CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2025; 31: e949466
DOI: 10.12659/MSM.949466

Received: 2025.04.18
Accepted: 2025.06.27
Available online: 2025.07.14
Published: 2025.08.25

Effect of Long-Term Smoking on Cervical Disc Degeneration: A Retrospective Study

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEFG 1 Murat Kiraz
CEFG 2 Hakan Kina

1 Department of Neurosurgery, Yuksek Ihtisas University, Ankara, Türkiye
2 Department of Neurosurgery, Istinye University Gaziosmanpasa Medical Park Hospital, Istanbul, Türkiye

Corresponding Author: Murat Kiraz, e-mail: kirazmurat@gmail.com
Financial support: None declared
Conflict of interest: None declared

Background: Although studies have shown that nicotine leads to disc degeneration, there is still a need for clinical and radiological studies. This study aimed to evaluate the effects of a smoking history of less than 10 years and of more than 10 years, compared with no smoking history, on cervical intervertebral disc degeneration at the C4-C5, C5-C6, and C6-C7 levels in 293 adult patients with documented degenerative changes, using magnetic resonance imaging (MRI) and the modified Pfirrmann grading system.

Material/Methods: A total of 293 adult patients with degenerative changes at C4-C5, C5-C6, and C6-C7 disc levels were included in this study. Patients were divided into 3 groups based on smoking duration: non-smokers (n=119), ≤10 years (n=93), and >10 years (n=81). Cervical disc degeneration was assessed using the modified Pfirrmann grading system, based on MRI findings. Each level was graded separately. Data were statistically analyzed to assess the relationship between smoking duration and disc degeneration.

Results: Cervical disc degeneration at the C4-C5, C5-C6, and C6-C7 levels was significantly higher in both smoking groups (≤10 years and >10 years) than in the non-smoking group (P=0.023-<0.001). However, no statistically significant difference was observed between the ≤10-year and >10-year smoking groups at any level (P=0.250-0.989). Age and sex distributions were statistically similar across all groups (P>0.05).

Conclusions: This study provides radiological evidence that smoking accelerates cervical disc degeneration and highlights the clinical importance of smoking cessation in patients with cervical spine disorders.

Keywords: Spine • Smoking • Magnetic Resonance Imaging

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/949466

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Introduction

Degenerative disc disease of the cervical spine generally develops equally in both sexes in the aging population. The prevalence of cervical degenerative disc disease increases with age, regardless of the patient's symptomatology [1]. In a study conducted in Japan involving 497 asymptomatic individuals, Matsumoto et al demonstrated that abnormal findings were present in nearly 90% of patients over the age of 60 years, irrespective of sex. In contrast, abnormalities were observed in 17% of men and 12% of women in their twenties [2].

Nicotine has been shown to reduce the proliferation rate of disc cells and the biosynthesis of glycosaminoglycans. Moreover, tobacco smoking leads to constriction of the vascular network surrounding the disc, thereby impairing the exchange of nutrients and anabolic agents from blood vessels to the disc [3]. Nicotine is the primary agent implicated in the association between cigarette smoke and cervical disc degeneration. The mechanisms by which chemicals in tobacco smoke contribute to degeneration involve the upregulation or downregulation of specific genes that could be critical for maintaining spinal integrity [4]. The cervical intervertebral disc has long been recognized as a common cause of neck pain. The progression of cervical disc degeneration into cervical disc disease and the surgeries performed as a result are routine in spinal surgery. Patients most commonly present with pain. Surgical intervention can be required for pain or other neurological symptoms [5].

The etiology and pathophysiology of degenerative disc disease, which is believed to result from the interaction of biological and biomechanical factors, remain controversial. While the initiating factor is not fully known, a decrease in aggrecan, the main proteoglycan of the nucleus pulposus, is noted as a characteristic of the early stages of the disease [6,7]. Biochemically, the decrease in proteoglycan content disrupts the balance of normal anabolic and catabolic functions in nucleus pulposus cells, reducing synthesis or increasing degradation. The gradual reduction in content leads to dehydration, due to impairment of hydrostatic and biomechanical properties [7]. Smoking reduces aggrecan, a key proteoglycan in the disc matrix, and increases its degradation, impairing the disc's ability to resist compressive forces; it also upregulates proinflammatory stress responses and catabolic enzymes (MMPs) and cytokines (IL-1β), leading to a shift toward a catabolic disc environment [8]. Smoking is one of the most prevalent public health issues concerning cancer and other diseases [9].

