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Association Between Schmorl's Nodes and Endplate Angulation in Patients Undergoing for Lumber Spine Magnetic Resonance Imaging

Shumaila Bibi[1]

Irfan Ullah[2]

Sana Saleem[3]

Aqib Usman[4]

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Abstract

Pathologist Christian Georg Schmorl first identified Schmorl's node, a particular form of vertebral lesion that primarily affects the thoracolumbar spine, in 1927. (SN). SNs are herniations of the nucleus pulposus (NP) through the cartilaginous and bony endplate into the body of an adjacent vertebra, as opposed to the more well-known horizontal disc herniations into the spinal canal or neural foramina. A strong association has been discovered between several SNs and both lower back pain and lumbar disc degeneration. There is currently no agreement on any of the many hypotheses that have been put forth to explain how SNs develop. While some studies consider SNs as a bone degenerative illness, others see it as a developmental disease. Yet, many researchers believe that one of the reasons behind the SN pathology includes the weakening of the disc and vertebral body. This study aims to find out an association between schmorl's nodes and endplate angulations on Lumber spine Magnetic Resonance Imaging. At Northwest General Hospital Peshawar, a cross-sectional study was conducted. In this 6-month trial, 148 patients with low back pain were included, however, only 44 of them were found to have SNs. Data was collected by Prospective and Retrospective Study and analyzed by using SPSS version 22. It is concluded from this study that many of SNs were observed in

[1]Department of Allied Health Sciences, northwest institute of health sciences Peshawar, Pakistan
e-mail:
[2] Department of Allied Health Sciences, northwest institute of health sciences Peshawar, Pakistan
e-mail:
[3] Department of Allied Health Sciences, northwest institute of health sciences Peshawar, Pakistan
e-mail:
[4]Khyber Medical University, Institute of Health Sciences, Islamabad, Pakistan
e-mail:

patients at various lumber spine levels, and females were seen as more affected by SNs than males. SNs were found to have affected more people with L3 and L2 lumber levels. The final study population included 148 patients with LBP coming to NWGH for Lumber MRI, out of which 44 patients were affected with SNs with a mean patient age of 45.64 years and a standard deviation of 14.332, and a range of 60.

Keywords: Schmorl's Nodes, Schmorl's Nodes, Lumber Spine, Magnetic Resonance Imaging

1 Introduction

1.1 Low Back Pain

One of the most prevalent issues in the world is low back pain, which is primarily addressed in basic healthcare settings. Low back pain can affect individuals of all ages, from youngsters to the old. Pain, stiffness in the muscles, and impairment are a few of the low back pain indications and symptoms. It is situated below the costal border and above the inferior gluteal folds, either with or without leg pain (sciatica) (Chou et al., 2007). The group of individuals with particular or non-specific low back pain will largely determine how the diagnosis is made. the meaning of There is various pathophysiological mechanisms that can cause low back discomfort, including rheumatoid arthritis, osteoporosis, disc herniation, fracture, tumor, and Schmorl's nodes.

1.2 Schmorl's Nodes

Schmorl´s nodes (SN) were named given after a German pathologist who describe this. Schmorl´s nodes (SN) are related to vertebral discs in which herniation defect occurs in disc material in the bony endplate (Z. Wang et al., n.d.). Their direct cause is unknown, Nonetheless, it was assumed that it could have been caused by intervertebral disc weakening (Tobing & Tobing, 2020) and high stresses that cause spinal degeneration. (Mok et al., 2010; Henríquez & Arriaza, 2013) , or due to autoimmune disease reaction (Dar et al., 2009). A strong relationship between the vertebral body's shape and the existence of SN has recently been discovered by certain studies (Dar et al., 2009).

These nodes typically show up in patients who have lumbar MRI for a variety of problems (Plomp et al., 2015), however, they may also be responsible for persistent lower back pain(Mattei & Rehman, 2014) . The prevalence of Schmorl's nodes in the general population ranges from 3.8% to 76%, as reported in studies (Newell et al., 2015; Sonne-Holm et al., 2013).

