies.
- (d) Calcification within the canal.

Lumbar spinal canal stenosis is a disorder where narrowing of the spinal canal occurs. The narrowing may be either of interpediculate distance and mid-sagittal diameter or the latter alone. The following changes may be seen on plain radiographs.

- (a) Short pedicles - resulting in reduction of mid-sagittal diameter and narrowing of intervertebral foramina.
- (b) Reduced interpediculate distances.
- (c) More vertically oriented laminae with narrowing of interlaminar space.
- (d) Posterior intervertebral joints lie close to the mid-line than normal, which can be seen on an antero-posterior view.

These radiological changes are subjective and hence actual measurements of mid-sagittal diameter and interpediculate distances on plain radiographs is an accurate method to assess the narrowing of the canal.

In this study greater emphasis will be given to developmental lumbar spinal canal stenosis, because of the difficulties that arise in its diagnosis by the normal appearance of the vertebrae.

Clinically, lumbar spinal canal stenosis may present with either claudication or sciatica, (8). In the former type

the patient experiences paraesthesia and eventual numbness in one or both legs after walking a certain distance. This may be associated with low back ache and unsteady gait. The symptoms are relieved by sitting down or flexing the spine. The patient with sciatica gives a long history of back ache then describes a more recent onset of leg pain which may be associated with paraesthesia and numbness usually confined to one side only and brought on by walking and running. These symptoms are relieved by crouching and lying down. In both these presentations the peripheral pulses are normal, differentiating them from vascular claudication.

To understand and assess lumbar spinal canal stenosis various authors carried out different studies. Measurements of interpediculate distances and mid-sagittal diameters were carried out in skeletons (3,6), on plain radiographs (4,5) and computed tomograms (9,12).

Measurements of these two dimensions were carried out in skeletons of South African caucasoids and negroids (3) and it was found that the spinal canal in the negroids was marginally less capacious than in the caucasoids.

At the moment, the normal ranges of interpediculate distances and mid-sagittal diameters, obtained in caucasoids are being used to assess lumbar canal size in Kenyan Africans. Since the lumbar canal in negroids is smaller than in caucasoids (3),

it was found necessary to obtain normal ranges for Kenyan Africans.

Measurements of these two dimensions of lumbar canal have been measured in North American caucasoids on plain radiographs (4,5). To assess the relative size of lumbar spinal canal on plain radiographs, a method was described by Jones and Thompson (7). They measured mid-sagittal diameter and interpediculate distance on plain radiographs and related the product of these two to the product of antero-posterior and transverse diameters of the vertebral body at that level. A ratio of 1:2 represented a large normal canal and a ratio of 1:4:5 meant a small normal canal. But this method was found unreliable by other authors (9,3).

Computed tomography has been used to assess the lumbar canal size. In a study carried out in sixty adult patients (thirty males and thirty females), values of 16mm and 11.5mm for interpediculate distances and mid-sagittal diameters respectively were considered small (12). In another study computed tomography was performed on twenty one normal subjects (eleven males and ten females) and a range of 19 to 27mm was found for the interpediculate distances. The mid-sagittal diameters measured 13.8 to 20.4mm at L1 and L5, and 13.4 to 18.5mm at L2 to L4. In the same study, either

mid-sagittal diameter or both mid-sagittal diameter and interpediculate distances were found to be reduced in stenotic patients

In an extensive study, two thousand myelogram were performed over a period of three years, during which thirty three patients were diagnosed to have lumbar spinal canal stenosis (10). The authors retrospectively evaluated lower three lumbar vertebra of these patients and found that eighteen patients had antero-posterior diameter less than 15mm and 80% had narrow interpediculate distances (using 16mm and 25mm as lower limits of normal for mid-sagittal diameter and interpediculate distance respectively.

Now it has become quite clear that the knowledge of normal range of values of mid-sagittal diameters and interpediculate distances is important in the assessment of lumbar spinal canal pathology, especially lumbar spinal canal stenosis.

CASE MATERIAL AND METHOD

Antero-posterior and lateral radiographs of lumbar spine were obtained from the filing section of department of diagnostic radiology at Kenyatta National Hospital, Nairobi. The radiographs were taken using standard techniques (1). A focus to film distance of 36" is used as a routine for both the projections. The peak kilovoltage used for antero-posterior and lateral views are 70 to 90 respectively, and the milliampere seconds used for these two views are 80 and 100 respectively with slight variation depending on the patients size.

