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ORGINAL ARTICLE

Lower Three Lumbar Intervertebral Foramina Measurements of Adult Egyptians in Relation to Age and Sex Using Magnetic Resonance Imaging

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ABSTRACT

Background: Intervertebral foramina (IVF) are present between adjacent vertebrae allowing connection between the vertebral canal and extra spinal elements. IVF acts as a tunnel transmitting roots of the spinal nerves and vascular structures which supply the spinal cord. Orientation of spinal cord vascularization is very important to all radiologists performing interventional procedures. **Objectives:** The aim of this study is to determine normal variations in dimensions of lumbar IVF at (L3- L4, L4- L5 & L5- S1) levels using Magnetic Resonance Imaging(MRI) in relation to age and sex to give basis for Egyptian measurements. **Subjects and methods:** Total number of studied individuals was (120) healthy individuals of both sexes with normal MRI. Subjects of study were divided into two age groups; Group(A) includes 90 persons whose ages ranged between 18-40 years old and Group(B) includes 30 persons whose ages ranged between 40-48 years old. The study was done using high field (1.5) Tesla magnetic resonance system in radiology units of Zagazig University Hospitals from April, 2017 to December, 2019. **Results:** Lumbar IVF dimensions were larger in the younger age group at the same levels and also larger in males than females at L3-L4 and L5-S1 levels. At L4-L5 level there was no difference in relation to age and sex. **Conclusion:** Application of this study can act as a data base for establishment of Egyptian measurements using MRI. IVF narrowing is responsible for different neurological symptoms that may need surgical intervention due to nerve root compression.

Key words: Lumbar, intervertebral foramen, MRI, spine, measurement.

INTRODUCTION

Vascular structures and spinal nerve roots supplying the spinal cord are passing through a tunnel called intervertebral foramen (IVF). This orifice has two articular parts: one posteroinferior part of the vertebral body which is mobile and formed by the posterior articular lamina covered by the yellow ligament in the back, and by the postero lateral aspect of the intervertebral disc in front and rigid immobile antero superior ring formed of the lower part of the pedicle. The first articular part is the part where degenerative and pressure related changes occur **(1)**. The foramen is oval at the lumbar region due to its long vertical axis. The most round and smallest IVF is at L5-S1 level. Here, most of the space of the orifice is occupied by the spinal ganglion. It is so important to understand the changes in the dimensions of the IVF occurring with movement **(2).** All the dimensions of the IVF are at their maximum in full flexion where the pedicles move slightly away from each other and the disc convexity is decreased as the posterior longitudinal ligament is tensed; the yellow ligament, also the posterior facet capsule are leant against the posterior articular processes **(3).** All the foramen dimensions decrease during extension, as the pedicles move nearer to each other, reducing the foramen height by about 20% **(4).** When the intervertebral discs degenerate and collapse, the foramen height is decreased. The presence of nerves in the upper bonny part of the foramen protects them slightly from the protruding disc, osteoarthritis of the posterior facet joint, and friction with inferior articular process during extension movements this is provided that the vertical dimension of the intervertebral space remains suitable **(5).** The vertically oval foramen is crossed by nerves. Its boundaries are formed by intervertebral disc and posterior longitudinal ligament anteriorly. The ligamentum flavum also, the facet capsule forms its posterior border.

Therfore, it can be seen like sagittal narrowing carrying out nerve compression. The nerves are liable to be compressed by transforaminal ligaments attached to the disc, capsule and the pedicle **(6)**.The IVF is always patent and the thickness of the ligamentum flavum is about few millimeters. With advance of age, degenerative changes and annular tears occur leading to disc herniation, with subsequent decrease of disc height and losing its hydrostatic properties. This will lead to more pressure on the facets and resulting in nerve compression **(7).** There are many items are closely found together in the area of the IVF such as nerve roots, spinal ganglions, fat, radicular arterioles, veins , the meningeal nerve and ligaments **(8).** The total area of the blood vessels and nerves represents about 20 to 50% of the total orifice area. The mixed spinal nerve is formed by union of the posterior sensory root and the anterior motor root merely after the spinal ganglion which is present just beneath the pedicle imprinting it **(9)**. This mixed spinal nerve divides into thin posterior branch and thicker anterior branch and at its exit from the foramen. Communication between external and internal vertebral venous plexuses is achieved by the foraminal veins. In the front of anterior and posterior roots of the spinal nerve, the radicular arteries are typically present. The foraminal fat plays crucial role in protecting and allowing flexibility of the vascular and nervous elements in this tiny space **(10).** Up to our knowledge there were few studies determined normal variations in the measurements of lumbar IVF in adults in Egypt so the current study aimed to measure normal lower three lumbar IVF dimensions and their correlation to age and sex through manual measuring at normal MRI images of subjects attending radiology unit, Zagazig University Hospitals.

