A MORPHOMETRIC STUDY OF THE LUMBAR SPINE IN ASYMPTOMATIC SUBJECTS IN SULAIMANI CITY BY MAGNETIC RESONANCE IMAGING

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ABSTRACT

Background

There are no available local data regarding normal dimensions of the lumbar spine. MRI (Magnetic Resonance Imaging) is a useful imaging method for the evaluation of spinal anatomy.

Objective

To evaluate normal dimensions of spinal canal, vertebral bodies and intervertebral discs.

Methods

This study was carried out on a total of 106 asymptomatic healthy Kurdish volunteers using a 1.5 Tesla MRI system in the imaging centre of Sulaimani Teaching Hospital.

Results

The mean midsagittal diameters of the lumbar bony spinal canal were 16.59 mm, 15.53 mm, 14.88 mm, 15.04 mm and 15.95 mm respectively. The mean intervertebral disc heights were 8.37 mm, 9.64 mm, 10.71 mm, 11.44 mm and 10.56 mm respectively.

Conclusion

The midsagittal spinal canal diameter is larger than that reported by other researchers in the neighboring countries.

***Keywords*:** *Lumbar Vertebrae, Spinal canal, MRI*

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INTRODUCTION

The definition of normal values is a prerequisite for the reliable evaluation of abnormality in the lumbar spine, such as spinal canal stenosis [(1)]. The values of normal midsagittal diameters of the lumbar spinal canal are different at various levels of the lumbar spinal canal in individuals of the same race and differ at identical levels in individuals of various races [(2)].

A number of authors had discussed methods of measuring the spinal canal [(3)]. In this study, an attempt has been made to establish the range of dimensions of lumbar spinal canal in Sulaimani populations on mid-sagittal MRI scans. In addition, height of intervertebral discs, and height and width of vertebral bodies were measured.

The mechanical properties of the intervertebral discs largely determine the mode and amount of transmission of forces from one vertebra to another [(4, 5)]. The integrity and the functional efficiency of the disc in turn depend on the biochemical and histological composition of both the annulus fibrosus and nucleus pulposus. Impairment of the mechanical properties of the disc is known to predispose to low back pain [(6, 7)].

PATIENTS AND METHODS

This is a cross-sectional study which was carried out in the MRI (Magnetic Resonance Imaging) unit of the imagiung center of Sulaimani Teaching Hospital. A random sample of 106 volunteers were chosen for this study, who underwent MRI examination of lumbar spine, from March 3, 2009 to July 23, 2009; their age was 19-67 years (the mean age was 32.83 ± 9.69 years), their body weight was 47-93 kg (the mean body weight was 68.85 ± 10.45 kg) and their height was 149-190 cm (the mean height was 166.71 ± 10.71 cm). The subjects consisted of 56 males and 50 females.

They were all asymptomatic volunteers. None of them had low back pain at the time of the present study, nor had any relevant history of chronic back pain with no past history of spinal operation or spinal injury. Volunteers were excluded from the study if they had significant backache that had necessitated an absence from work or had sciatica or if walking induced pain or sensory deficits distal to the knee.

The MRI machine used was Siemens MAGNETOM, Symphony Version Syngo MR 2004A 1.5 Tesla (Fig. 1). The usual imaging sequences were: **Sagittal T2- weighted images** {with a long repetition time (TR: 4000 ms), long echo time (TE: 116 ms), Fov read 310 mm and Fov phase 100%} and **Sagittal T2- weighted myelogram** {with a long repetition time (TR: 8000 ms), long echo time (TE: 1200 ms), Fov read 310 mm and Fov phase 100 %.}.

Distances and diameters were measured in millimeters using the software that accompanies the MRI system. Measurements were done at the midsagittal T2-weighted image which was identified when the tips of the spinous processes were seen as follows:

1. Midsagittal diameter of the lumbar spinal canal (bony canal): from the midpoint of the posterior border of the vertebral body (identified by the point of exit of the basivertebral vein) to the most anterior part of the spinous process (Fig. 2).
2. Mid-height of the vertebral body: between the mid points of the upper and lower vertebral end-plates (Fig. 3).
3. Antero-posterior diameter or width of the vertebral body: taken as greatest mid-waist distance, between mid points of anterior and posterior borders of the vertebral bodies (Fig 3).4.
4. Mid-height of the intervertebral discs: taken as the mid-height, between the mid points of the adjacent vertebral end plates (Fig. 4).