The radiographs were first screened for readability to avoid poor interpretation of the anatomical landmarks. Subjects with spinal anomalies, degenerative changes, spondylolisthesis, bony metastases and other lesions which would distort or mask radiological anatomy were excluded from the study. This selection of radiologically normal subjects assisted in reducing the bias introduced by the use of hospital population. Since the results obtained from this study were expected to be used for routine screening of plain radiographs, no attempt is made to correct the magnification.

Mid-sagittal diameters were measured in 180 male and 180 female subjects. The interpediculate distances were measured in 185 male and 185 female subjects. All the subjects were Kenyan Africans, above the age of eighteen years and measurements

were done at all the lumbar vertebral body levels, using Vernier callipers in millimeters to the first decimal point. To keep the readers error constant, measurements were carried out by the author alone. Since the diameters measured were small and needed meticulous concentration, the measurements were carried out over several days to reduce error due to fatigue.

The mid-sagittal diameter is the shortest mid-line, perpendicular distance from the posterior surface of the vertebral body to the inner surface of the neural arch (Fig. 1)(4). The shortest distance between the medial surfaces of the pedicles is the interpediculate distance (Fig. 2)(5).

The means, standard deviation and 90% tolerance range were calculated, seperately for both sexes (2). 90% tolerance range is that range in which 90% of the remaining 10% will have higher values than the upper limit of tolerance range, and the rest 5% will have lower values than the lower limit of the tolerance range.



FIGURE 1

The mid-sagittal diameters were measured from point A to point B, as shown in the picture, at all the lumbar vertebrae.



FIGURE II

The interpediculate distances measured from point C to point D, as shown in the photograph, at all the lumbar vertebrae.

RESULTS

The results of this study are presented in the form of tables (Tables 1 to 4) and graphs (Figures I to VI), which are explained in the following paragraphs. Tables 5 to 10 are the results of other authors included here for the purpose of comparison.

Mid-sagittal diameters: (Table 1 and 2)

The maximum mean mid-sagittal diameter in both sexes is found to be at L5. It is 21.6mm in males and 21.2mm in females. The highest value of upper limit of 90% tolerance is also found at this level for both sexes and is 24mm.

The minimum mean mid-sagittal diameter in both sexes is found at L3 and is 20.4mm in males and 19.9mm in females. The lower limit of 90% tolerance range at this level is also smallest, compared with at the other levels. In the males this is 18.0mm and in females 17.8mm.

The coefficient of variations is 6% in males and 5.4% to 7.2% in females. This means that standard deviation is at the most 5.4% to 7.2% of mean, and hence the measurements obtained in this study are fairly homogeneous.

Graphs of mid-sagittal diameter means, upper and lower limits of 90% tolerance limits are drawn against vertebral body levels. (Fig III, Fig. IV).

Interpediculate Distances: (Table 3 and 4)

The mean interpediculate distance at L1 is found to be smallest in both the sexes. The mean values gradually increase from L1 to L5 and the maximum value is at L5. The increments from L1 to L2; L2 to L3 and so on also increase as the level of the vertebrae increases. So the minimum increment is seen from L1 to L2 which is 0.9mm and maximum from L4 to L5 which is 3.0mm.

The lower limit of 90% tolerance range is smallest at L1 and is 21.3mm in males and 20.5 in females. The upper limit of 90% tolerance range is highest at L5 and is 34.5mm and 33.3mm in males and females respectively.

As the means rise, the standard deviation also shows a rise from L1 to L5, more so in males. The coefficient of variation ranges from 5.7% to 7.0%, suggesting small variation of values around the mean. Thus the measurements obtained in this study are fairly homogenous.

Graphs of mean interpediculate distances, upper and lower limits of 90% tolerance are drawn against the lumbar vertebral body levels. (Figure V, Fig VI).

