

Adolescent Lumbar Intervertebral Disc Herniation: Causes, Diagnosis and Treatment

Mahmoud El-Qadi^{1*}, Mohamed A. Thabit², Ehab Mohamed Eissa³, Alaa Abdel Fattah Abdel Aziz⁴, Ramy Kamel⁵

Neurosurgery department, Faculty of medicine, Cairo university, Egypt

*elqadi36@gmail.com

ABSTRACT

Background:

Lumbar disc herniation in adolescents is a relatively rare condition among those cases presented with low back pain. Trauma & genetics are the commonest predisposing factors in adolescent lumbar disc herniation. The clinical presentations of disc herniation in adolescents differ from those of the adults. Back pain is not all marked in adolescent patients.

Objective:

this study was subjected to discuss the etiology, diagnosis and treatment modalities and the variable outcomes for both medical and surgical treatment of lumbar disc herniation in adolescents.

Patients and Methods:

This prospective study was conducted on twenty patients between 10 and 19 years old presenting with lumbar disc herniation, managed and treated conservatively and/or surgically in *Neurosurgery Department at Kasr Al Ainy School of medicine, Cairo University* in the period from October 2015 to September 2016 with 12 months follow-up period.

Results:

in our study the peak incidence was between 17 and 19 years old (83.3% of males and 75% of females. Most of patients in our study were males (12 patients, 60%) with male: female ratio 1.5: 1. Twelve patients (60%) gave a positive family history, also 9 cases (45%) had a history of back trauma prior to affection with lumbar disc herniation. All the cases (100%) were presented with sciatic pain while only half of them had low back pain, Also 2 cases were presented with motor deficit. After performing MRI of lumbosacral spine (investigation of choice) for the patients, L5-S1 disc level was the most common level affected (50% of cases). All the patients were subjected to medical treatment which was effective in 40% of the cases and surgical treatment was the only curative method in 12 cases (60%). Half of the operated patients (6 patients) underwent conventional open laminectomy and discectomy with foraminotomy, 6 patients were operated upon using micro-discectomy with foraminotomy. In our study, the outcome was excellent in 90% of cases as they had significant to complete relief of pain and significant

improvement in the neurological deficits was achieved. While 10% of cases had moderate relief of pain and continued on some medical treatment.

Conclusion:

Lumbar disc herniation in adolescents is not as common as in adults but it's thought to be increasing in the society and it is mostly due to trauma. Diagnosis to a large extent is similar to adults. Conservative treatment is less effective for adolescent patients as compared with adults, even though it remains the first-line treatment for adolescent LDH. Proper selection of the surgical cases with the appropriate intervention is associated with good to excellent outcome.

Keywords:

Adolescents, Lumbar disc herniation.

INTRODUCTION

Lumbar disc herniation (LDH) is a common disorder among adults with degenerated lumbar intervertebral discs. However, its occurrence in adolescence is much less frequent mostly because adolescents tend to have a healthier lumbar spine as compared with adults.[1] Although almost all attention was given to adult LDH with adolescent LDH remaining partially understood, over the years, the number of studies in this regard was on a rise, which led to an ever increasing understanding of this entity.[2]

Trauma (mostly sport-related or self-reported injury) is commonly considered as the most likely cause. As many as 30–60% of children and adolescents with symptomatic LDH have a history of trauma before the onset of pain [3-8]. This is in contrast to adult patients who usually do not have any traumatic experiences before the symptoms occur. However, more recent studies suggest that instead of being a primary contributory factor, trauma is likely to be an inciting event in the exacerbation of the pre-existing lesion in the discs, e.g. micro-damage, degenerative changes, etc. [7,9,10]. The second generally recognized cause is genetic factor. Studies have shown that between 13 and 57% of adolescents with LDH have a first-degree relative with the same disorder [11-13].

lumbar disc herniation in adolescence is usually manifested by symptoms that are generally similar to those observed in adults [7,10].back pain is not all marked in adolescent patients. One distinctive feature is that up to 90% of patients have a positive straight-leg raising test [5,14]However, adolescents are less often seen with neurological symptoms such as numbness and weakness [12,15,16].

Although, Conservative treatment is generally recommended as the first-line treatment for LDH in adolescents without neurological deficits [11,16,17,18,19]; It has been widely agreed by most authors that conservative treatment is not as effective for pediatric LDH as it is for adults [6,9,16,20,21] and its successful rate was varied from 25 to 50% [11,13,22]. Also it was found that less than 1% of those patients had surgery for herniated lumbar disc [23]. Causes for the rarity of discectomy in adolescents are not clear, and the features of the few adolescent patients who required surgery have seldom be discussed.

