EVALUATION OF SAGITTAL PARAMETER OF THE LUMBAR SPINE USING 1.5T MRI

Mishka Mustafa[1*], Niraj Kumar Sah[2], Raushan Kumar[3], Mamta Verma[4], Prof. Dr. Rajul Rastogi[5], Navreet Boora[6]

Abstract

Background: The research problem of the previous study was that they only collected the data from the age 18 to 27 years range. In the recent study, they have done the measurement on the X-ray machine but in the present study, we have done the measurement on the MRI machine. Another study in which age ranged from 15-25 years, but in another research the age ranged from 25-82 years, in the study, there was an inclusion of 65 years old subjects but they have done the study in mountain areas. In this study, we have included subjects from 20 to 60 years from the plain area. In this study, we have calculated the Concavity Index from L1 to L5, Intervertebral Disc Height from L3 to L5, and measurement of the lumbar spine's intervertebral canal.

Aim & Objectives: The goal is to evaluate the Concavity Index, Intervertebral Disc Height and Intervertebral Canal of lumbar spine using 1.5T MRI on the basis of various parameters such as age, gender, height, weight and BMI. The objective is to calculate concavity Index from L1 to L5, to access IVDH from L3 to L5, to correlate CI, IVDH and IVC relation with age, gender, BMI and measurement of IVC.

Materials And Methods: This research was prospective involving 100 individuals (age 20-40 years). Furthermore, each participant's gender, age, height, weight, and BMI, were documented. Patients were excluded from the study who had osteoporosis, Scheuermann's disease, scoliosis, Spinal metastasis, Lordosis, Kyphosis, Pott's Spine, Bechterew disease, trauma and any spinal surgery, etc. Scans were performed using Siemens Magnetom Avanto Tim Dot 1.5T. We only used a single sequence involved in this study is T2 sagittal. On a T2 image, the dimensions of the anterior and central vertebral bodies were measured for the concavity index calculation, the height of the intervertebral disc, and the measurement of the spinal canal. The measurements were made on the mid-sagittal region of the vertebrae, which can be seen on an MRI. First, we measured the heights of the anterior and central vertebral bodies, and then we divided those heights by the ratio of the central to anterior vertebral bodies to obtain the concavity index.

Result: In our study there were 100 subjects were mean age, height, weight and BMI were 31.0 year, 1.61m (range 1.4 to 1.85m), 65.0 kg (range 40 to 92) and Body mass index of 25.1 kg/m^2 (range 16.3 to 39). There was a difference ($p < 0.05$) in anterior vertebral height and ($p < 0.05$) in Central vertebral height between males and females for L1, L2, L3, L4, and L5.Pearson's correlation factor, "r" was used to find the relation between age, height, weight, BMI; and AVH, CVH, CI. Height was positively correlated ($p < 0.05$) with AVH (L1, L2, L3 and L4); CVH (L1, L2, and L3); CI (L1, L2, and L3). Additionally, weight had a positive correlation with AVH (L1, L3, and L4), CVH (L1, L2, L3, and L4), and CI (L2) ($p<0.05$).

Conclusion: Through this study, it will be possible to anticipate instrument size, intervertebral disc distance, and other factors that will be important during surgical procedures for different disorders. It is believed that a higher CI is a sign of spinal deterioration and resultant low back pain. Patients with smaller canals viewed their disabilities as being more severe, yet there were no significant group variations.