Statistical analysis was carried out using the SPSS for windows software program, version 15.0. Descriptive statistical analysis was done for all data including mean and standard deviation. Student's t-test was used to evaluate the differences between male and female measurements. A P value < 0.05 was considered significant.

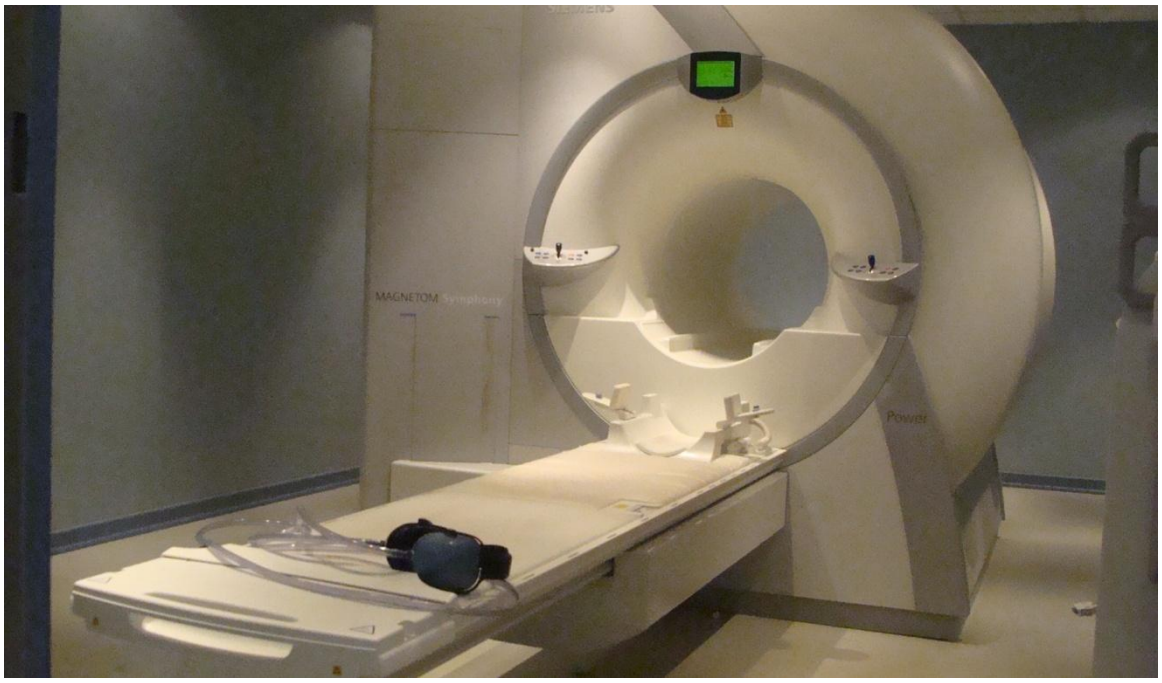

Figure 1. The MRI machine used to perform the study.