In 1927, Christian Georg Schmorl, a pathologist, described a distinct type of spinal lesion that occurs mainly in the thoracolumbar region, now recognized as Schmorl's nodes (SN) (Williams et al., 2007) . However, contrary to the initial belief, SNs are actually herniations of the nucleus pulposus (NP) that protrude into the body of an adjoining vertebra via the cartilaginous and bony endplate. Such SNs are not as frequent as the horizontal disc herniations that tend to protrude into the neural foramina or spinal canal (Abu-Ghanem et al., 2013). Several studies demonstrate the strong association between multiple SNs, lumbar disc degeneration, and lower back discomfort (Wu et al., 2006). Many theories have been put up to explain the pathophysiology of SNs; however, none of these theories are currently in agreement. SNs disease is considered a degenerative bone disease by some researchers (Abbas et al., 2017), while it is a developmental illness by others (Kovacs et al., 2013) . But many researchers think that one of the main reasons that cause SN pathology include the weakening of the disc and vertebral bodies (Jensen et al., 2008). Direct damage to the vertebrae is another factor in the formation of SNs (Smartz et al., 2012). Zhang et al. (Y. Zhang et al., 2009)propose that autoimmunity is likely to have a role in symptomatic SNs. Although the considerable study has gone into characterizing SNs, questions about their clinical importance, etiology, and therapy still exist.

Many pathologies or lesions of the endplate have been generally considered SN. About 150 years ago Luschka first recognized this but Schmorl further described in detail (Rijn et al., 2005) The relationship between Schmorl's nodes and their pathogenic causes, such as congenital (Inborn) conditions or injuries, as well as the links between them and disc degeneration and back pain, are still up for debate. Even the relationship between Schmorl's nodes and age is not entirely evident. Schmorl's nodes had no upper age limit; they were discovered at all ages(Vital et al., 2003), while they were more frequently observed in older adults(Marshman et al., 2007) or appeared equally frequently in persons under and over 50. (Kuisma et al., 2006) These disparities are caused by various study methods and definitions of Schmorl's nodules, among other things. This could have affected endplate lesions' frequency and distribution pattern as well as their tendency to form biased or weak associations. The frequency rate of Schmorl's nodes reported varies dramatically from 9% to 75%,(24), (Schmorl, 1903; Schmorl et al., 1971; Hilton et al., 1981) Reported Schmorl's nodule frequency rates varied dramatically between 9% and 75%, (Schmorl, 1903; Schmorl et al., 1971; Hilton et al., 1981)those which is assessed by cadaver spines is much higher than that detected and assessed by magnetic resonance (MR) image. Schmorl's nodules, on the other hand, are typically simply defined as local "depressions" or "defects" on the endplate. This is particularly true in radiological examinations, where Schmorl's nodules may be difficult to identify from other endplate morphological abnormalities. It is evident that there are other pathologies affecting the vertebral endplates besides Schmorl's nodes. Additional endplate lesions have been reported, including fracture (Keyes et al., 2023), microtrauma (Fahey et al., 1998) , destructive endplate lesions (Bray et al., 1998), vertebral rim lesions (Schmorl et al., 1971), and endplate calcification (Vernon et al., 1977; Martel et al., 1976).

Unfortunately, there are currently no comprehensive studies of lumbar endplate lesions. Modic changes in vertebral endplate signaling's clinical significance are still debatable, and their underlying pathophysiology is mostly unknown. (Dudli et al., 2018)

Complete studies of endplate lesions using large cadaver specimens are needed to advance our knowledge of endplate lesions. Because such studies can not only contribute to our understanding of the local pathological interactions between vertebral bodies and intervertebral discs but can also provide important clues. New insights into the etiology of degeneration of disc and low back pain.

Disc herniation is referred to as Schmorl's node in some cases. A herniated disc is a condition where the outer annulus fibrosis of the disc ruptures and the nucleus pulposus extends beyond the damaged outer annulus. In most intervertebral herniated discs, the herniated disc slides laterally on both sides of the spine, causing an intervertebral herniated disc. However, in Schmorl's node, a disc defect causes a herniated disc to slide up and down into the adjacent vertebrae, causing an intervertebral herniated disc.

Schmorl's nodes are usually asymptomatic, but inflammation and swelling of the surrounding vertebrae can cause low back pain. Rarely, Schmorl's nodes can become infected or irritate nerves down the spine, causing pain, numbness, or weakness of the muscle that spreads to the legs down.

However, the exact cause of Schmorl's nodes is still not fully understood. However, some of Schmorl's nodes are associated with vertical forces transmitted through weakened vertebrae (e.g., excessive walking, prolonged standing, landing after high jumps, driving a car, workload, inappropriate It has been found that it can be caused by endplate.