Keywords: Concavity index, Intervertebral disc height, Interveretbral canal

[1*]M. Sc RIT Research fellow (Department of Radiological Imaging Techniques, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, Contact no. 7992053600,
Email- sayyedamishka313@gmail.com
[2]Department of Radiological Imaging Techniques, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, Email- nirajsah98@gmail.com
[3]Department of Radiological Imaging Techniques, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh , India, Email- raushank.paramedical@tmu.ac.in
[4]Department of Radiological Imaging Techniques, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, Email- mamtav.paramedical@tmu.ac.in

[5]Department of Radio diagnosis, Teerthanker Mahaveer Medical College & Research Centre, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, Email- rajulrst@yahoo.co.in
[6]Department of Radio-imaging Technology, Faculty of Allied Health Sciences Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, India,
Email- Navreet999@gmail.com

***Corresponding author:** Mishka Mustafa
*Department of Radiological Imaging Techniques, Teerthanker Mahaveer University,
Contactno.7992053600, Email: sayyedamishka313@gmail.com

DOI: 10.48047/ecb/2023.12.si10.0077

INTRODUCTION

Routine, occupational, and recreation opportunities place heavy pressures on the lumbar spine. The lumbar spine must exhibit both stability and mobility to support heavy stationary and dynamic axial loads while also ensuring that the entire spine may move freely. The End plates, the nucleus pulposus, and the annulus fibrosus make up the Intervertebral (IV) disc, a dynamical framework that sits among the vertebrae. Magnetic Resonance Imaging is a non-invasive technique that offers a variety of data and on the lumbar soft tissues produces extremely good images of the sagittal plane, coronal plane as well as axial plane. Recently, MRI has risen to the top of widely used diagnostic way to determine the assessment of ruptured discs or lumbar spinal stenosis nucleolus purpose.[1]

The research problem of the previous study was that they only collected the data from the age 18 to 27 years range. Another study in which age ranged from 15-25 years, but in another research the age ranged from 25-82 years, in our study, there was an inclusion of 40 years old subjects but they have done the study in mountain areas. In our study, we have included subjects from 20 to 40 years from the plain area. In our study, we have calculated the Concavity Index from L1 to L5, Intervertebral Disc Height from L3 to L5, and measurement of the Intervertebral Canal of the lumbar spine.

The clinical significance is to anticipate instrument size, intervertebral disc distance, and other factors that will be important during surgical procedures for different disorders. It is believed that a higher CI is a sign of spinal deterioration and resultant low back pain. Patients with smaller canals viewed their disabilities as being more severe, yet there were no significant group variations.

Due to Tim® technology, a significant decrease in acoustic noise, and a wide application range up to 205cm entire scanning, MAGNETOM® Avanto, A Tim+Dot System is the benchmark in 1.5T imaging. The strength of Tim is increased with the inclusion of Dot®, leading in better image clarity, greater diagnosis assurance, improved usability, and a day that is more efficient than ever.

AIM

To evaluate the concavity index, intervertebral disc height and intervertebral canal of lumbar spine using 1.5T MRI.

MATERIALS AND METHODS

This investigation was prospective involving 100 individuals (55 male and 45 female) which was conducted at Department of Radio-diagnosis, Teerthanker Mahaveer Hospital and Research Centre, Moradabad, UP. Patient with age greater than 20 years till 40 years, OPD patients were included from 20th March 2022 to 21st March 2023. Furthermore, each participant's gender, age, height, weight, and BMI, were documented. Patients were excluded from the study that had osteoporosis, Scheuermann's disease, scoliosis, Spinal metastasis, Lordosis, Kyphosis, Pott's Spine, Bechterew disease, trauma and any spinal surgery, etc. Scans were performed using Siemens Magnetom Avanto Tim Dot 1.5T. The sequence involved in this study was T2 sagittal. T2 intensity image with a TE/TR of 84/4500 were created, respectively. The slice thickness was 4mm. The parameters measured in my study are shown in the MR images of fig 1.1, 1.2 and 1.3 respectively. The dimensions of anterior vertebral body and central vertebral body on MR images by T2 sequence on sagittal plane as shown in fig. 1.1 for the calculation of concavity index as well as the measurement of intervertebral disc height and measurement of spinal canal were performed on T2 image. The measurement were taken on the mid-sagittal region of the vertebrae, as visible on MRI, first of all we measured the anterior vertebral body and central vertebral body height and then divide the anterior vertebral body by central vertebral body for concavity index.