METHODS

Type of study: A cross-sectional descriptive study.

Study setting and time:

The total number of the studied individuals was 120 healthy individuals of both sexes who had normal MRI, including 57 males and63 females aged from 18 years to 48 years were examined during this study. This work had been carried out in the radiology unit, Zagazig University Hospitals, Faculty of medicine, in the period from April, 2017 to December, 2019. Subjects of study were divided into two age groups: Group (A) includes 90 persons whose ages ranged between 18-40 years and Group (B) includes 30 persons whose ages ranged between 40 to 48 years. All patients were subjected to: Complete neurological history taking and then MRI was done. Eventually, any positive criterion indicating a neurological pathology from the history taken or upon viewing the subject's MRI was an indicator to exclude this subject from the study protocol.

Study population:

Inclusion criteria: Include age from 18 – 48 years old, no history of lumber spine operation and no history of lumber spine trauma. **Exclusion criteria:** any abnormalities detected clinically or by MRI (congenital anomalies of the spine, inflammatory diseases, tumors, spine fractures…etc.) history of lumber spine trauma or operation and extremes of height (e.g. gigantism, dwarfism…etc.)

Sample size and technique:

As the attendance rate is about 1200 patients/year from them approximately 240 individuals /year shows normal lumbar MRI we took a comprehensive sample including all normal persons fulfilling inclusion criteria attending at MRI unit, Zagazig University Hospitals in period of 6 months (20/month) sample was composed 120 persons then examination of MRI images was established.

Study tools:

Method of measurement of the lower three lumbar intervertebral foramina **(11):** landmarks of the IVF on the best image were digitized and labeled by electronic cursor. The Foramen Height (FH) was estimated between its lowest and highest points in between the superior surface of the lower pedicle and the inferior surface of the upper pedicle at lower three lumbar levels (fig.1a)**.** The maximal depth of the intervertebral foramen; Antero-posterior diameter (APD) was measured from the inferior part of the posterior surface of vertebral body above to the opposite point on the inferior articular process of the same vertebrae (fig.1b)**.**

Daa analysis:

The data were coded, entered and processed on computer using Statistical package for social science (SPSS) (version 24). The results were represented in diagrammatic and tabular models then interpreted. Mean, standard deviation, range, frequency and percentage were used as descriptive statistics. The following tests were done:

Chi-Square test was used to test the association variables for categorical data.

Student's t-test was used to assess the statistical significance of the difference between two population means in a study involving independent samples. **P value was considered significant as the following:**

* P > 0.05: Non significant

* P ≤ 0.05: Significant

Administrative and ethical design:

The study protocol was approved from the ethical committee at the Faculty of Medicine Zagazig University and IRB “institutional review board”, (IRB#:4737/16-7-2018). All subjects had signed an informed consent stating that their imaging results may be used anonymously for research purposes. The patients' consent was taken from all subjects and all of them were informed that this procedure is free and their cases were kept secret, they have the freedom to leave this study at any time.

RESULTS

Mean and standard deviation (SD) value of measurements of the lower three lumbar intervertebral foramina levels are shown in **table 1**.