Like adults, modalities of surgical treatment for adolescence LDH consist of percutaneous endoscopic discectomy (PED, also known as microendoscopic discectomy) and open discectomy including microsurgical discectomy or microdiscectomy (MD), discectomy with laminotomy or laminectomy and spinal fusion.

Patients and Methods

This prospective study was conducted on twenty patients between 10 and 19 years old presenting with lumbar disc herniation, managed and treated in the Neurosurgery Department at Kasr Al Ainy School of medicine, Cairo University in the period from October 2015 to September 2016 with 12 months follow-up period.

Inclusion Criteria:

- 1- People aging 10 to 19 years with significant back and/or sciatic pain.
- 2- Radiological diagnosis of disc herniation by Magnetic Resonance Imaging (MRI).

Exclusion criteria:

- 1- Previous disc surgery.
- 2- Patients with spinal deformities.

Methodology

Patient Evaluation

- **History**

Personal history included; name, age, sex, occupation, physical activity, residence, associated medical disorders, and special habits of medical importance.

The presenting complaint was the most single distressing complaint to the patient, in addition to other complaints included in the patient's symptoms.

Present history included evaluation and analysis of the patient's symptomatology regarding the onset, course and duration, possible etiology, in addition to analysis of other neurological symptoms in focus.

Neurological symptoms included; symptoms of low back pain and/or leg pain, motor, sensory or sphincteric affection.

Past history included analysis of history of previous surgeries, medications received.

Family history: similar conditions in the family.

- **Examination**

Complete general examination including: the patient's vital signs, head, neck, chest and abdomen was performed for all patients.

A fully detailed and thorough neurological examination that included examination of the motor and sensory functions and reflexes. In addition to tests to detect nerve root tension signs was performed for all patients.

- **Investigations**

Routine laboratory investigations including CBC, blood sugar, liver and kidney functions, PT, PC and INR were performed.

Radiological investigations included pre-operative plain X-ray for lumbo-sacral spine with dynamic views to exclude congenital anomalies and instability. Also MRI (T1WI and T2WI) were done for all patients (Fig.1 & 2). Herniated discs were evaluated for site, size, direction of migration (if present) and degree of degeneration.

The modified Pfirrmann grading system [24] was used for lumbar disc degeneration detection in this study as degenerative disc disease is thought to have a role in the occurrence of lumbar disc herniation in adolescents [25]

- **Management**

Conservative treatment including bed rest and medications in the form of analgesics, muscle relaxants, neurotonics and steroids also physiotherapy. Conservative treatment was the mainstay of management of these cases for 3 to 6 weeks.

Surgical treatment was indicated for patients with intractable pain and failure of conservative treatment for more than 6 weeks with nerve tension sign and intervertebral disc herniation by magnetic resonance imaging (MRI). An Informed consent including parental permission and childhood assent for all cases.

A single-level discectomy through fenestration, partial or complete laminectomy was performed to remove the herniated disc and decompress the affected nerve root either microscopically or conventionally. Spinal fusion was not indicated in addition to the discectomy.

Clinical follow-up: The clinical symptoms were assessed at three, six and twelve months following the start of management. The outcome was classified using visual analogue scale, where measuring leg pain and low back pain were done at the start of management and through the period of follow up where the patients mark on the line the point that they feel represents their perception of their current state.

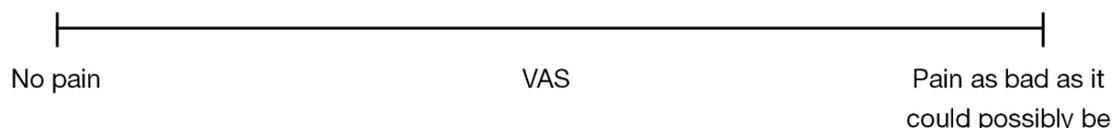


Figure 1. Visual analogue scale

The grade of pain relief in the follow up period was taken as complete if the pain score was 0, 1 to 2 was taken as significant relief of pain and 3–4 as moderate relief of pain. Also assessment of motor and sensory functions were done regularly in the follow up period.



Figure 2. Pre-operative MRI lumbo-sacral spine sagittal T2W images of 19 years old adolescent with L5-S1 disc herniation.

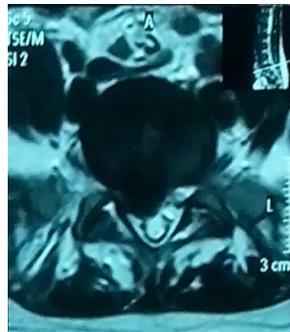


Figure 3. Pre-operative MRI lumbo-sacral spine axial T2W images with L5-S1 right disc herniation.