1.3 Vertebral Endplate

The endplates, which divide the intervertebral disc from the surrounding vertebrae, are two layers of cartilage and bone. Between the intervertebral discs and the vertebral trabeculae lie the vertebral endplates, which have a porous nature. The intervertebral discs are supplied with nutrients through the vertebral endplates, which also serve as load-transmitting structures Endplates have thicker outer portions than central parts. (Pouriesa et al., 2013) Endplates become more rigid and strong as they go away from the center (Duran et al., 2017). The biomechanical function of endplates depends on their structural stability and typical form. For lumbar intervertebral disc herniation and endplate fraction, the risk factors are abnormal morphological alterations (Albert et al., 2008;F. Wang et al., 2011). Endplate defects are pathological alterations to the vertebrae's lower or upper surface. An endplate defect classification system was developed using data from autopsies and imaging studies. Previous studies have reported a variety of endplate deficiencies. such as corner flaws, local defects, Schmorl's nodes, notches, fractures, erosion, and so forth (Dudli et al., 2015; Adams et al., 2000; Williams et al., 2007)

2 Radiological Diagnosis of Schmorl Nodes

2.1 Plain Radiograph

They typically involve the inferior endplate of the lower thoracic and lumbar vertebral bodies and are tiny, nodular lucent lesions. However, it is not unusual for both the inferior and superior endplates to be involved. A possible sclerotic margin is evident.

2.2 Computed Tomography

Schmorl nodes can be more easily recognized on CT scans, which display the same radiographic pattern.

2.3 Magnetic Resonance Imaging

Schmorl nodes are best diagnosed with MRI since they can be observed on sagittal MRI sequences (Saluja et al., 1986). Schmorl's nodes typically exhibit similar signal characteristics to the adjacent disc and may have a thin margin of sclerosis (Modic et al., 1988). Previous studies have identified a correlation between SNs and lumbar disc degeneration disease (DDD), with SNs being linked to the severity of DDD (Sadiq, 2019; Jevtic et al., n.d). MRI is the imaging modality that is most commonly used to evaluate disc degeneration and is the best tool for evaluating DDD. DDD was graded using the Schneiderman method in the following stages.

Stage 0: In stage 0 the signal of the disc does not change.

Stage 1: On the T2 sequence signal intensity of the disc is a mild decrease.

Stage 2: The height of the disc is preserved but the disc is markedly hypointense. Stage 3: The signal intensity of the disc and height of the disc is decreased.

3 Literature Review

Three hundred twenty-four (324) adult patients were involved in Israa Mohammed Sadiq's cross-sectional analytical study, which was published in the Egyptian Journal of Radiology and Nuclear Medicine in 2019. These patients were all recommended by their doctors for lumbosacral MRIs at MRI units. The study included a sample of 206 females and 118 males who met the following demographic criteria: the female-to-male ratio was 1.7:1; the average age was 45.5 ± 12.48 years; the average weight was 79.2 ± 101 kg; and the average height was 167.1 ± 6 cm. Schmorl's nodes were detected in 22.2% of the participants, with 41% having them at one level and 59% having them at more than one level. Males had a significantly higher prevalence of SNs than females ($P = 0.03$), with 28% of males and 18.8% of females having SNs. The average age of SN patients was 55 years, with 5.5% being under 40, 52.8% being between 40 and 59, and 41.7% being 60 or older. The frequency of SN rose substantially with age ($p = 0.0001$) and was lowest in the younger age group (40 years). There were a total of 1944 discs from 324 patients. On 144 CDs, SN could be seen. In 41% of patients, there was just one-disc level, while in 59% there were many disc levels. The most afflicted L1-L2 was 23.6%, then L2-L3, L3-L4, L4-L5, T12-L1, and L5-S1 in that order (20.8%, 18.1%, 16.7%), 12.5%, and 8.3%, respectively.). The results of SN-affected levels' degenerations were as follows: A score of 0 was assigned to 54 cases (37.5%), a score of 1 to 52 cases (36.1%), a score of 2 to 20 cases (13.9%), and a score of 3 to 18 cases (12.5%). P=0.76 for all assessments indicates that the presence of SNs had no effect on the degree of disc degeneration. 20.8% of those with SN in the lumbar spine also had disc bulges or herniations (30 levels). As P = 0.62 (OR = 1.4) indicates, there was no statistically significant correlation between SN and disc bulge/herniation. 22 disc levels (13.9%) saw the coexistence of MC and SN. As P = 0.00001 (OR = 7.9) indicates, there was a significant relationship between MC and SN. Schmorl's node, which affects the endplate angulation of the lumber spine, is frequently found in individuals who complain of lower back pain.