TABLE 1

MID SAGITTAL DIAMETERS IN MALES			
Level	Mean (mm)	S.D* (mm)	90% Tolerance Range (mm)
L1	21.3	1.3	19.0-23.6
L2	20.8	1.3	18.5-23.0
L3	20.4	1.31	18.0-22.7
L4	20.9	1.44	18.4-23.4
L5	21.6	1.45	19.0-24.0

*S.D = Standard deviation

TABLE 2

MID SAGITTAL DIAMETERS IN FEMALES			
Level	Mean (mm)	S.D (mm)	90% Tolerance Range (mm)
L1	20.9	1.2	18.8-23.0
L2	20.4	1.1	18.5-22.3
L3	19.9	1.2	17.8-22.0
L4	20.6	1.49	18.0-23.2
L5	21.2	1.53	18.5-24.0

TABLE 3

INTERPEDICULATE DISTANCES IN MALES			
Level	Mean (mm)	S.D. (mm)	90% Tolerance Range (mm)
L1	24.1	1.6	21.3-27.0
L2	25.0	1.66	22.0-28.0
L3	26.3	1.70	23.3-29.3
L4	28.0	2.0	24.5-31.5
L5	31.0	2.0	27.5-34.5

TABLE 4

INTERPEDICULATE DISTANCES IN FEMALES			
Level	Mean (mm)	S.D. (mm)	90% Tolerance Range (mm)
L1	23.2	1.48	20.5-25.8
L2	24.0	1.67	21.0-27.0
L3	25.3	1.50	22.7-28.0
L4	27.0	1.56	24.3-29.7
L5	30.0	1.88	26.7-33.3

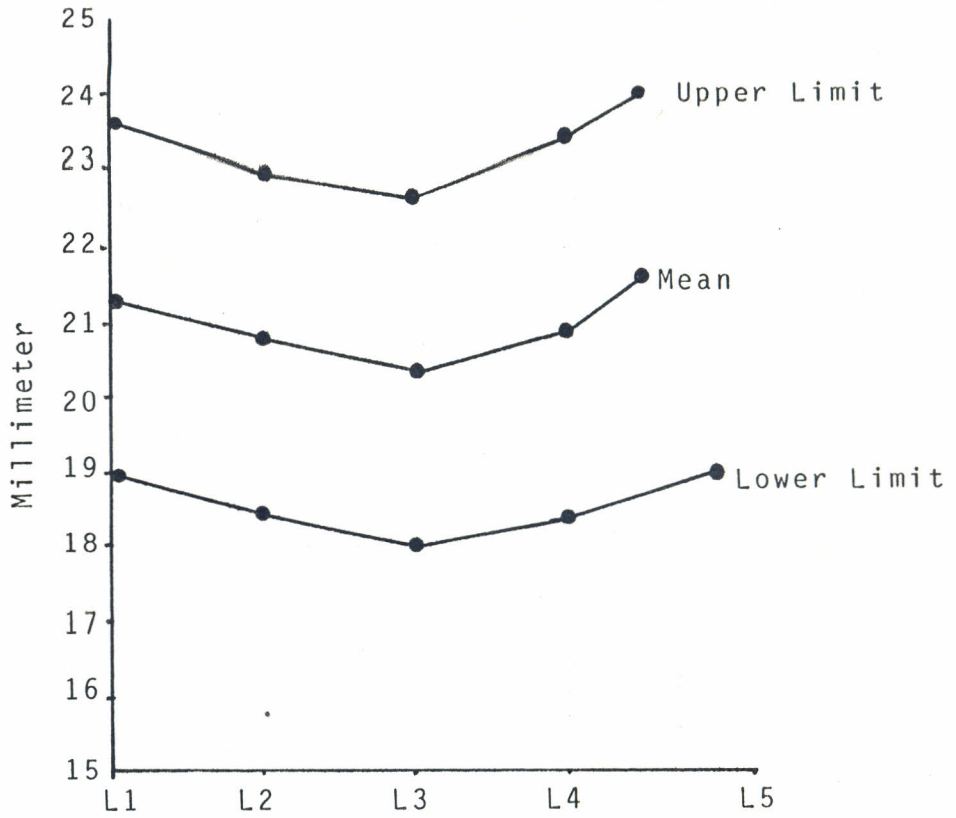


FIG. III

Mean, upper and lower limits of 90% Tolerance range of Mid-sagittal diameters in males.