Foramen dimensions changes in different age groups of subjects are described in **table 2**:

At level of L3-L4 IVF, there was increase in left foramen (LF) height (H) among group A (figure 2b, d) than group B (figure 3b, d) while there was no difference between the two groups regarding its Antero Posterior Diameter (APD) but on the right side there was no difference between the two groups; A (figure 2a, c) & B (figure 3a, c) regarding (H) and (APD). At level of L4-L5 IVF: there was increase in (H) among group A (figure 2) than group B (figure 3) with no difference between the two groups regarding its (APD) on both sides. On the other hand at level of L5-S1 intervertebral foramina: there was a decrease in left foramen height (H) among group A than group B while there was no difference between the two groups regarding width (APD). On the right side there was a decrease in APD among group A than group B with no statistically significant difference regarding (H).

Lower three lumbar intervertebral foramen dimensions in relation to sex of subjects were described in **table 3**.

At L3-L4 level there was decrease in the left side (APD) among males (figure 2b & 3b) than females (figure 2d & 3d) there was no difference between males and females regarding (H) while on the right side there was increase in height (H) among males (figure 2a & 3a) than females (figure 2c & 3c) but no difference between males and female regarding its APD. At L4-L5 level there was no difference between males and females regarding APD and H on both sides. At L5-S1 level there was an increase in Left Foramen height (H) between males than females with no difference between males and females regarding its Antero posterior diameter (APD). Overall, these results indicate that lumbar IVF dimensions were larger in the younger age group at the same levels and also were larger in males than females especially at L3-L4 and L5-S1 levels.

Table (1): Measurements the lower three lumbar intervertebral foramina.

		APD	H
L3-L4 LF	**Rang**	0.54 - 1.01	1.42 - 2.30
	Mean ± SD	0.78±0.15	1.96±0.23
L3-L4 RF	**Rang**	0.51 - 1.00	1.52 - 2.43
	Mean ± SD	0.74 ± 0.15	1.97 ± 0.21
L4-L5 LF	**Rang**	0.51 - 0.87	1.05 - 2.20
	Mean ± SD	0.69 ± 0.11	1.79 ± 0.25
L4-L5 RF	**Rang**	0.57 - 0.96	0.86 - 2.20
	Mean ± SD	0.69 ± 0.09	1.67 ± 0.38
L5-S1 LF	**Rang**	0.47 - 0.86	1.08 - 2.62
	Mean ± SD	0.64 ± 0.12	1.65 ± 0.31
L5-S1 RF	**Rang**	0.38 -1.01	1.16 - 2.10
	Mean ± SD	0.66 ± 0.17	1.69 ± 0.24

APD= Antero-posterior diameter. H=Height. SD=standard deviation. LF=Left Foramen. RF=Right Foramen

Table2: Comparison between foramen measurements in different age groups.

			Group A	Group B	t. test	P. value
L3-L4 LF	**APD**	**Mean ± SD**	0.77 ± 0.15	0.80 ± 0.15	0.801	0.425
	H	**Mean ± SD**	1.98 ± 0.19	1.87 ± 0.29	2.387	0.019
L3-L4 RF	**APD**	**Mean ± SD**	0.73 ± 0.15	0.76 ± 0.12	1.030	0.305
	H	**Mean ± SD**	1.95 ± 0.19	2.03 ± 0.23	1.931	0.056

			Group A	Group B	t. test	P. value
L4-L5 LF	**APD**	**Mean ± SD**	0.71 ± 0.11	0.65 ± 0.09	2.334	0.021
	H	**Mean ± SD**	1.85 ± 0.17	1.65 ±0.35	4.210	0.000
L4-L5 RF	**APD**	**Mean ± SD**	0.68 ± 0.07	0.70 ± 0.15	1.002	0.318
	H	**Mean ± SD**	1.73 ± 0.31	1.49 ± 0.53	2.982	0.003
L5-S1 LF	**APD**	**Mean ± SD**	0.64 ± 0.12	0.64 ± 0.13	0.157	0.876
	H	**Mean ± SD**	1.56 ± 0.22	1.92 ± 0.39	6.327	0.000
L5-S1 RF	**APD**	**Mean ± SD**	0.63 ± 0.16	0.75 ± 0.17	3.549	0.001
	H	**Mean ± SD**	1.68 ± 0.27	1.73 ± 0.14	0.828	0.409

Group A =18-40 years. Group B= > 40-48 years.