4 Methodology

This research has been designed as a Cross-Sectional study. The study has been conducted at Northwest General Hospital and Research Center This study has been completed in 6 Months. 148 Calculated by the Raosoft Sample Size Software through the Convenience sampling technique. All those patients with age 18 to 80 years. All those patients with spinal surgery performed. Individuals with endplate degeneration, kyphosis, and scoliosis Descriptive statistics like quartiles, range, standard deviation, and the means of the mean. Data is presented in the form of graphs such as bar graphs, pie charts, etc. Pearson correlation between variables to measure linear correlation. T-test and reliability analysis were also carried out for scale measurement. For all data analysis, the Statistical Package for the Social Sciences (SPSS) version was utilized (Marshman et al., 2007).

5 Result

This study was conducted at Northwest General Hospital Peshawar, Radiology Department MRI Unit. The study lasted for six months. In this study, 148 patients with low back discomfort who had been referred for a lumber MRI scan were included. Out of these 44 patients were affected with SNs with mean Age of 45.64 years (standard deviation = 14.332) and an age range between 20-80 years as shown in Table. 1. All eligible MRI reports were obtained from the participant and analyzed. The MRI unit of the Radiology Department at NWGH and the research center compromised 0.35 Tesla MRI machines and 2 MRI technologists.

5.1 Gender-Wise Distribution of Patients

In our study, a total of 148 individuals with Low Back Pain were examined, and 44 reports were collected from those patients who had Schmorl's nodes. Out of these 19(43.2%) patients were male and the remaining 25 (56.8%) were female as shown in Table. 2.

5.2 Mean Values of Various Endplates Angulation

Table 3. shows 13 patients out of 44 have L1 angulation that is affected by SNs, each patient has different angulation but the mean angulation noted was 154.408 (cranial) and 160.708 (caudal) with the standard deviation (SD) of 17.45 and 15.52 consecutively. At the L2 level, mean angulation of 157.85 (cranial) and 163.683 (caudal) with SD of 10.70 and 10.23. Similarly, the endplate angulation was reported higher at L3 cranial endplate at 160.55 compared to the caudal of 154.955 with SD=15. On contrary at the L4 level, higher angulation was seen in the caudal endplate (164.513; SD=5.67) compared to the cranial (162.35; SD=7.58). Finally, greater endplate angulation was reported in the caudal at an L5 level of 160.4 with SD=10.69 while smaller was seen at L5 cranial 156.54 with SD=13.759.

Table. 3 Mean Results of Endplate Angulations at Various Level of Lumbar Spine

	Mean	N	Std. Deviation
Age	45.64	44	14.332
Patient with SN	1.00	44	.000
Patient with EP Defects	1.00	44	.000
Levels		44	
L1 Cranial Angle	154.408	13	17.4588
L1 Caudal Angle	160.708	13	15.5242
L2 Cranial Angle	157.850	18	10.7053
L2 Caudal Angle	163.683	18	10.2392
L3 Cranial Angle	160.550	22	15.8550
L3 Caudal Angle	154.955	22	15.1789
L4 Cranial Angle	162.350	8	7.5887
L4 Caudal Angle	164.513	8	5.6759
L5 Cranial Angle	156.540	5	13.7593
L5 Caudal Angle	160.400	5	10.6921

Association between Various Endplates Angulation

Table. 4 Correlations between various endplate angulations at spinal levels

	L1 Cranial	L1 Cranial	L2 Cranial	L2 Cranial	L3 Cranial	L3 Cranial	L4 Cranial	L4 Cranial	L5 Cranial	L5 Cranial
L1 Cranial	1	-0.167	-0.452	-0.469	0.695	-0.442	.a	.a	.a	.a
		0.586	0.368	0.348	0.511	0.709	.	.	.	.
L1 Caudal	-0.167	1	-0.804	0.244	0.996	-0.92	.a	.a	.a	.a
	0.586		0.054	0.641	0.058	0.256	.	.	.	.
L2 Cranial	-0.452	-0.804	1	0.436	-0.236	0.117	.a	.a	.a	.a
	0.368	0.054		0.071	0.541	0.764	.	.	.	.
L2 Caudal	-0.469	0.244	0.436	1	-0.118	-0.073	.a	.a	.a	.a
	0.348	0.641	0.071		0.763	0.852	.	.	.	.
L3 Cranial	0.695	0.996	-0.236	-0.118	1	-0.079	1.000**	-1.000**	.a	.a
	0.511	0.058	0.541	0.763		0.728	.	.	.	.