CI= AVH/CVH [1]

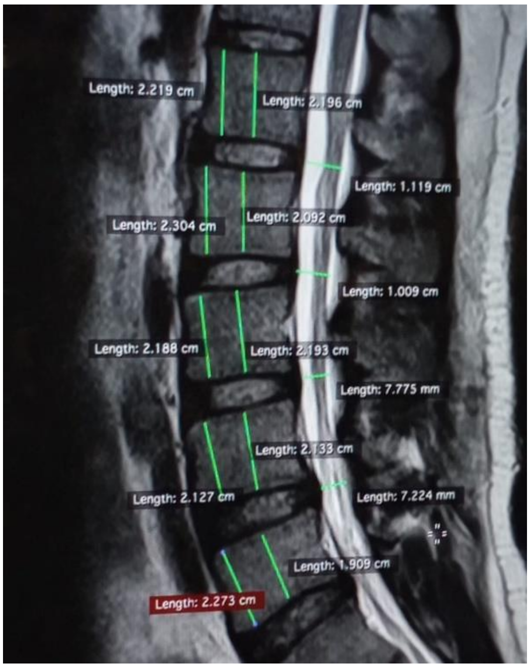

Figure 1.1 Measurement of AVH and CVH on MR images by T2 sequence on sagittal plane

Figure 1.2 Measurement of IVDH on MR image by T2 sequence on sagittal plane.

Figure 1.3Measurement of spinal canal on MR image by T2 sequence on sagittal plane.

The measurement of height of intervertebral disc is calculated by the measurement of anterior and posterior height of intervertebral disc and distance of superior and inferior intervertebral disc on T2 sagittal image as shown in fig. 1.2 using Osirix workstation.

It is calculated as **-** $[(Ha + Hp)/(Ds + Di)] \times 100$

RESULTS

In our study there were 100 subjects (45 female and 55 male), were included whose mean age is 36.62 year (range 20 to 40). Mean height is about 1.6m (range 1.4 to 1.85m) and mean weight is 65.0kg (range 40 to 92) and BMI of 25.1 kg/m^2 (range 16.3 to 39) as shown in table 1.1.

	Range	Mean	S.D.
Age (Years)	20 to 40	31.0	6.7
Height (M)	1.4 to 1.85	1.6	0.1
Weight (Kg)	40 to 92	65.0	11.4
BMI (Kg/M^2)	16.3 to 39	25.1	4.3

Table 1.1 The table shows the mean and std. deviation of age, height, weight and BMI

Statistical Analysis

The entire patient were subjected to excel sheet and SPSS Software (SPSS Inc; Chicago, II), version 26.0 was used for the result analysis.

It was compared using the Independent sample "t" test Concavity Index (CI) according to gender. There was no difference in CI between males and females for L1, L2, L3, L4, and L5 ($p < 0.05$). Comparisons were made with the Independent Sample "t" test AVH and CVH according to gender. There was a difference in CVH between males and females for L1, L2, L3, L4, and L5 ($p < 0.05$). The Independent sample "t" test was utilised to compare Inter Vertebral Disc Height (IVDH) according to gender. There was no difference in IVDH between males and females for L2-L3, L3-L4, and L4-L5 ($p > 0.05$).The one way ANOVA test was used to compare Anterior Vertebral Height (AVH) according to age. There was no difference in AVH according to age for L1, L2, L3, L4, and L5 ($p > 0.05$). The Independent sample "t" test was used to compare Anterior Vertebral Height (AVH) according to gender. There was a difference ($p < 0.05$) in AVH between males and females for L1, L2, L3, L4, and L5. To compare, the Independent Sample "t" Test was utilised CVH based on gender. The IVC was compared by gender using the Independent Sample "t" test. For L2-L3, L3-L4, and L4-L5, there was no change in IVC between males and females ($p > 0.05$).

It was assessed using the Independent sample "t" test Inter Vertebral Disc Height (IVDH) according to age groups. There was a difference ($p < 0.05$) in IVDH between the age groups for L2-L3.