Table3: Comparison between male and female foramen measurements.

			male	female	t. test	P. value
L3-L4 LF	**APD**	**Mean ± SD**	0.74 ± 0.15	0.82 ± 0.14	2.793	0.006
	H	**Mean ± SD**	1.97 ± 0.25	1.94 ± 0.19	0.909	0.365
L3 L4 RF	**APD**	**Mean ± SD**	0.74 ± 0.10	0.74 ± 0.18	0.079	0.937
	H	**Mean ± SD**	2.04 ± 0.18	1.91 ± 0.21	3.487	0.001
L4-L5 LF	**APD**	**Mean ± SD**	0.68 ± 0.10	0.71 ± 0.12	1.802	0.074
	H	**Mean ± SD**	1.81 ± 0.32	1.79 ± 0.14	0.428	0.669
L4-L5 RF	**APD**	**Mean ± SD**	0.67± 0.11	0.70 ± 0.08	1.599	0.112
	H	**Mean ± SD**	1.62 ± 0.45	1.71 ± 0.31	1.321	0.189
L5-S1 LF	**APD**	**Mean ± SD**	0.64 ± 0.11	0.64 ± 0.13	0.002	0.999
	H	**Mean ± SD**	1.77 ± 0.37	1.53 ± 0.17	4.718	0.000

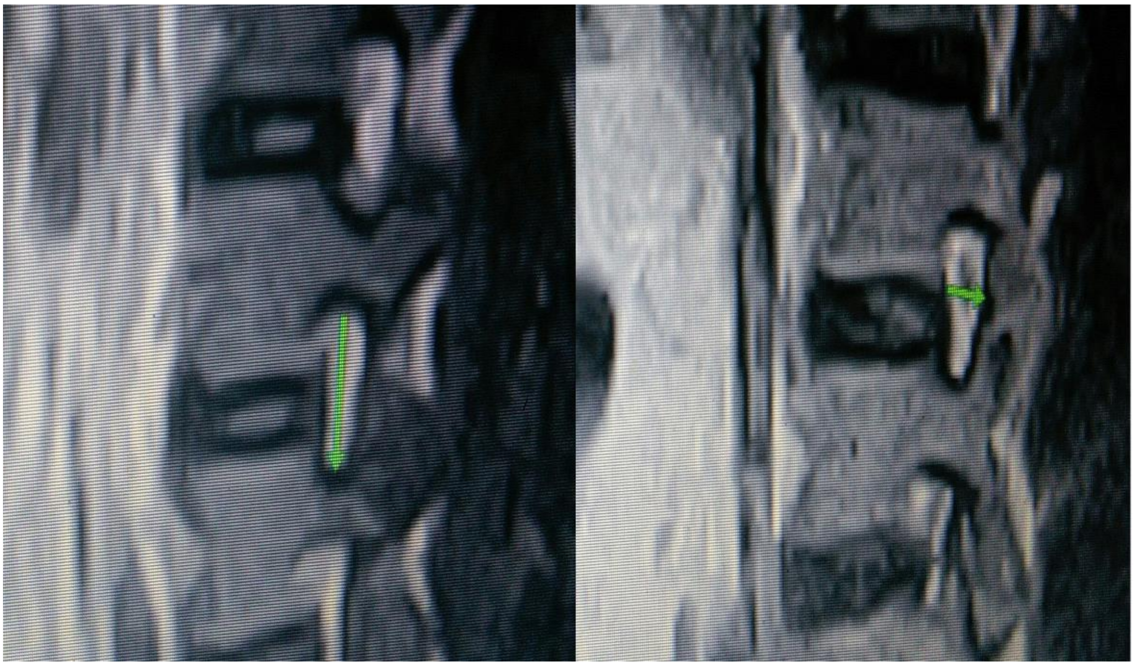

Figure (1): T2 MRI image at L3-L4 level showing: (a) foramen height (H), (b) Foramen Antero Posterior Diameter (APD).