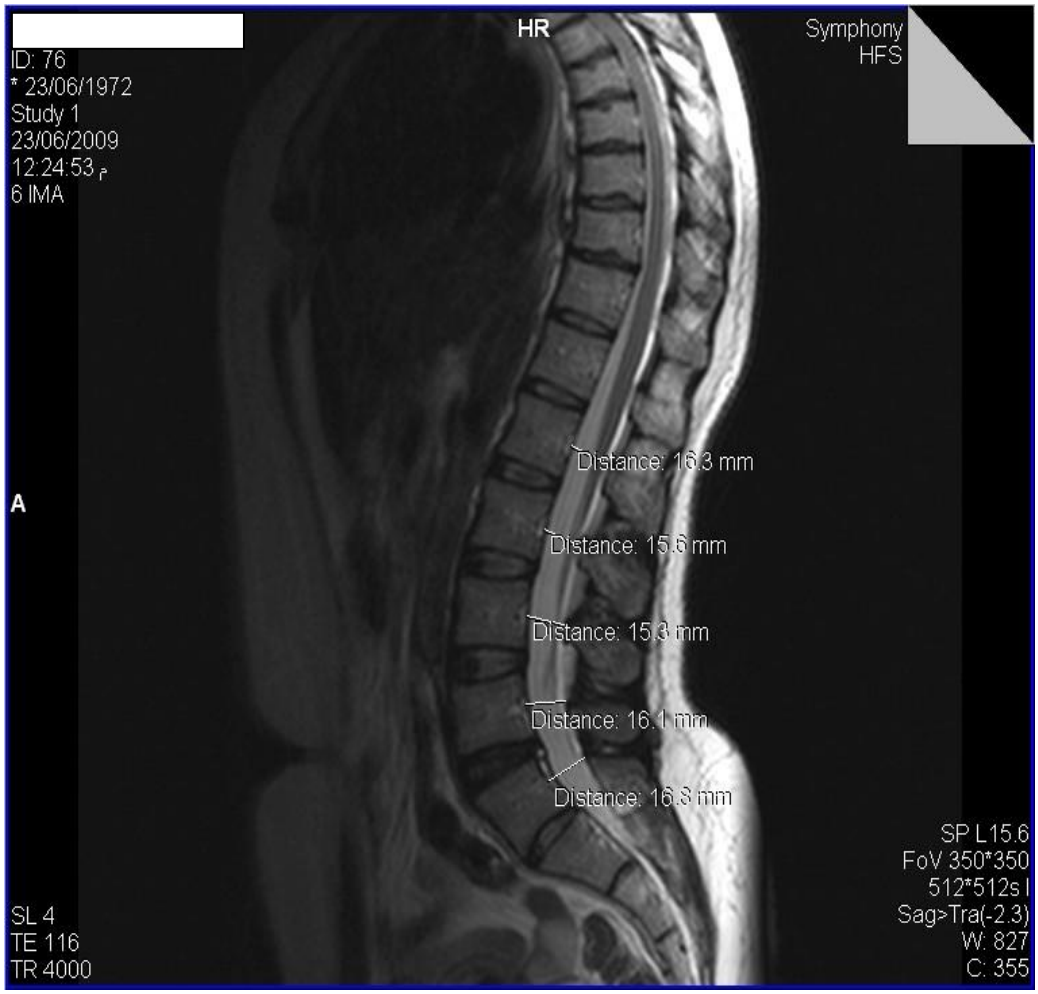

Figure 2. Method of measuring midsagittal diameter of the bony spinal canal.

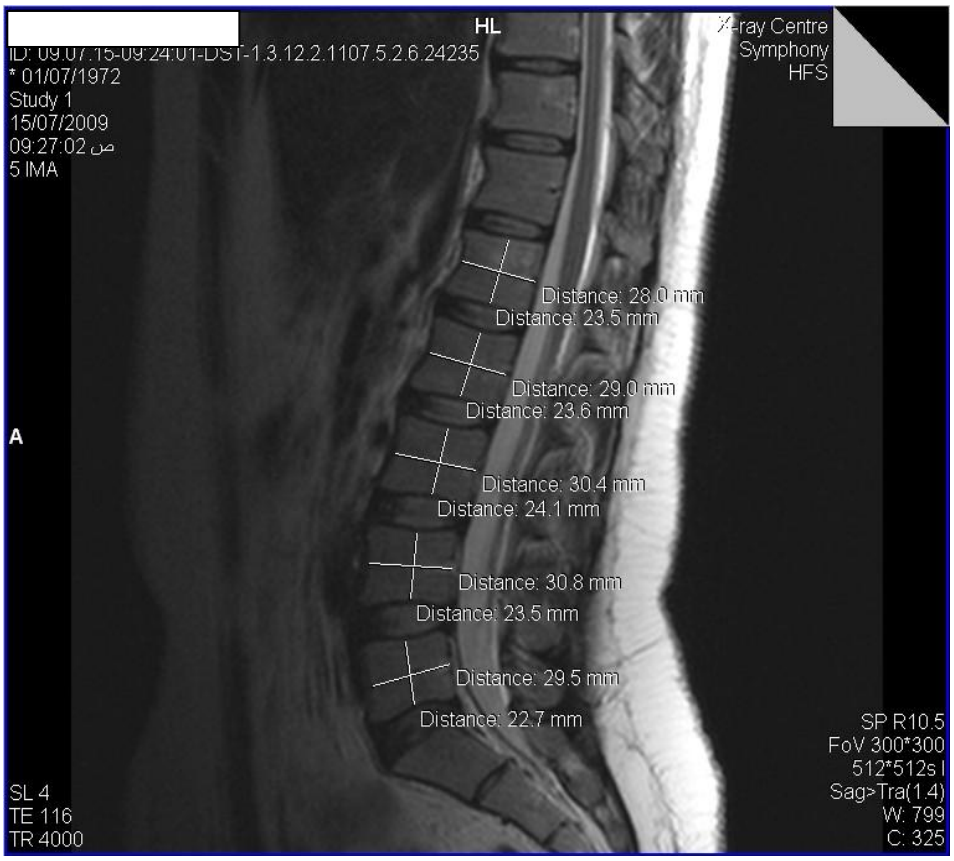

Figure 3. Method of measuring height and width of the vertebral bodies.