The modified Pfirrmann grading system was initially developed by Griffith et al to assess intervertebral disc degeneration using magnetic resonance imaging (MRI) for lumbar discs [10], and is shown in **Table 1**. Subsequently, its applicability, validity, and interobserver reliability for cervical discs were demonstrated by Xu et al [11].

While several studies have reported significant effects of smoking on disc degeneration and herniation, others have found no such relationship [6,12-14]. In the literature, no specific studies were found investigating the effect of smoking on cervical disc degeneration. This retrospective study aims to evaluate the effects of a smoking history of less than 10 years and of more than 10 years, compared with no smoking history, on cervical intervertebral disc degeneration at the C4-C5, C5-C6, and C6-C7 levels in 293 adult patients with documented degenerative changes, using MRI and the modified Pfirrmann grading system.

Material and Methods

Ethical Considerations

Participants were given an explanation of the study's goal, and the anonymity of the data gathered was guaranteed. An informed consent form was signed by each patient who consented to take part in the trial. Ethical approval for this retrospective study was obtained from the Ethics Committee of İstinye University in October 2024, with decision number 24-227.

Study Design

This retrospective study was based on the evaluation of cervical MRI scans obtained between 2022 and 2024.

Study Population

A total of 293 adult patients (aged 19-78 years, mean age 47.94 years) who presented to the neurosurgery outpatient clinic with symptoms of neck, shoulder, scapular, or arm pain and underwent cervical MRI were included. Exclusion criteria were as follows: presence of systemic diseases or ongoing systemic treatments; occupations requiring prolonged forward flexion of the head (eg, furniture or automobile repair work, certain factory jobs); history of cervical spine or neck surgery; prior cervical or severe head trauma; body mass index (BMI) ≥30 kg/m^2; first-degree relatives with a history of cervical disc herniation; and age under 18 years.

Data Collection

Informed consent was obtained from all participants either by phone or during outpatient follow-up visits. A structured data form was used to collect information on sociodemographic characteristics, duration of symptoms, smoking status and duration, age, height, weight, BMI, occupation, education level,

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 1. Modified Pfirrmann grading system [10,11].

Grade	Signal from nucleus and inner fibers of annulus*	Distinction between inner and outer fibers of anulus at posterior aspect of disc	Height of disc
1	Uniformly hyperintense, equal to cerebrospinal fluid	Distinct	Normal
2	Hyperintense (>presacral fat and <cerebrospinal fluid) ±hypointense intranuclear cleft	Distinct	Normal
3	Hyperintense though <presacral fat	Distinct	Normal
4	Mildly hyperintense (slightly >outer fibers of anulus)	Indistinct	Normal
5	Hypointense (=outer fibers of anulus)	Indistinct	Normal
6	Hypointense	Indistinct	<30% reduction
7	Hypointense	Indistinct	30-60% reduction
8	Hypointense	Indistinct	>60% reduction

* Grades 1, 2, and 3 are based on the signal intensity of the nucleus and inner fibers of anulus. For grade 4, the margins between the inner and other fibers of the anulus at the posterior margin of the disc are indistinct. For grade 5, the disc is uniformly hypointense, although there is no loss of disc space height. For grades, 6, 7, and 8, there is progressive loss of disc space height. These could be broadly classified as mild, moderate, to severe loss of disc space height. Very occasionally, although obvious disc collapse is present, hyperintense signal from the nucleus and inner fibers of the anulus is preserved. This is referred to by a double entry, eg 4/7, with the former reporting the disc signal and the latter the degree of collapse.

surgical history, history of cervical or head trauma, systemic diseases, and family history of cervical disc pathology.

Smoking Classification

Patients were categorized into 3 groups according to smoking history: no smoking (n=119), smoking less than or equal to 10 years (n=93), and smoking more than 10 years (n=81). The smoking criteria included individuals who smoked at least 1 pack per day, corresponding to ≥1 pack-year of exposure annually.