Age, height, weight, BMI, and AVH, CVH, and CI relationships were determined using the Pearson correlation coefficient, or "r," which stands for "r". Height and AVH (L1, L2, L3 and L4), CVH (L1, L2, and L3), and CI (L1, L2, and L3) all showed positive correlations (p 0.05).

Additionally, weight had a positive correlation with AVH (L1, L3, and L4), CVH (L1, L2, L3, and L4), and CI (L2) (p 0.05). The relationship between age, height, weight, BMI, and IVDH and IVC was discovered using the Pearson correlation coefficient, or "r". Age and IVDH (L2-L3), weight and IVC (L2-L3), and BMI and IVC (L4-L5) all had positive correlations ($p< 0.05$).

			Age	Height	Weight	BMI
L1	AVH	"r"	-0.006	0.520	0.311	-0.031
		p value	0.951	< 0.001*	0.002*	0.757
	CVH	"r"	-0.019	0.466	0.238	-0.057
		p value	0.848	< 0.001*	0.017*	0.574
	CI	"r"	0.033	0.385	0.191	-0.061
		p value	0.747	< 0.001*	0.056	0.548
L2	AVH	"r"	0.045	0.380	0.122	-0.100
		p value	0.657	< 0.001*	0.227	0.324
	CVH	"r"	0.029	0.450	0.219	-0.055
		p value	0.775	< 0.001*	0.029*	0.584
	CI	"r"	-0.117	0.428	0.289	-0.031
		p value	0.245	< 0.001*	0.004*	0.761
L3	AVH	"r"	-0.077	0.461	0.289	-0.017
		p value	0.448	< 0.001*	0.003*	0.869
	CVH	"r"	-0.050	0.407	0.280	0.016
		p value	0.625	< 0.001*	0.005*	0.876
	CI	"r"	-0.020	0.440	0.192	-0.077
		p value	0.846	< 0.001*	0.056	0.446
L4	AVH	"r"	0.095	0.505	0.223	-0.086
		p value	0.346	< 0.001*	0.026*	0.395
	CVH	"r"	0.166	-0.004	-0.022	0.019
		p value	0.099	0.969	0.831	0.853
	CI	"r"	0.047	-0.012	-0.141	-0.121
		p value	0.639	0.903	0.161	0.230
L5	AVH	"r"	0.129	-0.100	-0.094	-0.020
		p value	0.202	0.320	0.350	0.843
	CVH	"r"	0.049	-0.164	-0.025	0.105
		p value	0.629	0.104	0.805	0.299
	CI	"r"	-0.141	-0.170	-0.077	0.034
		p value	0.161	0.091	0.447	0.740
IVDH	L2-L3	"r"	0.285	-0.018	0.117	0.122
		p value	0.004*	0.856	0.248	0.228
	L3-L4	"r"	0.135	-0.040	0.143	0.143
		p value	0.181	0.691	0.157	0.155
	L4-L5	"r"	0.089	-0.121	0.094	0.120
		p value	0.379	0.232	0.350	0.233
IVC	L2-L3	"r"	-0.118	-0.129	-0.236	-0.172
		p value	0.242	0.200	0.018*	0.087
	L3-L4	"r"	-0.109	-0.083	-0.189	-0.156
		p value	0.280	0.410	0.060	0.122
	L4-L5	"r"	0.071	-0.154	0.083	0.255
		p value	0.481	0.125	0.410	0.010*

(* Significant)

Table 1.2 The table shows "r" and p value of AVH, CVH, CI, IVDH and IVC on the basis of the age, height, weight and BMI

All these correlation with their AVH, CVH, CI, IVDH and IVC according to age, height, weight, BMI is shown in table 1.2.