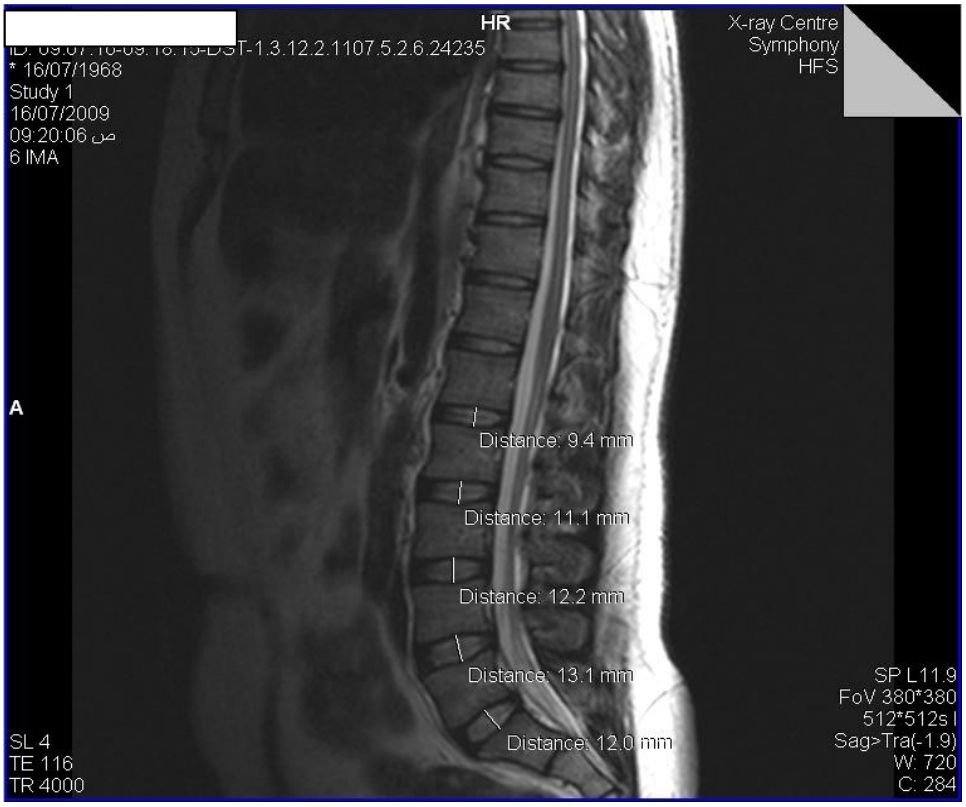

Figure 4. Method of measuring height of the intervertebral discs.

RESULTS

The overall mean midsagittal diameter of bony spinal canal was 15.60 ± 1.20 mm (SD) in the total sample of the subjects. The results of the measurements at all levels are shown in table (1).

The mean vertebral body height was found to be the largest at the level of L3 vertebra in both sexes. The results of the measurements at all lumbar levels are shown in table (2).

In both sexes, the mean antero-posterior width of the vertebral bodies was the largest at the level of L4 vertebra. The results of the measurements at all lumbar levels are shown in table (3).

The mean intervertebral disc height was found to be the largest at the level of L4-L5 disc in both genders. The results of the measurements at all disc levels are shown in table (4).

There was no significant gender difference about measurements of the spinal canal and height of the discs at most vertebral levels. However, the difference between male and female measurements regarding height and width of the vertebral bodies was significant at all levels (male values being larger at all levels).

Table 1. Measurements of the bony spinal canal in mm (millimeter).

Spinal bony canal (SBC)	L1		L2		L3		L4		L5	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total sample	**16.59**	**1.32**	**15.53**	**1.19**	**14.88**	**1.11**	**15.04**	**1.44**	**15.95**	**1.86**
Male subjects	**16.73**	**1.27**	**15.61**	**1.22**	**14.89**	**1.12**	**15.17**	**1.54**	**16.45**	**1.77**
Female subjects	**16.44**	**1.37**	**15.45**	**1.16**	**14.87**	**1.11**	**14.89**	**1.31**	**15.40**	**1.82**

Table 2. Measurements of the vertebral body height in mm.