L3 Caudal	-0.442	-0.92	0.117	-0.073	-0.079	1	1.000**	-1.000**	.a	.a
	0.709	0.256	0.764	0.852	0.728		.	.	.	.
L4 Cranial	.a	.a	.a	.a	1.000**	1.000**	1	0.092	-1.000**	-1.000**
	.	.	.	.	.	.		0.828	.	.
L4 Caudal	.a	.a	.a	.a	-1.000**	-1.000**	0.092	1	1.000**	1.000**
	.	.	.	.	.	.	0.828		.	.
	.a	.a	.a	.a	.a	.a	-1.000**	1.000**	1	0.441

Table 4. suggest Pearson's correlation between different spinal levels' endplates angulation. Schmorl's node-affected L1 endplate angulation was reported negatively (r=-0.452, -0.469, and -0.442) correlated with L2 and L3 endplates angulation except L3 cranial endplate which was positively (r=0.695) correlated while the p-value was not significant. L3 cranial endplate angle positively correlated with L1 level (cranial, r=0.695; caudal, r=0.996) while L3 caudal negatively correlated with L1 (cranial, r=- 0.442; caudal, r=-0,92). Both L3 endplates were seen as strongly positively correlated L4 endplates angulation with p<0.01 on the 2-tailed test (significant). Finally, in L4 both endplates' angles were strong positive correlated with L5 both endplates and in L3 both endplates with p-value significant at 0.01 at the 2-tailed test (Pearson's correlation). While L5 caudal endplate angulation was weakly correlated with r=0.441 with an insignificant value of p<0.457.

5.3 Schmorl's nodes frequency at a spinal level

The highest frequency of SNs (Marshman et al., 2007) was reported at the L3 level on both endplates, followed by L2 (18 on both endplates), L1 level (13), and L4 level (8) while the least (5) SNs found at L5 level of the lumbar spine as shown in figure 5.

6 Discussion

MRI is a type of imaging modality used to image the anatomy and physiological processes of the human body via non-ionizing radiation. The MRI scanner uses strong magnetic fields, radio waves, and magnetic field gradients to produce precise images of the body's organs. MRI scanners are used to diagnose illness, staging, and follow-up. Superior soft-tissue contrast is provided by MRI than CT. MRI scanners are more sensitive in detecting intervertebral disc illness, it made it easier to identify SNs (Schmorl's nodes). Acute, traumatic, and symptomatic SNs were diagnosed using MRI (Magnetic Resonance Imaging). Schmorl's nodes are NP herniations through a cartilaginous and hard endplate into the body of a nearby vertebra. This herniated tissue causes an Angulation deformity superiorly and inferiorly of the affected vertebra. This final study included 148 patients with Lower back pain out of which 44 patients of age (16 to 80) were having SNs and the prevalence of SNs is highest at ages (20 to 80) years.

As mentioned above there is a high prevalence of SNs in females (56.8%), the resulting study also indicates that females are more affected by SNs, whereas males (43.2%) are affected by SNs. Hence our results are Proportional to the previous studies showing that men are more affected by SNs than women.

The current study indicates that the L2 and L3 lumber levels have the largest reported number of Schmorl's nodes. Compared to other lumber vertebrae, the L2 and L3 vertebrae's caudal and cranial endplates have the most SNs.

This is a rare case and the first time carried out as an association of schmorl's node and endplate angulation in patients with low back pain on lumber spine MRI. 13 patients out of 44 have L1 angulation that is affected with SNs, and each patient has different angulation but the mean angulation noted was 154.408 (cranial) and 160.708 (caudal). At the L2 level, the mean angulation of 157.85 (cranial) and 163.683 (caudal). Similarly, the endplate angulation was reported higher at L3 cranial endplate at 160.55 compared to the caudal at 154.955. On contrary at the L4 level, higher angulation was seen in the caudal endplate (164.513) compared to the cranial (162.3500). Finally, greater endplate angulation was reported in the caudal at an L5 level of 160, while smaller was seen at L5 cranial 156.54. 18 (18) determined quality of life by SF36 he found that quality of life of PMPS patients are effected (19).

7 Conclusion

It is concluded from this study many SNs were observed in patients at various lumber spine levels, and females were more affected by SNs than males. MRI is the most sensitive modality in detecting SNs. Schmorl's nodes were found to have affected more people between the ages (of 20 to 80). Both multiple and single SNs are observed. Endplate angulation was mostly affected at L2 and L3 Lumber levels both cranially and caudally.