AVH	Male		Female		"t"	p value
	Mean	S.D.	Mean	S.D.		
L1	2.14	0.16	1.98	0.15	5.20	< 0.001*
L2	2.27	0.16	2.11	0.16	4.97	< 0.001*
L3	2.31	0.17	2.16	0.17	4.61	< 0.001*
L4	2.30	0.17	2.15	0.17	4.50	< 0.001*
L5	2.40	0.18	2.21	0.24	4.37	< 0.001*
CVH	Male		Female		"t"	p value
	Mean	S.D.	Mean	S.D.		
L1	2.11	0.22	1.95	0.17	4.07	< 0.001*
L2	2.18	0.16	2.01	0.17	5.22	< 0.001*
L3	2.16	0.18	2.00	0.16	4.61	< 0.001*
L4	2.10	0.17	1.92	0.21	4.83	< 0.001*
L5	2.02	0.20	1.82	0.23	4.70	< 0.001*
CI	Male		Female		"t"	p value
	Mean	S.D.	Mean	S.D.		
L1	1.02	0.12	1.02	0.06	0.15	0.878
L2	1.04	0.06	1.05	0.07	-1.17	0.246
L3	1.07	0.07	1.09	0.08	-0.84	0.406
L4	1.09	0.10	1.12	0.09	-1.64	0.103
L5	1.19	0.11	1.23	0.16	-1.56	0.122
IVDH	Male		Female		"t"	p value
	Mean	S.D.	Mean	S.D.		
L2-L3	27.51	5.37	28.54	5.27	-0.97	0.337
L3-L4	29.79	6.32	30.90	6.62	-0.85	0.395
L4-L5	33.27	6.98	34.52	6.08	-0.95	0.346
IVC	Male		Female		"t"	p value
	Mean	S.D.	Mean	S.D.		
L2-L3	1.02	0.23	1.16	0.73	-1.27	0.208
L3-L4	1.01	0.25	1.09	0.77	-0.68	0.500
L4-L5	0.97	0.26	1.12	1.13	-0.93	0.353

(* Significant)

Table 1.3 The table shows "t" and p value of AVH, CVH, CI, IVDH and IVC on the basis of the gender

All these correlation with their mean and std. deviation according to different gender group is shown in table 1.3.

DISCUSSION

In our study there were 100 subjects (45 female and 55 male), were included whose mean age is 36.62 year (range 20 to 40). Mean height is about 1.6m (range 1.4 to 1.85m) and mean weight is 65.0kg (range 40 to 92) and BMI of 25.1 kg/m^2 (range 16.3 to 39).

JS Pooni et al.[2] in their study showed a difference in AVH from L1 to L5. They observed a gradual increase in AVH whereas in our study, Additionally, there is a variation in AVH between men and women L1, L2, L3, L4, and L5 for (p<0.05) which is gradually increasing and also a difference in CVH between both gender for L1 to L5 (p<0.05).

C Kiss et al.[3] in their study they investigated that males had smaller ratio of anterior to central vertebral height than females but in our study, we find out that the AVH and CVH according to gender are greater in males than female.

C Kiss et al.[3] in their research there was no difference in AVH according to age for L1to L5 (p > 0.05). In our study the similar pattern of trend was observed. There was no difference in CI according to age for L1, L2, L3, L4, and L5 (p > 0.05).

Mehmet Demir et al.[1] in their investigation 80 of the 150 individuals were female, and 70 were male (age 18 to 27). Compared to women, the male showed higher lumbar disc values. From T12-L1 to L4-L5, the disc height increased for both gender before decreasing at L5-S1. But in our present study, we have taken patients aged from 20 to 40 years 45 females and 55 males are included. The IVDH is greater in females than males between L2-L3, L3-L5, and L4-L5 respectively. But there is no variation in IVDH between both genders for L2-L3, L3-L4, and L4-L5 but according to age groups for L2-L3 ($p < 0.05$).