RESULTS

The data collected from the 20 cases during the study were analyzed, compared and evaluated.

Age and sex distribution

Regarding the age distribution among twenty patients in our study, the peak incidence was between 17 and 19 years old (83.3% of males and 75% of females) and the least incidence was between the 15 and 17 years old (16.7% of males and 0% of females) and the age group between 13 and 15 years old (0 % of males and 25% of females). The mean age was 17.6 years. Most of patients in our study were males (12 patients, 60%), while 8 patients (40%) were females with M: F ratio (1.5: 1) and this may be due to early exposure to heavy work among males in the society and higher susceptibility to trauma as shown in table (1).

Table 1. Age and sex distribution among the studied group

AGE GROUP	SEX DISTRIBUTION			
	Male		Female	
	No.	%	No.	%
13-15	0	0	2	25
15-17	2	16.7	0	0
17-19	10	83.3	6	75
TOTAL	12	100	8	100

Family history and the presence of a possible etiology:

Among the twenty cases of this study, there were 12 cases (60%) who gave a positive family history in one or more of first degree relatives having a history of lumbar disc herniation. Also 9 cases (45%) of the studied group had a history of back trauma either sports related (2 cases), lifting heavy objects (2 cases) or a road traffic accidents (5 cases); all are suggested as a cause of lumbar disc herniation in those cases.

Table 2. Incidence of cases with positive family history and possible causes among adolescents with lumbar disc herniation

	No.	%
Positive family history	12	60
Possible etiology	9	45

Clinical presentation and signs in adolescents with lumbar disc herniation:

All the cases of this study were presented with features of lumbar disc herniation for at least 2 months with acute onset in fourteen cases (70%), while it was insidious in six cases (30%). The most common presenting feature in our study was sciatic pain representing 100% of the cases. It was unilateral in 17 cases (85%) and bilateral in 3 cases (15%); low back pain was the second common presentation in 10 patients representing 50% of the cases, sensory deficit was detected in 3 cases (15%), while partial unilateral foot drop was observed in only two cases (10%), none of the patients had sphincteric troubles. Straight leg raising test was positive (less than 60 degrees) in 16 cases representing 80% of them.

Table 3. Clinical presentation and signs in adolescents with lumbar disc herniation

Clinical presentation		No.	%
Type of onset	Acute	14	70
	Insidious	6	30
Sciatic pain		20	100
Unilateral sciatic pain		17	85
Bilateral sciatic pain		3	15
Persistent low back pain		10	50
Sensory deficit		3	15
Motor deficit		2	10
Positive S.L.R. test		16	80

Levels of lumbar disc herniation in the study:

According to MRI of lumbosacral spine (investigation of choice), all the cases had a single level affection and the most common level affected was at L5-S1 (ten patients, 50% of cases), followed by L4-L5 level with 8 cases affection (40%) as shown in table (4).

Table 4. Levels of lumbar disc herniation according to MRI

Disc level	No.	%
L5-S1	10	50
L4-L5	8	40
L3-4	2	10

Locality of the herniated disc:

According to MRI, eighteen patients (90%) were presented with laterally located disc herniation, only two of them (10% of the cases) were bilaterally located and the other sixteen (80%) were unilaterally located disc herniation. Centrally located disc herniation was in two cases of the studied group (10%).

Table 5. Locality of the herniated disc

Laterally located LDH		Centrally located LDH	
18 Cases	90%	2 Cases	10%
Unilateral LDH		Bilateral LDH	
16 Cases	80%	2 Cases	10%

Management of lumbar disc herniation in adolescents:

Regarding different modalities of management in those cases; conservative treatment was effective and sufficient in 8 cases (40%) 4 males and 4 females, while surgical treatment after the recommended period of medical treatment (6 weeks) was the only curative method in 12 patients (8 males and 4 females) representing 60% of the cases.

Table 6. Different modalities in management of cases

	No.	%
Conservative treatment	8	40
Surgical treatment	12	60

Table 7. Incidence of surgical interventions in different sexes

	Males		Females	
	Conservative	Surgical	Conservative	Surgical
No.	4	8	4	4
%	20%	40%	20%	20%
Total	12		8	

Detection of lumbar disc degeneration in the studied group:

The modified Pfirrmann grading system was used to detect lumbar disc degeneration among cases through Sagittal T2-weighted images of MRI. this grading system depends on the signal intensity of the nucleus pulposus, distinction between inner and outer fibers of annulus fibrosus and height of the disc, six (30%) levels of discs were grade 1, where signal intensity of the nucleus pulposus was equal to C.S.F. Twelve (60%) levels of discs were graded 3, in which the signal intensity of the nucleus pulposus was less than the presacral fat. Two (10%) levels of discs were graded 5, where the signal of the nucleus pulposus was hypointense and no distinction between the inner and outer fibers of the annulus fibrosus.