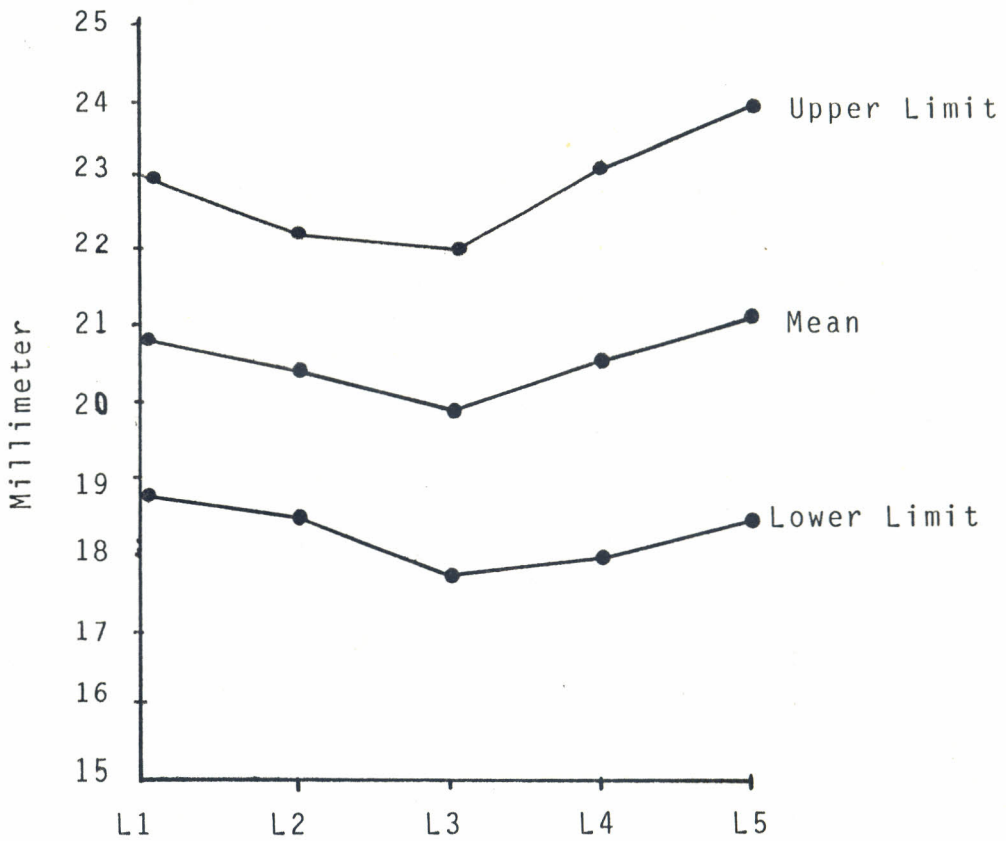


FIG. IV

Mean, upper and lower limits of 90% tolerance range of mid-sagittal diameters in females.