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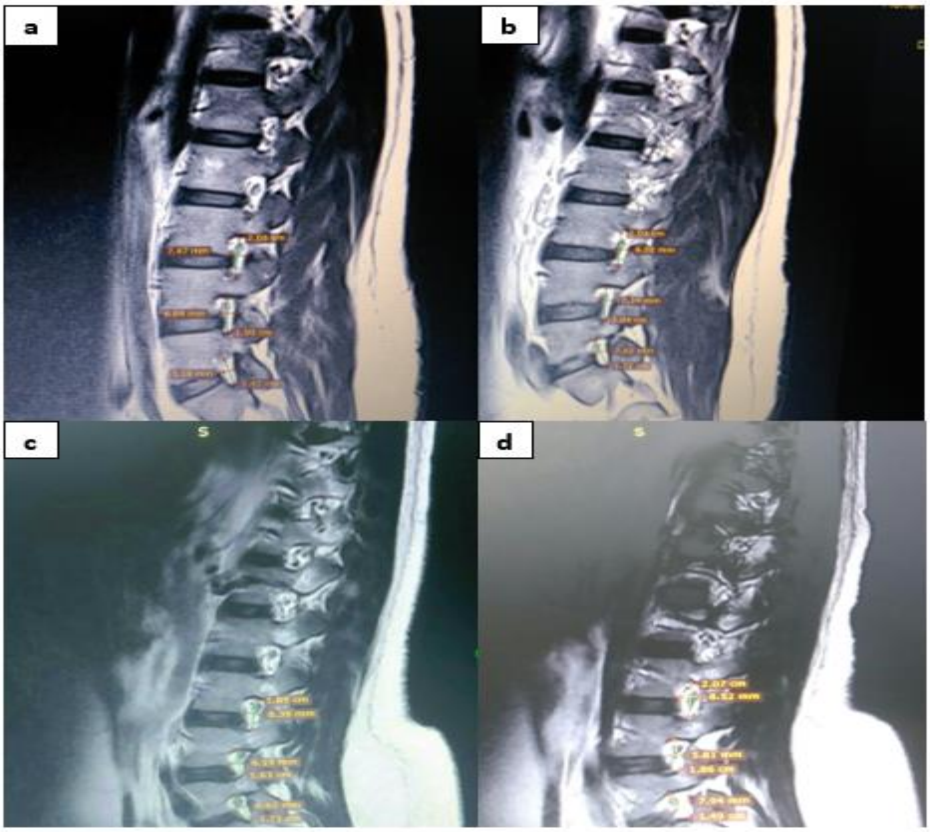

Figure (2): T2 MRI image showing lower three lumbar inter vertebral foramina (IVF) measurements in 33 years old male and 33 years old female; (a,c) right side, (b,d) left side respectively.