Table 8. Modified Pfirrmann Classification for lumbar disc degeneration detection

Grade	No. of levels	%
1	6	30%
3	12	60%
5	2	10%

Surgical procedures:

The applied surgical procedures in our study were: 1- conventional open laminectomy & discectomy in 6 cases (30% of the whole cases). 2- micro-discectomy in 6 cases (30%).

Table 9. Applied surgical procedure in the study

Surgical procedure	No.	%
Conventional laminectomy & discectomy	6	30
Micro-discectomy	6	30
Total	12	60

Operative findings:

Types of disc herniation found intraoperatively: subligamentous (sequestered) disc prolapse in 1 case (5%), disc bulge with intact annulus in 8 cases (40%) and extruded disc in 3 cases (15%). While Characteristics of the removed disc: it was soft, rubbery and hydrated in 10 cases (50%) but it was hard and dehydrated 2 (10%). The ligamentum flavum was hypertrophied in 6 cases (30%) among the twelve operated cases.

Table 10. The operative findings

Operative Finding		No	%
Type of disc herniation	Intact annulus	8	40%
	Extruded	3	15%
	Sub ligamentous	1	5%
Characteristics of the disc	Soft, hydrated	10	50%
	Hard, dehydrated	2	10%
The ligamentum flavum	Hypertrophied	6	30%
	Normal	6	30%
Total No. of operated cases		12	60%

Post-operative complications:

There was no intraoperative complication such as dural tear, root injury. None of the patients had postoperative wound infection or underwent any further surgery for recurrence of symptoms.

The outcome of the cases:**Pain relief**

The grade of pain at the start of the management and immediately post-operatively (for those who underwent surgical intervention) and through the twelve months follow up period, was obtained from the patients using the visual analogue scale. The mean score of leg pain for the patients in the start of management was 8, with a range from 7 to 10. Postoperative pain relief was taken as complete if the pain score was 0. 1-2 was taken as significant relief of pain and 3-4 as moderate relief of pain. At the end of follow up period, fourteen patients had complete relief of leg pain, four patients had significant relief, and two patients had moderate relief. while the mean score for back pain at the start of management was 4.6 and by the end of follow up period, sixteen patients had complete relief of back pain, while two patients had significant relief of pain, and another two patients had moderate relief of back pain.

Table 11. Visual analog score of patients at starting the management:

V.A.S for leg pain	No.	%	V.A.S for back pain	No.	%
7	5	25	1	2	10
8	7	35	2	3	15
9	6	30	3	5	25
10	2	10	5	1	5
			6	1	5
			7	6	30
			8	2	10
Total	20			20	

Table 12. Visual analog score of patients at the end of follow up period:

V.A.S for leg pain	No.	%	V.A.S for back pain	No.	%
0	14	70	0	16	80
1	3	15	1	2	10
2	1	5	2		
3	2	10	3	1	5
4			4	1	5
TOTAL	20			20	

Motor and sensory deficits:

Motor and sensory assessment through the follow up period was done, and by the end of follow up; the two cases who had presented with motor deficit they reported improvement in motor power. Regarding the sensory disturbance, two out of the three patients had improvement. One patient who presented with paresthesia had hypoesthesia in the same dermatome. All patients in the study regained their normal daily activities by the end of the follow up period

Table 13. Motor and sensory assessment at the end of follow up period:

	NO.	%
CASES WITH MOTOR DEFICIT	2	10
IMPROVEMENT IN MOTOR POWER	2	10
CASES WITH SENSORY DISTURBANCE	3	15
IMPROVEMENT OF SENSATION	2	10

Outcome of the surgically treated cases

Out of the twelve operated cases, eight patients had complete relief of leg pain, two cases had significant relief and two cases had moderate relief of leg pain. While back pain was relieved completely in ten patients and the other two cases had moderate relief.

All the five conditions who had neurological deficits were operated upon and the results are shown in table (14).