MRI Evaluation

Cervical MRIs were analyzed using the modified Pfirrmann grading system, to quantitatively assess intervertebral disc degeneration. A representative example of the grading scale derived from the patient population in our study is shown in **Figure 1**. This grading system evaluates each disc on an 8-point scale based on 4 criteria: disc structure, signal intensity, distinction between the nucleus pulposus and annulus fibrosus, and intervertebral disc height. Disc structure is categorized as homogeneous or inhomogeneous; signal intensity decreases progressively with degeneration; the nucleus-annulus border can be clearly defined, indistinct, or completely absent; and disc height can range from normal to severely reduced. Higher scores indicate more advanced degeneration. All images were independently assessed by 2 experienced radiologists who were blinded to clinical data. In cases of discrepancy, the images were jointly re-evaluated, and a consensus grade was assigned.

Statistical Method

Statistical analyses were performed using SPSS software (Version 22.0, IBM Corp, Armonk, NY, USA; license: Hitit University). Descriptive statistics were reported as numbers and percentages for categorical variables and as mean±standard deviation for numerical variables, based on data distribution. Data normality was evaluated using the Kolmogorov-Smirnov test.

One-way ANOVA was used to compare numerical measurements among more than 2 independent research groups, depending on the data distribution. For ANOVA tests showing statistically significant differences, post hoc tests, such as Tukey or Games-Howell, were used to identify the specific groups responsible for the differences, depending on the homogeneity of variances. A *P* value <0.05 was considered statistically significant.

Results

The average age and sex distribution were statistically similar across groups. Descriptive statistics are presented in **Table 2**.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

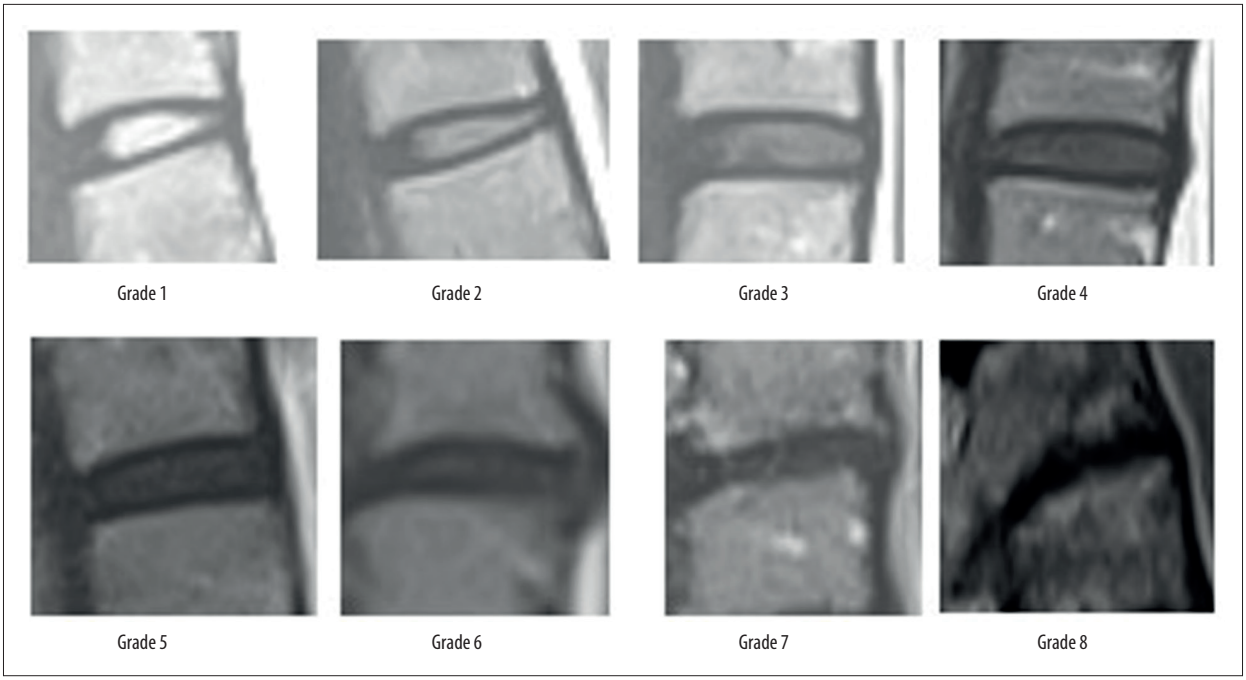

Figure 1. Modified Pfirrmann grading system based on cervical MRI derived from our patient cohort.