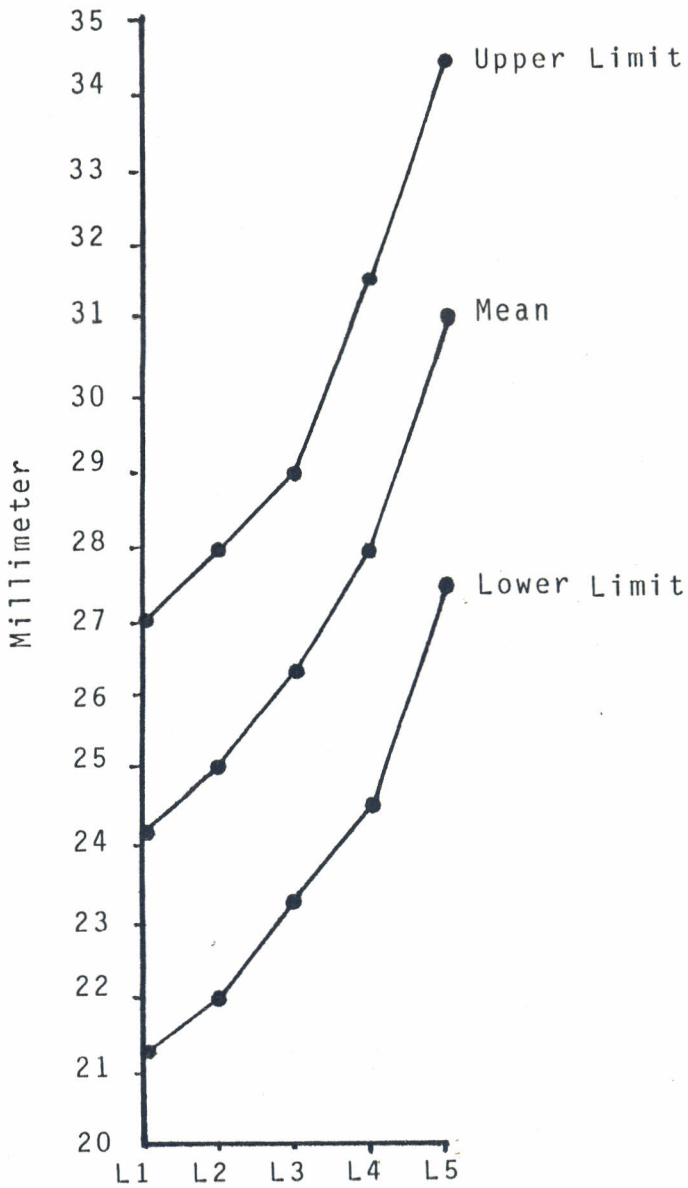


FIG V
Mean, upper and lower limits of 90%
Tolerance range of interpediculate
distances in males.

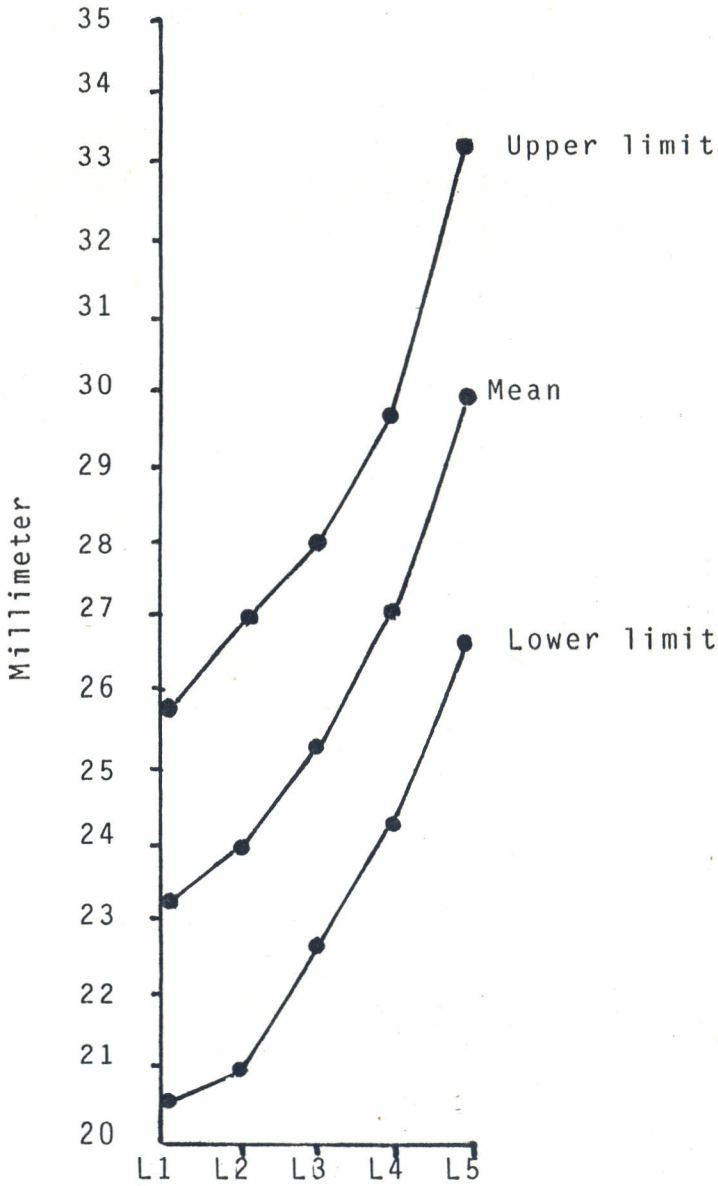


FIG VI

Mean, upper and lower limits of 90% Tolerance range of Interpediculate Distances in females.