Table 14. The outcome of pain relief among surgically treated cases:

Post-op. V.A.S for leg pain	No.	%	Post-op. V.A.S for back pain	No.	%
0	8	66	0	10	83
1	2	17	1		
2			2		
3	2	17	3	1	8.5
4			4	1	8.5
Total	12		Total	12	

DISCUSSION

Lumbar disc herniation is a common disorder among adults, with reported lifetime occurrence as high as 40% [26]. Although the true frequency of this condition in children and adolescents is not precisely defined. In adolescent patients presenting with back pain, less than 10% is attributed to disc herniation. [27]

The intervertebral disc gradually degenerate, e.g. the nucleus pulposus becomes less differentiated from the remainder of the disc as age progresses, and gradually becomes less hydrated. This degeneration has a role in intervertebral disc herniation. So adults are at greater

risk for lumbar disc herniation than adolescents. And this histology and morphology has an important impact on the natural history, course and management of lumbar disc herniation in adolescents.

Trauma either sport-related or self-reported injury e.g. Heavy lifting or falling is commonly considered as the most likely cause as many as 30–60% of children and adolescents with symptomatic LDH have a history of trauma before the onset of the disease. [3-8]

The second generally recognized cause is genetic factor. Studies have shown that between 13 and 57% of adolescents with LDH have a first-degree relative with the same disorder [11-13]. In the present study, trauma in young age and early contact to heavy work in our locality and genetic factor were supposed to have a role.

In this study the mean duration of symptoms was 3.1 months. While in M. Karademir et al. study the mean duration of symptoms was 7.21 months. [25]

In our study, regarding neurological deficits; 25% of the studied group were presented with neurological deficit (10% with motor & 15% with sensory deficit), Also straight leg raising test was positive in 80 % of the cases while low back pain associated with leg pain was reported in 50% of cases and leg pain alone in 50% of the studied group (leg pain in 100% of the cases). Parisini et al. reported that Low back pain associated with leg pain was the main clinical symptom in 82%, back pain in 13%, and leg pain in 5% and signs of neurological deficit were often absent.[10] and in another study it was found that up to 90% of patients have a positive straight leg raising test [5, 14]. Also children and adolescents are less often seen with neurological symptoms such as numbness and weakness. [3,16,28] Although in a recent study gross motor weakness was met in 57.1% of the studies group and leg pain alone was seen in 26 out of 28 patients, while 22 patients had both radicular and local back pain .[29]

According to Lih-Huei Chen et al. in their series conducted on twenty eight patients where the level of disc herniation was L4-L5 in twenty three patients and L5-S1 in five patients. [30] Mustafa Karademira et al. in their study conducted on 70 cases, they reported that the most commonly involved level was L4–5 in 38 of patients. L5–S1 was seen in 24 patients, L3–4 was seen in 6 patients. [25] in our study it was different where the most common level of disc herniation was L5-S1 in ten patients (50%), eight (40%) at L4-L5 and only 2 cases (10%) at L3-L4. Although single level involvement was reported in all cases but these patients should be followed for probability of involvement of other level in the future as shown by studies with longer follow up. [9]

Among the studied group, all patients had MRI to confirm diagnosis where disc herniation was located laterally in eighteen patients (90%) with two of them were bilaterally. 2 patients in the study (10%) had central disc herniation while in the study of Chia-Hsieh Chang et al. there were twenty-four patients underwent MRI studies; disc herniation was located laterally in nineteen patients (76%) and five patients (24%) had central disc herniation. [31]

A search of the literature indicates that the short to long-term success rate of conservative treatment for adolescence LDH without neurological deficits varied from 25 to 50% [11,13,22]. Which is similar to our study where conservative treatment was effective in 8 cases (40%).

Kurth et al.[22] compared outcome of conservative treatment with surgical treatment for 33 patients in the second decade of life (18 conservatively and 15 surgically treated cases) with a follow-up of 5.4 years, and found no significance between the two groups. DeLuca et al. [13], however, found that surgical treatment lead to a significant better outcome than conservative treatment by carrying out a similar study on 31 patients in the same age group (8 conservative, 23 surgical) with a 6-year follow-up. Regardless of the controversy, it has been widely agreed by most authors that conservative treatment is not as effective for pediatric and adolescents LDH as it is for adults. [6,9,16,20,21] And this may be explained by herniated lumbar disc in adolescents is less degenerated, more hydrated and viscous so it doesn't dry or resorb as compared with adults.[6, 9,32] Also adolescence LDH is often associated with trauma where the annulus fibrosus could be severely ruptured [33] and the epiphyseal cartilage of the vertebral body in children and adolescents is not fully fused, hence severe trauma could rupture the epiphyseal ring forming a large inelastic mass along with the herniated disc. [34] beside that adolescents are active and less likely to comply with strict bed rest. Nevertheless, conservative treatment is still generally recommended as the first-line treatment for LDH in children and adolescents without neurological deficits. [11,16,17,18,19]

Two forms of surgical modalities were used in this study; lumbar microdiscectomy (MD) in 50% of the operated cases and conventional open laminectomy and discectomy was performed for the other 50%.