Table 2. Mean age and sex distribution among groups.

		No smoking (n=119)	Smoking 1-10 years (n=93)	Smoking >10 years (n=81)	*P*
Age		47.45±15.83	47.46±13.7	49.20±12.62	0.648*
Sex	Male	57 (47.9%)	51 (54.8%)	41 (50.6%)	0.604**
	Female	62 (52.1%)	42 (45.2%)	40 (49.4%)	

* One-way ANOVA; ** Chi-square test.

Table 3. Disc degeneration by smoking groups.

		n	Mean	Std. deviation	*P*	Post hoc *P*
C4-5	None	119	3.74	1.586		**1-2: 0.023****
	1-10 years	93	4.44	2.124	**<0.001***	**1-3: <0.001****
	>10 years	81	4.94	1.983		2-3: 0.250**
C5-6	None	119	3.89	1.661		**1-2: <0.001*****
	1-10 years	93	4.96	1.916	**<0.001***	**1-3: <0.001*****
	>10 years	81	5.05	1.580		2-3: 0.934***
C6-7	None	119	3.75	1.673		**1-2: <0.001*****
	1-10 years	93	4.75	1.786	**<0.001***	**1-3: <0.001*****
	>10 years	81	4.72	1.614		2-3: 0.989***

* One-way ANOVA; ** Games-Howell post hoc tests; *** Tukey post hoc tests

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

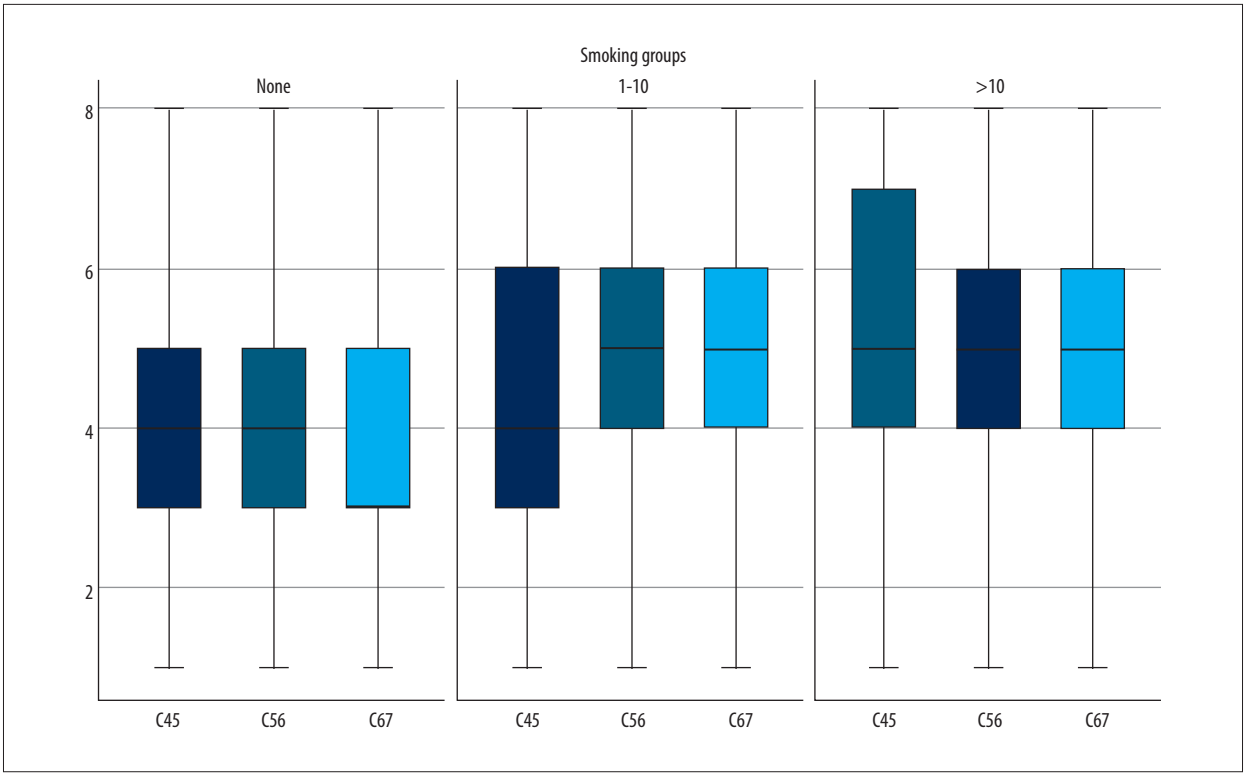

Figure 2. The relationship between cervical disc degeneration and smoking group is shown with a box plot graph.

The cervical disc degeneration in all evaluated levels, C4-C5, C5-C6, and C6-C7, was statistically significantly higher in the smoking groups than in the non-smoking group. No significant difference was observed between the groups smoking for more than 10 (>10) years and those smoking for less than or equal to 10 (≤10) years. Cervical disc degeneration by smoking status is shown in **Table 3**.

At the C4-C5 level, the score of the group smoking ≤10 years was statistically significantly higher than that of the non-smoking group (post hoc *P*=0.023b). The score of the group smoking >10 years was also statistically significantly higher than the non-smoking group (post hoc *P*<0.001b). However, there was no statistically significant difference between the scores of the groups smoking ≤10 years and >10 years (post hoc *P*=0.250b).

At the C5-C6 level, the score of the group smoking ≤10 years was statistically significantly higher than the non-smoking group (post hoc *P*<0.001c). The score of the group smoking >10 years was also statistically significantly higher than the non-smoking group (post hoc *P*<0.001c). There was no statistically significant difference between the scores of the groups smoking ≤10 years and >10 years (post hoc *P*=0.934c).