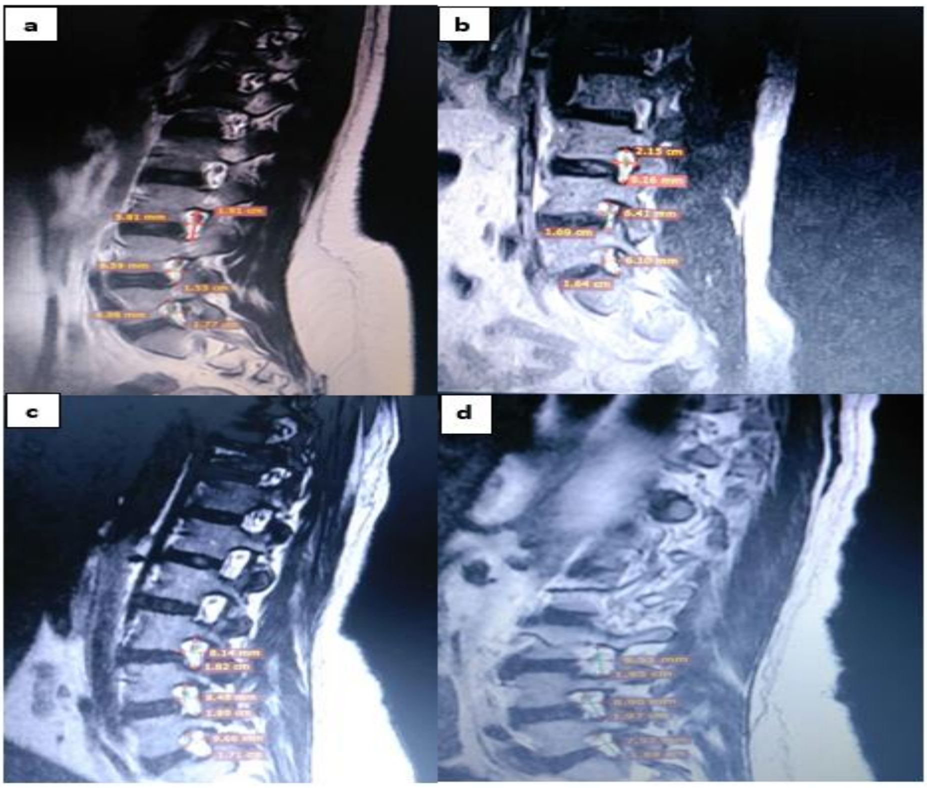

Figure (3): T2 MRI image showing lower three lumbar inter vertebral foramina (IVF) measurements in 43 years old male and 45 years old female; (a,c) right side, (b,d) left side respectively.

DISCUSSION

The present study was designed to determine normal variations in the measurements of lumbar IVF in adults in Egypt using MRI. **(12)** found MRI to be an important diagnostic methodology in description of age changes in lumbar spine and reported that the information of these images helps the physicians to make more accurate evaluation of the IFV better than other tools, like computed tomography (CT). The used method was also in agree with **(13)** who confirmed that MRI offers a clear presentation for the disc anatomy and disco-vertebral complex, which will enable detailed study of degenerative disc changes. This study was conducted on 120 healthy individuals of both sexes who had normal lumbar MRI. The age range of the studied cases was (18-48) years and the mean of age was (32.95 ± 7.64). The number of cases between 18-40years was 90 (75%) while cases between 40-48 years were 30 cases (25%). The current study found that IVF measurements, (H) and (APD) decreased with advance of age of subjects especially at level of L3-L4 and L4-L5 intervertebral foramina. This was in agree with **(14)** who studied 48 subjects of Australian/European ethnic origin (24 male and 24 female) of similar age groups included in the present study. They reported that the IVF height decreased with ageing at mentioned levels. With controversy to the present measurements, they found the greatest decline was seen at L5-S1 levels. (APD) in their study was greater at the L5-S1 level than at higher levels and it increased with ageing while there was no difference between the two age groups in the present study. **(15), (16)** and **(17)** approved that lumbar IVF become narrower in advanced age and the decreased IVF vertical length (Height) can compress the nervous elements passing through. **(18)** Evaluated measurements of all lumbar IVF, they measured their APD and height. and their results were in the same line with the present study from L3 to L5 level IVF measurements. **(19)** Found that the awareness of foramen dimensions could help the surgeons to identify the patency of lumbar IVF in individuals suspected for foramen stenosis. Regarding to the lower three lumbar IVF diameters in relation to sex of individuals, the present study results at L3-L4 level were against **(20)** who demonstrated that a statistically significant difference in the APD measurements of the lumbar IVFs of females being more than those of males on both sides. At L4 - L5 level the present study found that there was no statistically significant difference between male and female regarding APD and H on each side and that was consistent with the values reported by **(21)** and **(19).** At L5-S1 level there was increase in left foramen (LF) height (H) between males than females with no statistically significant difference regarding its (APD) and these results were in the same line with **(22)** who found that the size of the left lumbar IVF was the largest at L5-S1 level. In the current study there was no statistically significant difference between males and females regarding right foramen (H) while there was increase in its (APD) in males than females. Also our results showed a decrease in the measured foramen dimensions in females than males which correlates with **(17)** and this could be attributed to difference in hight between males and females as men are frequently longer than women of the same age. **(15)** Reported similar results at the lower three lumbar IVF levels showing that the decreased foramen height was obvious only in females which could be due to short stature related to the osteoporosis changes of the spine. The decreased female measurements in the present study did not coincide with **(23)** who found that measurements of the males were significantly smaller than females in all lumbar IVF. **(24)** mentioned that the lumbar IVF height is very important because in 15 foramina they studied, 12 nerve roots were compressed by encroachment of sublaxated facets and ligamentum flavum. **(25)** and **(26)** suggested that the dimensions of the lumbar IVF were different between populations and this is may be attributed to the dynamic changes of the spine, axial loading and time of day.