Mehmet Demir et al.[1] in their study a higher concavity index value was seen in men at the L5 vertebra whereas females showed a higher CI at the L2, L3, and L4 vertebrae. Age caused a decrease in the T12, L1, L2, L3, and L4 vertebral concavity index. But in our present study, we have taken patients aged from 20 to 40 years where 45 females and 55 males are included. A greater concavity index in females than in males the maximum concavity index is shown in L5 and the minimum concavity index is shown in L1. The concavity index is increasing for L1, L2, L3, L4, and L5 respectively.

Menekse Salar et al.[4] in their research studied CIs at all levels, and gender disparities were seen, especially for the L5-S1. While L3/L4 CIs exhibited little variation, other lumbar areas (L2/L3, L4/L5, and L5/S1) have more striking variations that might be gender-related. But in our study, a greater concavity index in females than in males, and the maximum concavity index is shown in L4-L5 and the minimum concavity index is shown in L1-L2.

Zengwu Shao et al.[5] in their research, both males and females between the ages of 20 and 69, lumbar discs T12-L1, and for other consecutive sets heights grew with age. Between the ages of 20 and 87 for males and 20 to 92 for women,T12, L1, L2, L3, L4, and L5 vertebral concavity indices aged linearly (0.9-1.5% for men and 1.6-3.2% for women), decreasing. With another word, as people aged, endplates of the vertebral column's bodies got more concave. In the lumbar spine, Osteophytes were more prevalent in male than in female, and their frequency rose with age. But in our study, a greater concavity index in females than in males, and the maximum concavity index is shown in L5 and the minimum concavity index is shown in L1. The concavity index is increasing for L1, L2, L3, L4, and L5 respectively in both genders.

Ozdemir Sevinc et al.[6] in their study they investigated that women had greater values for their upper lumbar vertebrae were measured using each of the three indicators than did men for the same vertebrae. Women experienced a decline in the index of compression values for whole lumbar vertebrae as they aged, whereas males experienced a decline in the compression index values for the L1-L4 vertebrae. The anterior wedge index value did not differ significantly between the sex. Males' L1 and L5 vertebral concavity indices declined as they aged. These findings may help assess the morphological changes in the lumbar vertebrae brought on by aging. In our study, the concavity index is increasing for L1, L2, L3, L4, and L5 respectively in both genders. Age-related Concavity Index (CI) comparison using the one-way ANOVA test. There was no difference ($p > 0.05$) in CI according to age for L1, L2, L3, L4, and L5.

Andrew Hughes et al.[7] in their investigation provide the coefficient, which is the ratio of the entire region among the lateral canals to a cross-section region of the dural sac, to describe the condition of the spinal canal ("coefficient of stenosis"). Significant statistical discrepancies existed between the main and control groups when comparing the mean values of the "coefficient of stenosis" (t = -12,5; p 0.0001). The derived coefficient showed a strong statistically significance association using the SSS and ODI scales (p 0.05). On the contrary, our study shows no significant difference in the canal size from L2-L3, L3-L4, and L4-L5, as our study didn't focus on the mean value of the coefficient of stenosis because no pathology is taken into consi duration.

Michael E. Geisser et al.[8] evaluated that the location or intensity of clinical complaints was not substantially related to spinal stenosis as measured by AP spinal canal diameter. Walking distance and BMI were shown to be strongly correlated, but not in terms of reported functioning or discomfort. But in our study, the IVC is greater in females than males between L2-L3 but males have a greater IVC between L2-L3.

Zengwu Shao et al.[5] in their research, both males and females between the ages of 20 and 69, T12-L1, L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 lumbar discs heights grew with age. Between the ages of 20 and 87 for males and 20 to 92 for women,T12 to L5 vertebral concavity indices age was accompanied by a linear decline (0.9-1.5% in male and 1.6-3.2% in female). With other words, as people aged, endplates of the vertebral bodies got more concave. In the lumbar spine, Osteophytes were more prevalent when compared to women, and their frequency rose with age. But in our study, a greater concavity index in females than in males, and the maximum concavity index is shown in L5 and the minimum concavity index is shown in L1. The concavity index is increasing for L1, L2, L3, L4, and L5 respectively in both genders.