TABLE 5

MID SAGITTAL DIAMETERS (Hinck et al) (4)					
Level	Male Mean (mm)	Female Mean (mm)	Male S.D. (mm)	Female S.D. (mm)	Combined 90% 90% Tolerance Range (mm)
L2	22.2	21.3	3.1	2.3	16-27
L2	22.3	21.2	2.7	2.1	16-27
L3	21.7	21.3	2.6	2.1	17-26
L4	21.8	21.3	2.4	1.9	17-26
L5	22.6	20.4	2.4	2.4	16-27

TABLE 6

INTERPEDICULATE DISTANCES (Hinck et al) (15)				
Level	Male Mean (mm)	Female Mean (mm)	Combined S.D. (mm)	Combined 90% Tolerance Range (mm)
L1	25.9	24.3	2.2	21-29
L2	26.5	24.9	2.3	21-30
L3	26.8	25.4	2.7	21-31
L4	27.6	26.4	3.0	21-33
L5	30.7	29.0	3.7	23-37

TABLE 7

INTERPEDICULATE DISTANCES IN SKELETON (S.EISENSTEIN) (3)						
Level	ZULU		SOTHO		CAUCASOID	
	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
L1	21	20	21	20	23	22
L2	22	21	21	20	24	22
L3	22	21	22	21	23	23
L4	23	22	23	22	24	23
L5	26	24	25	24	26	25

TABLE 8

MID-SAGITTAL DIAMETERS IN SKELETONS (S.EISENSTEIN) (3)						
Level	ZULU		SOTHO		CAUCASOID	
	Male (mm)	Female (mm)	Male (mm)	Female (mm)	Male (mm)	Female (mm)
L1	16	17	16	16	18	18
L2	15	16	15	16	17	17
L3	15	15	14	15	16	17
L4	15	16	15	15	16	16
L5	16	16	16	16	18	18

TABLE 9

* I.P.D. IN SKELETON (HUIZINGA ET AL) (6)			
Level	Mean (mm)	Longest (mm)	Shortest (mm)
L1	23.4	28	19
L2	23.4	26	20
L3	23.5	28	20
L4	23.5	29	19
L5	23.8	32	20

*I.P.D.= Interpediculate Distances

TABLE 10

MID-SAGITTAL DIAMETERS (HUIZINGA ET AL) (6)		
Level	Normal Maximum (mm)	Normal Minimum (mm)
L1	22	14
L2	20	13
L3	27	12
L4	22	11
L5	22	12

DISCUSSION

Mid-sagittal Diameters:-

The mean minimum and maximum mid-sagittal diameters in both sexes are found at L3 and L5 respectively. The difference in values between L5 and L3 is 1.2mm in males and 1.3mm in females. The increase or decrease in mean at two adjacent vertebral levels is no greater than 0.7mm. The greatest difference between the means across the sex was no greater than 0.5mm at any level.

Now it is clear that the difference in mean mid-sagittal diameter at different levels in a subject are not high especially so between two adjacent mid-sagittal diameters. If one or two adjacent mid-sagittal diameters show a sudden increase or decrease in size, relative to the diameters at the rest of the lumbar levels and still be within normal range, then these should be viewed with suspicion.

Since the variation in size of the mid-sagittal diameters in the same person and across the sex are not significantly big, a common upper and lower limit of normal can be set for both sexes. With this in mind a 90% tolerance range of 17.8mm to 24mm is set for both sexes. But a further 5% of normal subjects will have values higher and another 5% lower than this range. Thus as a general rule for both

sexes, values greater than 25mm and less than 17mm should be viewed with suspicion.

In a similar study (4) carried out in North American caucasoid children and adults, an all age, all sex normal range of 15mm to 25mm was suggested. The upper limit of 25mm coincides with the upper limit in this study, whereas the lower limit of 15mm is smaller by 2mm. It is probably due to a bigger sample size, small interperson variation and non-inclusion of children in this study.

In comparing the results of these two studies, it is also found that the mean mid-sagittal diameter in Kenyan Africans are generally smaller than in the North American caucasoids (Table 5). This racial variation was also observed in another study (3) where mid-sagittal diameters were fractionally smaller in South African negroids than in caucasoids.

The fact that mid-sagittal diameters are smaller in females than in males is confirmed in other studies as well, which were carried out on plain radiographs (4) and in skeletons (3). This observation is true in negroids as well as caucasoids.