CONCLUSION

Application of this study to share in establishment of Egyptian measurements using Magnetic Resonance Imaging will be of a great value to help clinicians to evaluate patient MRI scans with suspected lumbar foramen stenosis and nerve root compression.

Recommendation:

-Taking larger sample of population will be more useful to determine Egyptian population measurements.

- Large scale of age groups can provide more information about relation with age.

- Many observers can take the measurements of the subjects as it depends on manual measuring methods.

Conflict of interest: None.

Financial disclosure: None.

REFERENCES

1. **Mehrkens A, Müller AM, Valderrabano V, Schären S, Vavken P.** Tissue engineering approaches to degenerative disc disease--a meta-analysis of controlled animal trials. Osteoarthritis Cartilage. 2012 Nov;20(11):1316-25.
2. **Yu H, Hou G, Cao J, Yin Y, Zhao Y, Cheng L.** Mangiferin Alleviates Mitochondrial ROS in Nucleus Pulposus Cells and Protects against Intervertebral Disc Degeneration via Suppression of NF-κB Signaling Pathway. Oxidative Medicine and Cellular Longevity, Jun 11;2021: Article 6632786
3. **Lyu FJ, Cui H, Pan H, Mc Cheung K, Cao X, Iatridis JC, Zheng Z.** Painful intervertebral disc degeneration and inflammation: from laboratory evidence to clinical interventions. Bone Res. 2021 Jan 29;9(1):7.