At the C6-C7 level, the score of the group smoking ≤10 years was statistically significantly higher than the non-smoking group (post hoc *P*<0.001c). The score of the group smoking >10 years was also statistically significantly higher than the non-smoking group (post hoc *P*<0.001c). However, there was no statistically significant difference between the scores of the groups smoking ≤10 years and >10 years (post hoc *P*=0.989c).

The relationship between cervical disc degenerations and smoking groups is shown with a box plot graph (**Figure 2**).

Discussion

In this study, we found that smoking is associated with increased cervical disc degeneration at the C4-C5, C5-C6, and C6-C7 levels. Cervical disc degeneration was evaluated using the modified Pfirrmann grading system, a classification system used to assess the severity of lumbar disc degeneration for clinical or research purposes [10]. Although it was initially developed to evaluate lumbar disc degeneration, the Pfirrmann classification is also used to classify cervical disc degeneration. In 2017, the Suzuki classification system was introduced as a system specifically designed to evaluate cervical disc degeneration [15]. Since the Suzuki classification system is newer than the modified Pfirrmann grading system, there are fewer reports of its use in the literature. Both classification systems are applicable options for grading cervical disc degeneration. While the modified Pfirrmann grading system was not specifically designed for cervical disc degeneration, it is a more reliable and widely used

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

option for grading cervical disc degeneration [16]. The modified Pfirrmann grading system was originally suggested for grading degeneration in older individuals, but over time, its use has been reported in the literature across all age groups. Since it is more widely used and more reliable than other classification systems, and allows for precise statistical measurements, we preferred this system for our study. However, we believe the Suzuki classification system is also highly successful, and if we had used it in our study, we believe we would have obtained similar results.

Several histopathological studies have shown that exposure to smoking leads to a reduction in aggrecan production and other biochemical changes that contribute to disc degeneration [17-20]. In our study, the level of degeneration in the C4-C5, C5-C6, and C6-C7 segments was statistically significantly lower in non-smokers than in smokers. Our results are consistent with the aforementioned histological studies.