Vertebral body height (VBH)	L1		L2		L3		L4		L5	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total sample	**22.24**	**1.85**	**22.63**	**1.83**	**22.65**	**1.83**	**22.15**	**1.85**	**21.35**	**1.79**
Male subjects	**23.39**	**1.40**	**23.48**	**1.71**	**23.46**	**1.73**	**22.96**	**1.78**	**22.04**	**1.78**
Female subjects	**20.96**	**1.40**	**21.67**	**1.44**	**21.74**	**1.49**	**21.24**	**1.48**	**20.57**	**1.46**

Table 3. Measurements of the vertebral body width in mm.

Vertebral body width (VBW)	L1		L2		L3		L4		L5	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total sample	**26.69**	**3.22**	**28.37**	**3.21**	**29.77**	**3.08**	**30.00**	**2.45**	**29.15**	**2.32**
Male subjects	**28.59**	**2.50**	**30.33**	**2.44**	**31.39**	**2.81**	**31.44**	**1.85**	**30.33**	**1.96**
Female subjects	**24.57**	**2.53**	**26.18**	**2.47**	**27.97**	**2.27**	**28.37**	**1.99**	**27.82**	**1.97**

Table 4. Measurements of the intervertebral disc height in mm.

Inter-vertebral disc height (DH)	L1-L2		L2-L3		L3-L4		L4-L5		L5-S1	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total sample	**8.37**	**1.10**	**9.64**	**1.44**	**10.71**	**1.40**	**11.44**	**1.49**	**10.56**	**1.65**
Male subjects	**8.56**	**1.06**	**10.03**	**1.46**	**10.96**	**1.48**	**11.49**	**1.52**	**10.50**	**1.59**
Female subjects	**8.15**	**1.11**	**9.20**	**1.30**	**10.43**	**1.25**	**11.39**	**1.46**	**10.62**	**1.72**

Table 5. Comparison between mean bony spinal canal measurements from the present study and previous studies, (A) performed by MRI, (B) performed directly from cadavers

	Vertebral level	Ulmer *et al.* (1994)	Malas *et al.* (1997)	Shukri (2002)	Jahangir *et al.* (2003)	This study (2009)
(A)	**L1**	17 ± 1.5	14.84 ± 1.24	15.08	16.5 ± 1.7	16.59 ± 1.32
	L2	16 ± 1.5	13.72 ± 1.43	—	16.2 ± 1.5	15.53 ± 1.19
	L3	16 ± 1.6	13.42 ± 1.65	13.98	16.2 ± 1.4	14.78 ± 1.11
	L4	16 ± 2.3	13.41 ± 1.63	—	16.0 ± 1.4	15.04 ± 1.44
	L5	17 ± 2.0	13.52 ± 1.61	13.51	16.1 ± 1.5	15.95 ± 1.86

	Vertebral level	Amonoo-Kuofi (1985)		Maqbool *et al.* (1997)		This study (2009)	
		Male	Female	Male	Female	Male	Female
(B)	L1	16.6±1.0	15.8±1.2	16.2±1.2	15.3±1.1	16.73±1.27	16.44±1.37
	L2	15.8±1.0	15.1±1.1	15.1±1.2	14.4±1.2	15.61±1.22	15.45±1.16
	L3	14.9±1.0	14.2±1.1	14.6±1.3	13.7±1.1	14.89±1.12	14.87±1.11
	L4	15.6±2.0	14.1±1.3	14.9±2.0	13.6±1.3	15.17±1.54	14.89±1.31
	L5	16.0±2.4	14.6±1.2	15.3±2.3	14.1±1.5	16.45±1.77	15.40±1.82

DISCUSSION

MR image interpretation is becoming a necessary knowledge for all physicians; this is because of the importance and accuracy of this type of examination.