4. **Grunhagen T, Shirazi-Adl A, Fairbank JC, Urban JP.** Intervertebral disk nutrition: a review of factors influencing concentrations of nutrients and metabolites. Orthop Clin North Am. 2011 Oct;42(4):465-77, vii.
5. **Hitchon PW, Awe OO, Close L, Sukkarieh HG.** Minimally invasive pars approach for foraminal disc herniation. J Clin Neurosci. 2015 Jul;22(7):1128-32.
6. **Peng B, Hao J, Hou S, Wu W, Jiang D, Fu X, Yang Y.** Possible pathogenesis of painful intervertebral disc degeneration. Spine (Phila Pa 1976). 2006 Mar 1;31(5):560-6.
7. **Demondion X, Lefebvre G, Fisch O, Vandenbussche L, Cepparo J, Balbi V.** Radiographic anatomy of the intervertebral cervical and lumbar foramina (vessels and variants). Diagn Interv Imaging. 2012 Sep;93(9):690-697.
8. **Simpson AK, Biswas D, Emerson JW, Lawrence BD, Grauer JN.** Quantifying the effects of age, gender, degeneration, and adjacent level degeneration on cervical spine range of motion using multivariate analyses. Spine (Phila Pa 1976). 2008 Jan 15;33(2):183-6.
9. **Bibby SR, Urban JP.** Effect of nutrient deprivation on the viability of intervertebral disc cells. Eur Spine J. 2004 Dec;13(8):695-701.
10. **Al-Hadidi MT, Abu-Ghaida JH, Badran DH, Al-Hadidi AM, Ramadan HN, Massad DF.** Magnetic resonance imaging of normal lumbar intervertebral foraminal height. Neurosciences (Riyadh). 2003 Jul;8(3):165-70.
11. **Ren W, Cui S, Alini M, Grad S, Zhou Q, Li Z, Razansky D.** Noninvasive multimodal fluorescence and magnetic resonance imaging of whole-organ intervertebral discs. Biomed Opt Express. 2021 May 7;12(6):3214-3227.
12. **Kerr GJ, To B, White I, Millecamps M, Beier F, Grol MW, Stone LS, Séguin CA.** Diet-induced obesity leads to behavioral indicators of pain preceding structural joint damage in wild-type mice. Arthritis Res Ther. 2021 Mar 22;23(1):93.
13. **Thorpe Lowis CG, Xu Z, Zhang M.** Visualisation of facet joint recesses of the cadaveric spine: a micro-CT and sheet plastination study. BMJ Open Sport Exerc Med. 2018 Feb 28;4(1):e000338.
14. **Toosizadeh N, Nussbaum MA, Bazrgari B, Madigan ML.** Load-relaxation properties of the human trunk in response to prolonged flexion: measuring and modeling the effect of flexion angle. PLoS One. 2012;7(11):e48625.
15. **Radiographic Measurement of Lumbar Spinal Canal Size and Canal/Body Ratio in Normal Adult Saudis.** 2007 March.Neurosurgery Quarterly 17(1):19-22
16. **Gkasdaris G, Tripsianis G, Kotopoulos K, Kapetanakis S.** Clinical anatomy and significance of the thoracic intervertebral foramen: A cadaveric study and review of the literature. J Craniovertebr Junction Spine. 2016 Oct-Dec;7(4):228-235.
17. **Iliescu, Madalina, Bordei, P., Albina, Sandica and Ionescu, C..** "Morphology of the intervertebral foramen: a direct relation with low back pain" ARS Medica Tomitana, vol.18, no.2, 2013, pp.62-65.
18. **Cramer GD, Cantu JA, Dorsett RD, Greenstein JS, McGregor M, Howe JE, Glenn WV.** Dimensions of the lumbar intervertebral foramina as determined from the sagittal plane magnetic resonance imaging scans of 95 normal subjects. J Manipulative Physiol Ther. 2003 Mar-Apr;26(3):160-70.
19. **Soldatos T, Chalian M, Thawait S, Belzberg AJ, Eng J, Carrino JA, Chhabra A.** Spectrum of magnetic resonance imaging findings in congenital lumbar spinal stenosis. World J Clin Cases. 2014 Dec 16;2(12):883-7.
20. **Gkasdaris G, Hourmouzi D, Chaniotakis C, Haritoudis G, Ashrafi MM, Mouselimis D, Kapetanakis S.** CT Assessment of the in vivo Osseous Lumbar Intervertebral Foramen: a Radiologic Study with Clinical Applications. Maedica (Bucur). 2018 Dec;13(4):294-304. Greek, Modern.
21. **Hu E, Shao J, Momin A, Lee MY, Gould HP, Xiao R, Haines CM, Moore DK, Mroz TE, Steinmetz MP**. Comparative Effectiveness Between Primary and Revision Foraminotomy for the Treatment of Lumbar Foraminal Stenosis. Int J Spine Surg. 2020 Aug;14(4):511-517.
22. **Ramadan N, Abd El-Salam MH, Hanon AF .** Identification of sex and age for Egyptians using computed tomography of the first lumbar vertebra. *Egypt J Forensic Sci* 2017 December 6. (7): 22 .
23. **Modi HN, Suh SW, Song HR, Yang JH.** Lumbar nerve root occupancy in the foramen in achondroplasia: a morphometric analysis. Clin Orthop Relat Res. 2008 Apr;466(4):907-13.
24. In vivo dynamic changes of dimensions in the lumbar intervertebral foramen. Spine J. 2015 Jul 1;15(7):1653-9.
25. **Fujiwara A, An HS, Lim TH, Haughton VM.** Morphologic changes in the lumbar intervertebral foramen due to flexion-extension, lateral bending, and axial rotation: an in vitro anatomic and biomechanical study. Spine (Phila Pa 1976). 2001 Apr 15;26(8):876-82.
26. **Hung IY, Shih TT, Chen BB, Guo YL**. Prediction of Lumbar Disc Bulging and **Zhong W, Driscoll SJ, Tsai TY, Wang S, Mao H, Cha TD, Wood KB, Li G.** Protrusion by Anthropometric Factors and Disc Morphology. Int J Environ Res Public Health. 2021 Mar 4;18(5):2521.

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