A systematic review provided strong evidence suggesting that smoking does not correlate with the progression of intervertebral disc degeneration [21]. Conversely, a study examining the relationship between smoking and cervical disc degeneration – similar to our findings – reported that smoking increased cervical disc degeneration [22]. Since the 1990s, the relationship between smoking and disc degeneration has been debated, with conflicting viewpoints. While recent studies predominantly support the idea that smoking accelerates disc degeneration, the topic remains controversial. Our study contributes to the literature and helps clarify this still-debated issue.

Disc tissue is nourished by diffusion from the cartilaginous endplates, and like all cells, it requires oxygen and glucose [23]. It is believed that one of the primary causes of disc degeneration is insufficient nutrition to the disc. When nutrition is impaired, the pH in the nucleus decreases due to increased lactic acid. Experimental studies have shown that low oxygen levels and acidic pH concentrations lead to rapid cell death [24-26]. Smoking impairs oxygen transport through the formation of carboxyhemoglobin [27], causes vasoconstriction [28], leads to atherosclerosis [29], and disrupts fibrinolytic activity. As a result, decreased blood flow negatively impacts intervertebral disc nutrition [30]. Reduced blood flow leads to lower oxygen levels and reduced proteoglycan and collagen synthesis, and accelerates disc degeneration [31].

Nicotine has been shown to penetrate the capillaries of the intervertebral disc, diffuse into the nucleus pulposus [32], affect vertebral chondrocytes [33], reduce bone mineral density [34], inhibit collagen synthesis [35], and negatively impact cell proliferation by reducing DNA synthesis [36-39]. Additionally, nicotine has been reported to cause intervertebral disc degeneration by reducing the viscoelastic properties of the nucleus pulposus [40].

Despite these studies, the idea that smoking accelerates disc degeneration is not universally accepted by clinicians. In practice, clinicians do not routinely advise patients with cervical disc degeneration to quit smoking, at least not in our country, Turkey. This may be due to the limited number of clinical and radiological studies or the lack of awareness on this issue. Our study is valuable as it demonstrates radiologically that smoking contributes to disc degeneration.

Age is an important factor influencing disc degeneration, with degeneration significantly increasing as age advances [41]. In our study, the average age and sex distribution were statistically similar between the research groups formed according to smoking status, which ensured that the results were not influenced by age.

There are studies showing that physical activity affects disc degeneration [42,43]. Occupational or sports-related physical activities can also have a negative impact on disc degeneration [44]. Workers involved in jobs that require prolonged flexion of the head, such as furniture or car repairmen and certain factory workers, were excluded from our study to eliminate the influence of physical activities that could cause cervical disc degeneration.

Studies have shown that individuals with a family history of disc degeneration tend to experience greater degrees of disc degeneration [45], and there is strong evidence that genetic factors play a significant role in its development [46]. In our study, patients with a family history of cervical disc herniation were excluded to minimize the potential effect of this variable on the outcomes. One of the main strengths of our study is the broad exclusion criteria, which allowed us to eliminate other contributing factors to cervical disc degeneration and thereby specifically examine the relationship between smoking and cervical disc degeneration. However, some limitations must be acknowledged. Despite excluding patients with a family history, other important etiological factors, such as genetic predisposition and loss of cervical lordosis, could not be fully ruled out. More meaningful and conclusive results might be obtained by conducting a similar study in a population without cervical lordosis loss. Another limitation of our study is the relatively small sample size, as it was conducted with only 293 patients. Therefore, further studies with larger populations are warranted to validate our findings.

Conclusions

In this study, after excluding risk factors such as systemic diseases, systemic treatments, occupations requiring prolonged posture (eg, furniture makers, car repairmen, certain factory workers), previous cervical disc surgeries, cervical trauma or severe head trauma history, body mass index ≥30 kg/m^2, and

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

family history of cervical disc hernia surgeries, we found that smoking increases cervical disc degeneration. While the role of smoking in cervical disc degeneration is still not fully clear, this study supports the existing evidence for recommending smoking cessation in patients with cervical disc degeneration.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval for this study was obtained from the Ethics Committee of İstinye University in October 2024, with decision number 24-227

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

References:

1. Fakhoury J, Dowling TJ. Cervical degenerative disc disease. 2023 Aug 14. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025
2. Matsumoto M, Fujimura Y, Suzuki N, et al. MRI of cervical intervertebral discs in asymptomatic subjects. J Bone Joint Surg Br. 1998;80(1):19-24
3. Elmasry S, Asfour S, de Rivero Vaccari JP, Travascio F. Effects of tobacco smoking on the degeneration of the intervertebral disc: A finite element study. PLoS One. 2015;10(8):e0136137
4. Rajesh N, Moudgil-Joshi J, Kaliaperumal C. Smoking and degenerative spinal disease: A systematic review. Brain Spine. 2022;2:100916
5. Peng B, DePalma MJ. Cervical disc degeneration and neck pain. J Pain Res. 2018;11:2853-57
6. Kiraz M, Demir E. Relationship of lumbar disc degeneration with hemoglobin value and smoking. Neurochirurgie. 2020;66(5):373-77
7. Wallach CJ, Gilbertson LG, Kang JD. Gene therapy applications for intervertebral disc degeneration. Spine (Phila Pa 1976). 2003;28(15 Suppl.):S93-98
8. Kadow T, Sowa G, Vo N, Kang JD. Molecular basis of intervertebral disc degeneration and herniations: What are the important translational questions? Clin Orthop Relat Res. 2015;473(6):1903-12
9. Doll R, Peto R, Boreham J, Sutherland I. Mortality in relation to smoking: 50 years' observations on male British doctors. BMJ. 2004;328(7455):1519
10. Griffith JF, Wang YX, Antonio GE, et al. Modified Pfirrmann grading system for lumbar intervertebral disc degeneration. Spine (Phila Pa 1976). 2007;32(24):E708-12
11. Xu C, Yin M, Mo W. An independent agreement study of modified Pfirrmann grading system for cervical inter-vertebral disc degeneration in cervical spondylotic myelopathy. Br J Neurosurg. 2024;38(2):260-64
12. Battié MC, Videman T, Gill K, et al. 1991 Volvo Award in clinical sciences. Smoking and lumbar intervertebral disc degeneration: An MRI study of identical twins. Spine (Phila Pa 1976). 1991;16(9):1015-21
13. Hangai M, Kaneoka K, Kuno S, et al. Factors associated with lumbar intervertebral disc degeneration in the elderly. Spine J. 2008;8(5):732-40
14. Kanayama M, Togawa D, Takahashi C, et al. Cross-sectional magnetic resonance imaging study of lumbar disc degeneration in 200 healthy individuals. J Neurosurg Spine. 2009;11(4):501-7
15. Suzuki A, Daubs MD, Hayashi T, et al. Magnetic resonance classification system of cervical intervertebral disk degeneration: Its validity and meaning. Clin Spine Surg. 2017;30(5):E547-E53
16. Urbanschitz L, Bensler S, Merat S, et al. How should we grade cervical disk degeneration? A comparison of two popular classification systems. Spine Surg Relat Res. 2021;5(6):347-51
17. Nemoto Y, Matsuzaki H, Tokuhasi Y, et al. Histological changes in intervertebral discs after smoking and cessation: Experimental study using a rat passive smoking model. J Orthop Sci. 2006;11(2):191-97
18. Ogawa T, Matsuzaki H, Uei H, et al. Alteration of gene expression in intervertebral disc degeneration of passive cigarette- smoking rats: Separate quantitation in separated nucleus pulposus and annulus fibrosus. Pathobiology. 2005;72(3):146-51
19. Vo N, Wang D, Sowa G, et al. Differential effects of nicotine and tobacco smoke condensate on human annulus fibrosus cell metabolism. J Orthop Res. 2011;29(10):1585-91
20. Wang D, Nasto LA, Roughley P, et al. Spine degeneration in a murine model of chronic human tobacco smokers. Osteoarthritis Cartilage. 2012;20(8):896-905
21. Rustenburg CME, Faraj SSA, Ket JCF, et al. Prognostic factors in the progression of intervertebral disc degeneration: Which patient should be targeted with regenerative therapies? JOR Spine. 2019;2(3):e1063
22. Chen Z, Li X, Pan F, et al. A retrospective study: Does cigarette smoking induce cervical disc degeneration? Int J Surg. 2018;53:269-73
23. Benzel EC. Degenerative and inflammatory diseases of the spine. In: Biomechanics of Spine Stabilization. Chicago, Illinois: American Association of Neurological Surgeons. 2001: 45-60
24. Holm SH. Nutrition of the intervertebral disc. In: Weinstein JN, Wiesel SW, editors. The lumbar spine. Philadelphia, W.B. Saunders Corp. 1990;244-60
25. Urban JP, Roberts S. Degeneration of the intervertebral disc. Arthritis Res Ther. 2003;5(3):120-30
26. Horner HA, Urban JP. 2001 Volvo Award Winner in Basic Science Studies: Effect of nutrient supply on the viability of cells from the nucleus pulposus of the intervertebral disc. Spine (Phila Pa 1976). 2001;26(23):2543-49
27. Ernst E. Smoking a cause of back trouble? Br J Rheumatol. 1993;32:239-42
28. Miller VM, Clouse WD, Tonnessen BH, et al. Time and dose effect of transdermal nicotine on endothelial function. Am J Physiol Heart Circ Physio. 2000;279(4):H1913-21
29. Jayson MI, Keegan A, Million R, Tomlinson I. A fibrinolytic defect in chronic back pain syndromes. Lancet. 1984;2(8413):1186-87
30. Ernst E. Smoking is a risk factor for spinal diseases: Hypothesis of the pathomechanism. Wien Klin Wochenschr. 1992;104:626-30
31. Ishihara H, Hirano N, Ooshima H. Effects of oxygen tension on cell metabolism and matrix synthesis in the intervertebral disc. Clin Orthop Surg. 1994;29:357-61
32. Akmal M, Kesani A, Anand B, et al. Effect of nicotine on spinal disc cells: A cellular mechanism for disc degeneration. Spine (Phila Pa 1976). 2004;29(5):568-75
33. Khan MA, Provenza DV, Olson NO. Nicotine toxicity in chick vertebral chondrocytes in vitro. Chem Biol Interact. 1981;35:363-67
34. Broulik PD, Jarab J. The effect of chronic administration of nicotine on bone mineral content in mice. Horm Metab. 1993;25:219-21
35. Ramp WK, Lenz LG, Galvin RJ. Nicotine inhibits collagen synthesis and alkaline phosphatase activity, but stimulates DNA synthesis in osteoblast-like cells. J Exp Biol Med. 1991;197:36-43