It was necessary to concentrate this study on the measurements of diameter of the lumbar spinal canal, since it was found that previous researchers, who gave figures for the measurements of the midsagittal diameter of the lumbar spinal canal, avoided defining the precise locations and plains of their measurements in the lumbar bony spinal canal. In fact, most of them depended on the measurements given by Ullrich *et al*. [8] and Nagler and Hausan [9] who found that the normal adult sagittal diameter of the lumbar spinal canal ranges from 14-15 mm as measured by CT scan. Others depended on the measurements given by Hinck *et al*. [10], Eisenstein [11], Larsen & Smith [12] and Amonoo-Kuofi [13], who measured the sagittal canal diameter on plain radiographs or osteological specimens from cadavers. In this study, it was tried to determine the mean values of normal spinal canal diameters in a healthy, young to mid-age Kurdish population from Sulaimani city.

There are many studies (using different modalities) about the measurement of spinal canal diameters in foreign populations [11, 13, 14, 15, 16, 17]. To our knowledge, there is no report of normal lumbar spinal canal diameters in Iraqi population especially in Kurdish population that had been done on asymptomatic subjects. In the male subjects, a steady narrowing of the sagittal diameter from the level of L1 to L3 vertebrae was followed by widening at L4 and L5. The range of diameters for the female canals followed a similar pattern, except that, at all levels, the mean diameters were narrower than males. In both genders, the midsagittal diameter of the vertebral canal was wider at the cephalic end than it was at the caudal end, and showed a mid-lumbar narrowing. This 'hour-glass' shape of the canal has been observed in other populations such as Nigerian population [13], Pakistani population [18] and Indian population [2].

On the other hand, Rema and Rajagopalan [19] observed a gradual decrease in the sagittal diameter of the spinal canal from L1 to L5. Wang and Shih [20] also reported that there is a progressive decrease in the diameter of the spinal canal from L1 to L5.

Morphometric studies of the lumbar vertebral canal have reported age, gender and racial differences in the diameter of the canal [10, 11, 13]. The mean midsagittal diameter of the lumbar bony spinal canal was narrower in female than in male subjects. This finding corroborates with those of Amonoo-Kuofi [13], Maqbool *et al*. [18], Shukri [21] and Al-Anazi *et al*.[22], who also reported that the diameter of the lumbar spinal canal was larger in male than female subjects.

On the other hand, Eisenstein [11] reported that South African population females have wider vertebral canals than males. Similar findings have been reported by Malas *et al*. [23] who also found

that the Turkish females have wider diameters than males.

The results of the present study confirm that there are differences in the size of the adult canal between Kurdish subjects of Sulaimani city and other populations.

In order to correlate the size of the vertebral canal in this population with those of other populations, the mean midsagittal diameters obtained in the present study were compared with those of other populations (Table 5). It was found that:

1. The mean midsagittal diameters of the lumbar bony spinal canal in this population were larger than those reported for Turkish population studied by Malas *et al*.[23] by MRI, Iraqi population studied by Shukri [21] by MRI, Iranian population studied by Midia and Miabi [24] by CT scan, Indian population studied by Rema and Rajagopalan [19] and Pakistani population studied by Maqbool *et al*.[18] from cadaveric study.

2. The mean midsagittal diameters of the lumbar bony spinal canal in this study were smaller than those reported for American population studied by Ulmer *et al*. [25] and Tong *et al*. [26] by MRI.

3. The mean midsagittal diameters of the lumbar spinal canal were nearly similar to those reported for Indian (Kashmiri) population studied by Jahangir *et al*. [2] by MRI and Nigerian population studied by Amonoo-Kuofi [13] from cadaveric study.

Although this difference might be probably due to that most of the previous studies have been performed on symptomatic subjects or due to different ways of measurements, as most of the previous studies were done either by CT scan, plain radiographs or direct measurement from cadavers, other factors probably play a major role in this difference such as racial factors.

The above mentioned fact suggests that racial influences are involved in determining the size of the vertebral canal. This inference is also supported by the findings of Lee el al [16] who reported that the Koreans have a smaller vertebral canal than that of whites and Africans. Similarly, in another study, the mean dimensions of the spinal canal were significantly greater in the Italian than in the Indian skeletons [27].

As in the other populations studied, the widest anteroposterior diameter of the lumbar spinal canal measured in the present study was at the level of L1. Davis [28] noted that in most individuals the L1 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 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 transitional regions. 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 [28].

At the lower lumbar levels (L4 and L5), there was greater variability than what is observed at higher levels with the males showing a wider spread from the mean diameter than the females. The reason for such wide variations in sagittal diameter especially at the L5 level is unclear. But since this is the site of the lumbosacral angulation, it has been suggested that the tendency for an increase in this dimension at L5 is as 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 [13].