8 References

A Systematic Pathological Study of the Dorsolumbar Spine, D10-L5—ProQuest. (n.d.). Retrieved April 5, 2023, from https://www.proquest.com/openview/11f9c8f9d92ab7eecec024dfe2eeb951/1?pq-origsite=gscholar&cbl=51922&diss=y

A Three-Year Follow-up of Lumbar Spine Endplate (Modic) Chan... : Spine. (n.d.). Retrieved April 5, 2023, from https://journals.lww.com/spinejournal/Abstract/2006/07010/A_Three_Year_Follow_up_of_Lumbar_Spine_Endplate.14.aspx

Abbas, J., Slon, V., Stein, D., Peled, N., Hershkovitz, I., & Hamoud, K. (2017). In the quest for degenerative lumbar spinal stenosis etiology: The Schmorl's nodes model. *BMC Musculoskeletal Disorders*, *18*(1), 164. https://doi.org/10.1186/s12891-017-1512-6

Abu-Ghanem, S., Ohana, N., Abu-Ghanem, Y., Kittani, M., & Shelef, I. (2013). Acute Schmorl Node in Dorsal Spine: An Unusual Cause of a Sudden Onset of Severe Back Pain in a Young Female. *Asian Spine Journal*, *7*(2), 131–135. https://doi.org/10.4184/asj.2013.7.2.131

Albert, H. B., Kjaer, P., Jensen, T. S., Sorensen, J. S., Bendix, T., & Manniche, C. (2008). Modic changes, possible causes and relation to low back pain. *Medical Hypotheses*, *70*(2), 361–368. https://doi.org/10.1016/j.mehy.2007.05.014

Chou, R., Qaseem, A., Snow, V., Casey, D., Cross, J. T., Shekelle, P., & Owens, D. K. (2007). Diagnosis and Treatment of Low Back Pain: A Joint Clinical Practice Guideline from the

American College of Physicians and the American Pain Society. *Annals of Internal Medicine*, *147*(7), 478–491. https://doi.org/10.7326/0003-4819-147-7-200710020-00006

Course of Modic 1 Six Months After Lumbar Posterior Osteosyn... : Spine. (n.d.). Retrieved April 5, 2023, from https://journals.lww.com/spinejournal/Abstract/2003/04010/Course_of_Modic_1_Six_Months_After_Lumbar.17.aspx

Dar, G., Peleg, S., Masharawi, Y., Steinberg, N., May, H., & Hershkovitz, I. (2009). Demographical Aspects of Schmorl Nodes: A Skeletal Study. *Spine*, *34*(9), E312. https://doi.org/10.1097/BRS.0b013e3181995fc5

DEGENERATIVE CHANGES IN THE INTERVERTEBRAL DISCS OF THE LUMBAR SPINE AND THEIR SEQUELAE | Rheumatology | Oxford Academic*. (n.d.). Retrieved April 5, 2023, from https://academic.oup.com/rheumatology/article-abstract/16/1/13/1775290

Degenerative disk disease: Assessment of changes in vertebral body marrow with MR imaging. | Radiology. (n.d.). Retrieved April 6, 2023, from https://pubs.rsna.org/doi/abs/10.1148/radiology.166.1.3336678

Dudli, S., Enns-Bray, W., Pauchard, Y., Römmeler, A., Fields, A. J., Ferguson, S. J., & Helgason, B. (2018). Larger vertebral endplate concavities cause higher failure load and work at failure under high-rate impact loading of rabbit spinal explants. *Journal of the Mechanical Behavior of Biomedical Materials*, *80*, 104–110. https://doi.org/10.1016/j.jmbbm.2018.01.019

Dudli, S., Haschtmann, D., & Ferguson, S. J. (2015). Persistent degenerative changes in the intervertebral disc after burst fracture in an in vitro model mimicking physiological post-traumatic conditions. *European Spine Journal*, *24*(9), 1901–1908. https://doi.org/10.1007/s00586-014-3301-3

Duran, S., Cavusoglu, M., Hatipoglu, H. G., Sozmen Cılız, D., & Sakman, B. (2017). Association between Measures of Vertebral Endplate Morphology and Lumbar Intervertebral Disc Degeneration. *Canadian Association of Radiologists Journal*, *68*(2), 210–216. https://doi.org/10.1016/j.carj.2016.11.002

Henríquez, M., & Arriaza, B. (2013). DISTRIBUCIÓN Y FRECUENCIA DE NÓDULOS DE SCHMÖRL EN LA COLUMNA VERTEBRAL DE POBLACIONES PREHISPÁNICAS DE ARICA: ¿INDICADORES DE LA CARGA LABORAL? *Chungará (Arica)*, *45*(2), 311–319. https://doi.org/10.4067/S0717-73562013000200007