Donna M. Urquhart et al.[9]in their research work after adjusting for well-popular co-founders like age, gender, weight and height, they were able to find persistent BMI and disc height have a statistically significant relationship with one another. Being overweight was related to decreased height of the lumbar discs. The relationship was determined using the Pearson correlation coefficient, or "r" among age, height, weight, BMI; and AVH, CVH, CI. Height was positively correlated ($p < 0.05$) with AVH (L1, L2, L3 and L4); CVH (L1, L2, and L3); CI (L1, L2, and L3). Also, weight was linked positively ($p < 0.05$) with AVH (L1, L3 and L4); CVH (L1, L2, L3 and L4); CI (L2). The Pearson correlation coefficient, "r" was used to find the relation between age, height, weight, BMI; and IVDH, IVC. There was a positive correlation ($p < 0.05$) among age and IVDH (L2-L3); weight and IVC (L2-L3); BMI and IVC (L4-L5).

LIMITATION

Patients with specific professional were the limitation.

Subjects with involvement in sports activities are a limitation of the current study.

CONCLUSION

Age had no effect on the lumbar vertebrae's concavity index, which was noticed. Due to the cross-sectional nature of this study, the findings cannot be generalised to the entire population in this age range. However, these findings will act as standards for lumbar spine radiological examination in young, healthy people. Through this study, it will be possible to anticipate instrument size, intervertebral disc distance, and other factors that will be important during surgical procedures for different disorders. It is believed that a higher CI is a sign of spinal deterioration and resultant low back pain. Patients with smaller canals viewed their disabilities as being more severe, yet there were no significant group variations. None of the clinical symptom markers examined across the entire cohort significantly correlated with the AP spinal canal diameter.

CONFLICT OF INTEREST

The author has no conflict of interest to declare.

REFERENCE

1. Demir M, Atay E, Seringec N, Yoldas A, Cicek M, Ertogrul R, et al. Intervertebral disc heights and concavity index of the lumbar spine in young healthy adults. International Journal of Experimental and Clinical Anatomy. 2018;1;12(1):34–7.
2. Pooni JS, Hukins DW, Harris PF, Hilton RC, Davies KE. Comparison of the structure of human intervertebral discs in the cervical, thoracic and lumbar regions of the spine. Surgical and radiologic anatomy. 1986;8(3):175-82.
3. Kiss C, Szilagyi M, Felsenberg D, O Neill TW, Silman A, Poor G. Normal values of vertebral heights in a representative population survey in Hungary. Orvosi Hetilap. 1999 1;140(7):347-52.
4. Salar M, Sesek RF, Schall MC. The Concavity Index. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2016;15;60(1):953–7.
5. Shao Z, Rompe G, Schilten wolf M. Radiographic changes in the lumbar intervertebral discs and lumbar vertebrae with age. Spine (Phila Pa 1976). 2002 1;27(3):263-8
6. Sevinc O, Barut C, Is M, Eryoruk N, Safak AA. Influence of age and sex on lumbar vertebral morphometry determined using sagittal magnetic resonance imaging. Annals of Anatomy - Anatomischer Anzeiger. 2008;190(3):277–83.
7. Hughes A, Makirov SK, Osadchiy V. Measuring spinal canal size in lumbar spinal stenosis: description of method and preliminary results. Int J Spine Surg. 2015:1;9:8.
8. Geisser ME, Haig AJ, Tong HC, Yamakawa KSJ, Quint DJ, Hoff JT, et al. Spinal Canal Size and Clinical Symptoms Among Persons Diagnosed With Lumbar Spinal Stenosis. Clin J Pain. 2007;23(9):780–5.
9. Urquhart DM, Kurniadi I, Triangto K, Wang Y, Wluka AE, O'Sullivan R, et al. Obesity Is Associated With Reduced Disc Height in the Lumbar Spine but Not at the Lumbosacral Junction. Spine (Phila Pa 1976). 2014;39 (16): E962–6.