Kumar et al. in their series conducted on thirty five adolescents preferred endoscopic discectomy in 57% of cases followed by microdiscectomy in 28% of cases while open lumbar discectomy was used in only 15% of cases. [9] Also in many studies microdiscectomy has been used for the treatment of adolescent LDH [16,25,34,35,36] and associated with good result.

In our study, both techniques (microdiscectomy and conventional open laminectomy and discectomy) were associated with good to excellent success in 83% of the operated cases which is less than a previous study made by Kuh et al. who reviewed one hundred and eighty five adolescent patients reported in the literature and in their series the rate of excellent and good results after surgery was 93%. [36]

In previous studies, early post-operative complications found in children and adolescents patients include wound hematoma (1–4%) and delayed wound healing (3%). [3,7,37] Post-operative infection, e.g. wound infection and discitis secondary to lumbar spine surgery is rare in children and adolescents with only few cases being reported in the literature. [10,35,38]

In our study there was no intraoperative complication such as dural tear or root injury. None of the patients had postoperative wound infection or underwent any further surgery for recurrence of symptoms.

The results of our study were generally satisfactory as our series demonstrated excellent results in 90% of cases as they had significant to complete relief of pain and significant improvement in the neurological deficits was achieved and patients returned to their daily activities by the end of the follow up period. While 10% of cases had moderate relief of pain and continued on some medical treatment.it is worth noting that surgical treatment for young patients with LDH is

associated with excellent short-term outcome regardless the chosen modality and it does not appear to have a negative impact on overall health and well-being except in patients with significant deficits prior to surgery. [29]

CONCLUSION

Lumbar disc herniation in adolescents is not as common as in adults but it's thought to be increasing in the society and it is mostly due to trauma. Diagnosis to a large extent is similar to adults. Conservative treatment is less effective for adolescent patients as compared with adults, even though it remains the first-line treatment for adolescent LDH. Proper selection of the surgical cases with the appropriate intervention is associated with good to excellent outcome.

Limitations and future studies

- 1-the number of cases shall be larger.
- 2-follow up period shall be longer.
- 3-multi-centricity shall be taken into consideration for more concrete evidence and results.

Acknowledgement

I am greatly honored to express my deepest appreciation and profound gratitude and respect to all my professors, colleagues and my family.

REFERNCES

- [1] Dang L, Liu Z. A review of current treatment for lumbar disc herniation in children and adolescents. *Eur Spine J.* 2010 Feb;19(2):205-14. doi: 10.1007/s00586-009-1202-7. Epub 2009 Nov 5. PMID: 19890666; PMCID: PMC2899810.
- [2] Kristjánisdóttir G. Prevalence of self-reported back pain in school children: a study of sociodemographic differences. *Eur J Pediatr.* 1996 Nov;155(11):984-6. doi: 10.1007/BF02282892. PMID: 8911902.
- [3] Kurihara A, Kataoka O. Lumbar disc herniation in children and adolescents. A review of 70 operated cases and their minimum 5-year follow-up studies. *Spine (Phila Pa 1976).* 1980 Sep-Oct;5(5):443-51. PMID: 7455775.
- [4] Durham SR, Sun PP, Sutton LN. Surgically treated lumbar disc disease in the pediatric population: an outcome study. *J Neurosurg.* 2000 Jan;92(1 Suppl):1-6. doi: 10.3171/spi.2000.92.1.0001. PMID: 10616050.
- [5] Gennuso R, Humphreys RP, Hoffman HJ, Hendrick EB, Drake JM. Lumbar intervertebral disc disease in the pediatric population. *Pediatr Neurosurg.* 1992;18(5-6):282-6. doi: 10.1159/000120676. PMID: 1476937.
- [6] Shillito J Jr. Pediatric lumbar disc surgery: 20 patients under 15 years of age. *Surg Neurol.* 1996 Jul;46(1):14-8. doi: 10.1016/0090-3019(96)00035-3. PMID: 8677479.
- [7] Papagelopoulos PJ, Shaughnessy WJ, Ebersold MJ, Bianco AJ Jr, Quast LM. Long-term outcome of lumbar discectomy in children and adolescents sixteen years of age or younger. *J*