Jensen, T. S., Karppinen, J., Sorensen, J. S., Niinimäki, J., & Leboeuf-Yde, C. (2008). Vertebral endplate signal changes (Modic change): A systematic literature review of prevalence and association with non-specific low back pain. *European Spine Journal*, *17*(11), 1407–1422. https://doi.org/10.1007/s00586-008-0770-2

Kovacs, F. M., Royuela, A., Arana, E., Estremera, A., Amengual, G., Asenjo, B., Sarasíbar, H., Galarraga, I., Martínez, C., & Abraira, V. (2013). Re: ISSLS prize winner: lumbar vertebral endplate lesions associations with disc degeneration and back pain history. Spine 2012;37:1490-6. *Spine*, *38*(1), 93. https://doi.org/10.1097/BRS.0b013e31827885a0

Magnetic resonance imaging appearances of different discovertebral lesions | SpringerLink. (n.d.). Retrieved April 6, 2023, from https://link.springer.com/article/10.1007/s003300000727

Mattei, T. A., & Rehman, A. A. (2014). Schmorl's nodes: Current pathophysiological, diagnostic, and therapeutic paradigms. *Neurosurgical Review*, *37*(1), 39–46. https://doi.org/10.1007/s10143-013-0488-4

McCall, I. W., Park, W. M., O'Brien, J. P., & Seal, V. (1985). Acute traumatic intraosseous disc herniation. *Spine*, *10*(2), 134–137. https://doi.org/10.1097/00007632-198503000-00004

Mechanical Initiation of Intervertebral Disc Degeneration: Spine. (n.d.). Retrieved April 5, 2023, from https://journals.lww.com/spinejournal/Abstract/2000/07010/Mechanical_Initiation_of_Intervertebral_Disc.5.aspx

Mok, F. P. S., Samartzis, D., Karppinen, J., Luk, K. D. K., Fong, D. Y. T., & Cheung, K. M. C. (2010). ISSLS Prize Winner: Prevalence, Determinants, and Association of Schmorl Nodes of the Lumbar Spine With Disc Degeneration: A Population-Based Study of 2449 Individuals. *Spine*, *35*(21), 1944. https://doi.org/10.1097/BRS.0b013e3181d534f3

Newell, N., Grant, C. A., Izatt, M. T., Little, J. P., Pearcy, M. J., & Adam, C. J. (2015). A semiautomatic method to identify vertebral end plate lesions (Schmorl's nodes). *The Spine Journal*, *15*(7), 1665–1673. https://doi.org/10.1016/j.spinee.2015.04.027

Plomp, K., Roberts, C., & Strand Vidarsdottir, U. (2015). Does the correlation between schmorl's nodes and vertebral morphology extend into the lumbar spine? *American Journal of Physical Anthropology*, *157*(3), 526–534. https://doi.org/10.1002/ajpa.22730

Pouriesa, M., Fouladi, R. F., & Mesbahi, S. (2013). Disproportion of end plates and the lumbar intervertebral disc herniation. *The Spine Journal*, *13*(4), 402–407. https://doi.org/10.1016/j.spinee.2012.11.047

Reverse transformation of Modic Type 2 changes to Modic Type 1 changes during sustained chronic low-back pain severity in: Journal of Neurosurgery: Spine Volume 6 Issue 2 (2007) Journals. (n.d.). Retrieved April 5, 2023, from https://thejns.org/spine/view/journals/j-neurosurg-spine/6/2/article-p152.xml

Rijn, J., Klemetsö, N., Reitsma, J., Majoie, C., Hulsmans, F.-J., Peul, W., Stam, J., Bossuyt, P., & Heeten, G. (2005). Observer Variation in MRI Evaluation of Patients Suspected of Lumbar Disk Herniation. *AJR. American Journal of Roentgenology*, *184*, 299–303. https://doi.org/10.2214/ajr.184.1.01840299

Sadiq, I. M. (2019). Lumbar spine Schmorl's nodes; prevalence in adults with back pain, and their relation to vertebral endplate degeneration. *Egyptian Journal of Radiology and Nuclear Medicine*, *50*(1), 65. https://doi.org/10.1186/s43055-019-0069-9

Schmorl, G. (1903). Verh. Dtsch. Path. *Ges*, *6*, 109.