Dimensions of the vertebral bodies were larger in male than in female subjects at all levels. This is in accordance with those of Amonoo-Kuofi [29], Maqbool *et al*.[18] and Shukri [21]. This difference is more marked in the heights of the vertebral bodies than their widths. In contrast, Frobin *et al*. [30] reported that the height of the lumbar vertebral body is larger in female than that in male subjects.

In both genders L3 had the tallest vertebral body. This is probably related to the great axial weight bearing at L3 vertebra which is the mid-lumbar level. However, it was found that L5 has a shorter body than the rest, in spite of having the largest body among the lumbar vertebrae [31, 32].

The widths of the vertebral bodies have increased from L1 to L4 and then decrease at L5 level. Standring et al [31] reported that there is a cephalocaudal increase in the width of the vertebral bodies from the second cervical to the third lumbar vertebra which is associated with an increased load-bearing function.

The mean heights and widths of the vertebral bodies were compared with the results of other studies done. It was found that the mean vertebral body heights were similar to the results obtained by Shukri [21]. He reported that the height of the vertebral body has increased from L1 to L3 and it was the smallest at L5 just similar to the results of this study. However, the mean height and antero-posterior diameter or width of the vertebral body at L4 were generally smaller than those reported by Junno *et al*.[33] who measured dimensions of L4 vertebra by MRI.

The mean antero-posterior diameter of the vertebral body of the present study was comparable with those of Amonoo-Kuofi [13] and Maqbool et al [18] who carried out direct measurements of the anteroposterior width of the vertebral body from osteological specimens. On the other hand, the vertebral body dimensions were smaller than that reported by Eisenstein [11]. This difference is probably due to the radiographic magnification that occurs when making x-ray scans [13].

Theoretically, it was expected that the size of the vertebral body should vary proportionately with the build of the individual. This means that there will 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 of the intervertebral foramen) [13].

Lastly, it was found that the results of the present study were more comparable with the results of those studies which reported the dimensions of the lumbar spinal canal and vertebral bodies from direct measurements of osteological specimens [13,18], than those studies which were carried out using CT scan or plain radiographs. This indicates that the results obtained by MRI are more accurate than those results obtained by CT or plain radiographs.

In both genders, the disc height had increased from the L1-L2 disc to L4-L5 disc. The height of the L5-S1 disc was quite variable; in some subjects, it was small, however, in others it was the largest one. The L4-L5 intervertebral disc was the largest disc in about 63% of the subjects which is in accordance with that of Bogduk *et al*. [34] who reported that the L4-L5 disc is the largest intervertebral disc of the human body. This is probably related to the greater mobility at that level of the lumbar spine. The mean disc height was larger in male than in female subjects at all levels except at L5-S1, at which the disc height was slightly larger in females. Amonoo-Kuofi [29] and Frobin *et al*. [30] also reported that intervertebral disc height is larger in male than that in female subjects.

The mean intervertebral disc height was compared with that of other studies. The measurements were nearly comparable with those of Eijkelkamp *et al*. [35] who reported that the height of the intervertebral discs increases from L1-L2 disc to L4-L5 disc and then decreases at L5-S1. However, the mean heights of the discs in their study were larger than in the present study; in their study, the mean heights of L3-L4 and L4-l5 discs were about 14 mm, while that of L2-L3 disc was about 13 mm. In addition, Moeller and Reif [36] reported that the height of the intervertebral discs is about 8-12 mm; it increases from L1-L2 to L4-L5 and usually decreases at L5-S1, but may be the same as or greater than L4-L5. This is in accordance with the results of the present study. On the other hand, the disc heights in this study were smaller than those found by Amonoo-Kuofi [29]. This difference is also probably due to radiographic magnification.

In conclusion, MRI is the best imaging modality to measure the normal dimensions of the lumbar spine. The mean midsagittal spinal canal diameter was larger than that reported by other workers in the neighboring countries and even than that reported for Iraqi population in Baghdad. The dimensions of the vertebral bodies in this population are different from data given by other researchers in other populations. Most of the measurements were larger in male than female subjects.

We recommend further studies are suggested to measure the diameter of the lumbar spinal canal, vertebral body dimensions and intervertebral disc height at different age groups.

Other studies may consider measurements of the transverse diameter of the lumbar spinal canal, or measurements of anterior and posterior heights of the vertebral bodies and intervertebral discs.

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