Interpediculate Diameters:-

The mean interpediculate distances in the males are greater than in the females at all the levels, although the differences at any level are not greater than 1mm. Other authors who carried out measurements of interpediculate distances, on plain radiographs of North American caucasoids (5), and on skeletons of South African caucasoids and negroids (3), had also found this dimension to be smaller in females than in males.

The mean interpediculate distances from L1 to L3 in North American caucasoids are found to be greater but are smaller at L4 and L5, than in Kenyan Africans (Compare Table 3,4 and 6). This fact was not observed by Eisenstein (3), who found a generally smaller canal in South African negroids in comparison to the caucasoids. This probably would mean that the South African negroids are racially distinct from the Kenyan Africans. To confirm this, measurements of interpediculate distances and mid-sagittal diameters will have to be carried out in the skeletons of Kenyan African and of course other anthropometric studies will have to be done as well.

Since the upper and lower limits of 90% tolerance range vary greatly from L1 (21.3mm to 27mm) to L5 (27.5mm to 34.5mm) in males, and in females from L1 (20.5mm to 25.8mm) to L5 (26.7mm to 33.3mm), no absolute values can be assigned for upper and lower limits of normal range to the lumbar

spine as a whole. And hence a graph of mean, upper and lower limits of 90% tolerance range (Fig V, Fig VI) is prepared which is more accurate than postulating an approximate range of upper and lower limits. The interpretation of the graphs is easy. Interpediculate distances falling above or below the normal range should be viewed with suspicion. There may be other values which would show a sudden upward or downward shift from the normal shape of the curve, (although these values may be well within the normal range) and these should be viewed with suspicion. Similar graphs have been presented to assess the mid-sagittal diameters (Fig III, Fig IV), and can be used with the help of general guidelines mentioned above.

So far the two dimensions of the lumbar spinal canal have been discussed separately for better understanding. Now these will be briefly discussed together. With tumours of the spinal cord, meninges and other expansile lesions of spinal cord, it is the widening of the interpediculate distances which is commonly seen than an increase in mid-sagittal diameter on plain radiographs. This probably is due to better visualisation of pedicles than the rest of the neural arch on plain radiographs.

In lumbar spinal canal stenosis narrowing of the mid-sagittal diameter is more frequent than the narrowing of the interpediculate distances (3,12), although these may co-exist. But absence of narrowing or widening of these dimensions

does not rule pathology. The pathology may exist in the soft tissues of the spinal canal. Stenosis of canal may get complicated by the thickening of the laminae and the ligamentum flava or by a disc protrusion. This goes to suggest that depending on patient's symptoms and clinical presentation other radiological investigation such as computed tomography and radiculography may have to be carried out.

Now that it has been shown in this study that the two dimensions of the lumbar spinal canal are different in the caucasoids than in the Kenyan Africans, a normal range of interpediculate distances and mid-sagittal diameters could be established in the latter on computed tomography, and compared with those of other authors.

CONCLUSION

- (1) The mid-sagittal diameters in Kenyan Africans are generally smaller than in the North American caucasoids.
- (2) The interpediculate distances in the Kenyan Africans are smaller at L1, L2 and L3, and bigger at L4 and L5, than in the North American caucasoids.
- (3) The mean mid-sagittal diameters and interpediculate distances in the Kenyan males are greater than in the females, a fact which was observed by other authors as well (3,4,5).
- (4) The upper and lower limits of normal range of 25mm and 17mm respectively is established for the mid-sagittal diameters in both sexes.

RECOMMENDATIONS

- (1) The routine use of upper and lower limits of mid-sagittal diameters, and graphs of 90% tolerance range for interpediculate distances and mid-sagittal diameters as shown in this study, for the assessment of lumbar spinal canal pathology in Kenyan Africans.
- (2) To carry out a study in stenotic patients and measure the interpediculate distances and mid-sagittal diameters on plain radiographs and compare these with the lower limits of normals found in this study.
- (3) To obtain a normal range for these two dimensions on computed tomography.
- (4) To measure interpediculate distances and mid-sagittal diameters in the skeletons so as to compare with other studies.
- (5) To carry out anthropometric studies in Kenyan Africans and South African negroids to determine racial differences between the two groups.

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