Schmorl's Nodes on Magnetic Resonance Imaging: Their Inciden... : Spine. (n.d.). Retrieved April 5, 2023, from https://journals.lww.com/spinejournal/Abstract/1994/02001/Schmorl_s_Nodes_on_Magnetic_Resonance_Imaging_.12.aspx

Sonne-Holm, S., Jacobsen, S., Rovsing, H., & Monrad, H. (2013). The epidemiology of Schmorl's nodes and their correlation to radiographic degeneration in 4,151 subjects. *European Spine Journal*, *22*(8), 1907–1912. https://doi.org/10.1007/s00586-013-2735-3

The association of lumbar intervertebral disc degeneration on magnetic resonance imaging with body mass index in overweight and obese adults: A population-based study—Samartzis—2012—Arthritis & Rheumatism—Wiley Online Library. (n.d.). Retrieved April 5, 2023, from https://onlinelibrary.wiley.com/doi/abs/10.1002/art.33462

The canine intervertebral disk. Part Two: Degenerative changes—Nonchondrodystrophoid versus chondrodystrophoid disks | Journal of the American Animal Hospital Association. (n.d.). Retrieved April 5, 2023, from https://meridian.allenpress.com/jaaha/article-abstract/34/2/135/175510/The-canine-intervertebral-disk-Part-Two

The human spine in health and disease | New York; Grune & Stratton; 2.ed; 1971. Xi,504 p. Ilus. | colecionaSUS. (n.d.). Retrieved April 5, 2023, from https://pesquisa.bvsalud.org/portal/resource/pt/biblio-925196

THE NORMAL AND PATHOLOGICAL PHYSIOLOGY OF THE NUCLEUS PULPOS... : JBJS. (n.d.). Retrieved April 5, 2023, from https://journals.lww.com/jbjsjournal/Abstract/1932/14040/THE_NORMAL_AND_PATHOLOGICAL_PHYSIOLOGY_OF_THE.20.aspx

The Pathogenesis of Schmorl's Nodes in Relation to Acute Tra... : Spine. (n.d.). Retrieved April 5, 2023, from https://journals.lww.com/spinejournal/Abstract/1998/11010/The_Pathogenesis_of_Schmorl_s_Nodes_in_Relation_to.4.aspx

Tobing, J. F., & Tobing, S. D. A. L. (2020). The use of kyphoplasty balloon-assisted vertebroplasty in treating chronic symptomatic schmorl node in a young adult patient: A case report. *Jurnal Orthopaedi Dan Traumatologi Indonesia*, *3*(2), Article 2. https://doi.org/10.31282/joti.v3n2.58

Traumatic lesions of the discovertebral junction in the lumbar spine: American Journal of Roentgenology: Vol. 127, No. 3 (AJR). (n.d.). Retrieved April 5, 2023, from https://www.ajronline.org/doi/abs/10.2214/ajr.127.3.457

Wang, F., Jiang, J.-M., Deng, C.-H., Wang, F.-L., Fu, Z.-Z., & Zhang, Z.-F. (2011). Expression of Fas receptor and apoptosis in vertebral endplates with degenerative disc diseases categorized as Modic type I or II. *Injury*, *42*(8), 790–795. https://doi.org/10.1016/j.injury.2011.01.034

Wang, Z., Yuan, L., Ma, D., & Yang, J. (n.d.). *18F-FDG PET/CT can differentiate vertebral metastases from Schmorl's nodes by distribution characteristics of the 18F-FDG*.

Williams, F. M. K., Manek, N. J., Sambrook, P. N., Spector, T. D., & Macgregor, A. J. (2007). Schmorl's nodes: Common, highly heritable, and related to lumbar disc disease. *Arthritis Care & Research*, *57*(5), 855–860. https://doi.org/10.1002/art.22789

Wu, H.-T. H., Morrison, W. B., & Schweitzer, M. E. (2006). Edematous Schmorl's nodes on thoracolumbar MR imaging: Characteristic patterns and changes over time. *Skeletal Radiology*, *35*(4), 212–219. https://doi.org/10.1007/s00256-005-0068-y

Zhang, N., Li, F.-C., Huang, Y.-J., Teng, C., & Chen, W.-S. (2010). Possible key role of immune system in Schmorl's nodes. *Medical Hypotheses*, *74*(3), 552–554. https://doi.org/10.1016/j.mehy.2009.09.044

Zhang, Y., Sun, Z., Liu, J., Wang, S., Ren, F., & Guo, X. (2009). Features of intervertebral disc degeneration in rat's aging process. *Journal of Zhejiang University SCIENCE B*, *10*(7), 522–527. https://doi.org/10.1631/jzus.B0820295