- Bone Joint Surg Am. 1998 May;80(5):689-98. doi: 10.2106/00004623-199805000-00009. PMID: 9611029.
- [8] Beks JW, ter Weeme CA. Herniated lumbar discs in teenagers. *Acta Neurochir (Wien)*. 1975;31(3-4):195-9. PMID: 1181813.
- [9] Kumar R, Kumar V, Das NK, Behari S, Mahapatra AK. Adolescent lumbar disc disease: findings and outcome. *Childs Nerv Syst*. 2007 Nov;23(11):1295-9. doi: 10.1007/s00381-007-0370-1. Epub 2007 May 31. PMID: 17541606.
- [10] Parisini P, Di Silvestre M, Greggi T, Miglietta A, Paderni S. Lumbar disc excision in children and adolescents. *Spine (Phila Pa 1976)*. 2001 Sep 15;26(18):1997-2000. doi: 10.1097/00007632-200109150-00011. PMID: 11547199.
- [11] Zamani MH, MacEwen GD. Herniation of the lumbar disc in children and adolescents. *J Pediatr Orthop*. 1982;2(5):528-33. doi: 10.1097/01241398-198212000-00012. PMID: 6219127.
- [12] Clarke NM, Cleak DK. Intervertebral lumbar disc prolapse in children and adolescents. *J Pediatr Orthop*. 1983 May;3(2):202-6. doi: 10.1097/01241398-198305000-00009. PMID: 6863525.
- [13] DeLuca PF, Mason DE, Weiland R, Howard R, Bassett GS. Excision of herniated nucleus pulposus in children and adolescents. *J Pediatr Orthop*. 1994 May-Jun;14(3):318-22. doi: 10.1097/01241398-199405000-00008. PMID: 8006161.
- [14] Epstein JA, Epstein NE, Marc J, Rosenthal AD, Lavine LS. Lumbar intervertebral disk herniation in teenage children: recognition and management of associated anomalies. *Spine (Phila Pa 1976)*. 1984 May-Jun;9(4):427-32. doi: 10.1097/00007632-198405000-00019. PMID: 6474257.
- [15] Garrido E, Humphreys RP, Hendrick EB, Hoffman HJ. Lumbar disc disease in children. *Neurosurgery*. 1978 Jan-Feb;2(1):22-26. doi: 10.1227/00006123-197801000-00004. PMID: 683478.
- [16] Ozgen S, Konya D, Toktas OZ, Dagcinar A, Ozek MM. Lumbar disc herniation in adolescence. *Pediatr Neurosurg*. 2007;43(2):77-81. doi: 10.1159/000098377. PMID: 17337916.
- [17] Slotkin JR, Mislow JM, Day AL, Proctor MR. Pediatric disk disease. *Neurosurg Clin N Am*. 2007 Oct;18(4):659-67. doi: 10.1016/j.nec.2007.08.001. PMID: 17991589.
- [18] King HA. Back pain in children. *Orthop Clin North Am*. 1999 Jul;30(3):467-74, ix. doi: 10.1016/s0030-5898(05)70099-7. PMID: 10393768.
- [19] Weinert AM Jr, Rizzo TD Jr. Nonoperative management of multilevel lumbar disk herniations in an adolescent athlete. *Mayo Clin Proc*. 1992 Feb;67(2):137-41. doi: 10.1016/s0025-6196(12)61314-7. PMID: 1545577.
- [20] Bulos S. Herniated intervertebral lumbar disc in the teenager. *J Bone Joint Surg Br*. 1973 May;55(2):273-8. PMID: 4707295.
- [21] Kamel M, Rosman M. Disc protrusion in the growing child. *Clin Orthop Relat Res*. 1984 May;(185):46-52. PMID: 6705398.
- [22] Kurth AA, Rau S, Wang C, Schmitt E. Treatment of lumbar disc herniation in the second decade of life. *Eur Spine J*. 1996;5(4):220-4. doi: 10.1007/BF00301323. PMID: 8886732.