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

36. Fang MA, Frost PJ, Had-Klein A. Effects of nicotine on cellular function in UMR 106–01 osteoblast-like cells. Bone. 1991;12:283-86
37. Yuhara S, Kasagi S, Inoue A. Effects of nicotine on cultured cells suggest that it can influence the formation and resorption of bone. Eur J Pharm. 1999;383:387-93
38. Fertig JB, Pomerleau OF, Sanders B. Nicotine-produced antinociception in minimally deprived smokers and exsmokers. Addict Behav. 1986;11:239-48
39. Pomerleau OF, Turk DC, Fertig JB. The effects of cigarette smoking on pain and anxiety. Addict Behav. 1984;9:265-71
40. Iatridis JC, Setton LA, Weidenbaum M, et al. Alterations in the mechanical behaviour of the human lumbar nucleus pulposis with degeneration and aging. J Orthop Res. 1997;15:318-22
41. Miller JA, Schmatz C, Schultz AB. Lumbar disc degeneration: Correlation with age, sex, and spine level in 600 autopsy specimens. Spine. 1988;13:173-78
42. Battie MC, Videman T. Lumbar disc degeneration epidemiology and genetic influences. Spine. 2004;29(23):2679-90
43. Ong A, Anderson J, Roche J. A pilot study of the prevalence of lumbar disc degeneration in elite athletes with lower back pain at the Sydney 2000 Olympic Games. Br J Sports Med. 2003;37(3):263-66
44. Pye SR, Reid D, Adams J, et al: Influence of weight, body mass index and lifestyle factors on radiographic features of lumbar disc degeneration. Ann Rheum Dis. 2007;66:426-27
45. Kalichman L, Hunter DJ. The genetics of intervertebral disc degeneration. Familial predisposition and heritability estimation. Joint Bone Spine. 2008;75(4):383-87
46. Ala-Kokko L. Genetic risc factors for lumbar disc disease. Ann Med. 2002;34:42-47

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]