- [23] Ebersold MJ, Quast LM, Bianco AJ Jr. Results of lumbar discectomy in the pediatric patient. *J Neurosurg.* 1987 Nov;67(5):643-7. doi: 10.3171/jns.1987.67.5.0643. PMID: 3668632.
- [24] Griffith JF, Wang YX, Antonio GE, Choi KC, Yu A, Ahuja AT, Leung PC. Modified Pfirrmann grading system for lumbar intervertebral disc degeneration. *Spine (Phila Pa 1976).* 2007 Nov 15;32(24):E708-12. doi: 10.1097/BRS.0b013e31815a59a0. PMID: 18007231.
- [25] Karademir M, Eser O, Karavelioglu E. Adolescent lumbar disc herniation: Impact, diagnosis, and treatment. *J Back Musculoskelet Rehabil.* 2017;30(2):347-352. doi: 10.3233/BMR-160572. PMID: 27858699.
- [26] Frymoyer JW, Pope MH, Clements JH, Wilder DG, MacPherson B, Ashikaga T. Risk factors in low-back pain. An epidemiological survey. *J Bone Joint Surg Am.* 1983 Feb;65(2):213-8. doi: 10.2106/00004623-198365020-00010. PMID: 6218171.
- [27] Carey TS, Garrett J, Jackman A, McLaughlin C, Fryer J, Smucker DR. The outcomes and costs of care for acute low back pain among patients seen by primary care practitioners, chiropractors, and orthopedic surgeons. The North Carolina Back Pain Project. *N Engl J Med.* 1995 Oct 5;333(14):913-7. doi: 10.1056/NEJM199510053331406. PMID: 7666878.
- [28] Bradford DS, Garcia A. Herniations of the lumbar intervertebral disk in children and adolescents. A review of 30 surgically treated cases. *JAMA.* 1969 Dec 15;210(11):2045-51. PMID: 5395205.
- [29] Sarma P, Thirupathi RT, Srinivas D, Somanna S. Adolescent prolapsed lumbar intervertebral disc: Management strategies and outcome. *J Pediatr Neurosci.* 2016 Jan-Mar;11(1):20-4. doi: 10.4103/1817-1745.181259. PMID: 27195028; PMCID: PMC4862283.
- [30] Chen LH, Chang CH, Lee ZL, Niu CC, Lai PL, Tan CF, Chen WJ. Intervertebral disc herniation in adolescents. *Chang Gung Med J.* 2004 Jan;27(1):22-8. PMID: 15074886.
- [31] Chen LH, Chang CH, Lee ZL, Niu CC, Lai PL, Tan CF, Chen WJ. Intervertebral disc herniation in adolescents. *Chang Gung Med J.* 2004 Jan;27(1):22-8. PMID: 15074886.
- [32] Villarejo-Ortega FJ, Torres Campa-Santamarina JM, Bencosme-Abinader JA, Alvarez- Sastre C, Pascual Martín-Gamero A, Pérez-Díaz C, Cordobés-Tapia F, González-Mediero I. Hernia discal lumbar en adolescentes [Lumbar disc disease in adolescents]. *Rev Neurol.* 2003 Mar 16-31;36(6):514-7. Spanish. PMID: 12652411.
- [33] Baba H, Uchida K, Furusawa N, Maezawa Y, Azuchi M, Kamitani K, Annen S, Imura S, Tomita K. Posterior limb vertebral lesions causing lumbosacral radiculopathy and the cauda equina syndrome. *Spinal Cord.* 1996 Jul;34(7):427-32. doi: 10.1038/sc.1996.76. PMID: 8963999.
- [34] Silvers HR, Lewis PJ, Clabeaux DE, Asch HL. Lumbar disc excisions in patients under the age of 21 years. *Spine (Phila Pa 1976).* 1994 Nov 1;19(21):2387-91; discussion 2392. doi: 10.1097/00007632-199411000-00002. PMID: 7846589.
- [35] Luukkonen M, Partanen K, Vapalahti M. Lumbar disc herniations in children: a long-term clinical and magnetic resonance imaging follow-up study. *Br J Neurosurg.* 1997 Aug;11(4):280-5. doi: 10.1080/02688699746041. PMID: 9337924.

- [36] Kuh SU, Kim YS, Cho YE, Yoon YS, Jin BH, Kim KS, Chin DK. Surgical treatments for lumbar disc disease in adolescent patients; chemonucleolysis / microsurgical discectomy/ PLIF with cages. *Yonsei Med J.* 2005 Feb 28;46(1):125-32. doi: 10.3349/ymj.2005.46.1.125. PMID: 15744815; PMCID: PMC2823038.
- [37] DeOrio JK, Bianco AJ Jr. Lumbar disc excision in children and adolescents. *J Bone Joint Surg Am.* 1982 Sep;64(7):991-6. PMID: 6214560.
- [38] Frino J, McCarthy RE, Sparks CY, McCullough FL. Trends in adolescent lumbar disk herniation. *J Pediatr Orthop.* 2006 Sep-Oct;26(5):579-81. doi: 10.1097/01.bpo.0000229974.78565.cc. PMID: 16932094.