Tan *et al.*
European Journal of Medical Research (2025) 30:194
https://doi.org/10.1186/s40001-025-02455-0

European Journal of Medical Research

RESEARCH

Open Access

Association of dyslipidemia with intervertebral disc degeneration: a case–control study

Bing Tan[1], Shanlin Xiang[2], Yuhao Zheng[1], Jianyuan Ouyang[1] and Nian Zhou[2*]

Abstract

Purpose To investigate the relationship between dyslipidemia and intervertebral disc degeneration (IVDD).

Methods A total of 269 patients with lumbar disc herniation (Grade III–VIII using the modified Pfirrmann Grading Systems and Total End Plate Damage Score (TEPS) III–VI grade) and 269 patients with lumbar vertebral fracture (LVF, Grade I–II using the modified Pfirrmann Grading Systems and TEPS I–II grade) were enrolled in this study. The total cholesterol level (TC), low-density lipoprotein-cholesterol level (LDL-C), triglyceride level (TG), high-density lipoprotein-cholesterol level (HDL-C), nonHDL-C, ApoB level, ApoB A1 level and arteriosclerosis index (AI) were measured. The 269 patients with single-level LDH who underwent surgery were assigned to the disc herniation group (DH) and 269 patients who underwent surgical treatment for lumbar vertebral fracture during the same period were enrolled as the control group. The participants in the control group were selected randomly and matched for sex.

Results The analysis revealed that the levels of TC, TG, LDL, nonHDL-C, APOB, and APOA1 in patients with LDH were significantly higher compared with those in the controls. The proportion of high-TC, borderline high-total cholesterol, high LDL-C, high-TG, borderline high LDL-C, high APO B, high arteriosclerosis index (AI), and high-ApoB/ApoA1 in the LDH group was significantly higher relative to that of the control group. The ratio of TC/HDL-C, TG/HDL-C, LDL-C/HDL-C, nonHDL-C/HDL-C, and ApoB/ApoA1 in the LDH group was significantly higher compared with that of the control group. Multivariate logistic regression analysis showed that the levels of serum TG, Apo B/ApoA1 ratio, atherogenic index(AI), labour intensity, and age were positively associated with the risk of LDH and were independent risk factors predicting IVDD development.

Conclusion Overall, this study indicates that age, labour intensity, TG, ApoB/ApoA1 ratio and atherogenic index (AI) may increase the risk of IVDD. The levels of TC, TG, LDL-C, nonHDL-C, Apo B, and atherogenic index (AI) may be related to the degree of cartilage endplate (CEP) and intervertebral disc degeneration (IVDD). Moreover, dyslipidemia may be a useful predictor of IVDD.

Keywords Dyslipidemia, Lumbar disc herniation, Intervertebral disc degeneration

*Correspondence:
Nian Zhou
zhounian_2008@126.com
[1] Department of Spine Surgery, The Third Hospital of Mianyang, Sichuan Mental Health Center, 190 Jiannan Road East Section, Youxian, Mianyang 621000, Sichuan, China
[2] Department of Orthopedic, The First Affiliated Hospital of Chongqing Medical University, Yuanjiagang Friendship Road No. 1, Yuzhong 400042, Chongqing, China

Introduction

Low back pain (LBP) is a highly disabling disease affecting about 70–80% of people worldwide. In previous studies, intervertebral disc degeneration (IVDD) was found to be strongly associated with low back pain [1]. Numerous factors contribute to the pathogenesis of IVDD, including metabolic disorders, mechanisms, nutritional deficiencies, and oxidative stress. However,

the specific mechanisms underlying the pathogenesis of IVDD remain unknown [2]. Lumbar disc herniation (LDH) is the most common imaging manifestation of IVDD. Symptomatic LDH often leads to low back pain and sciatica syndrome, which are the main causes of disability and necessitate surgical treatment [3]. In addition, IVDD is primarily caused by inadequate blood supply to the spine. Many studies have demonstrated that the incidence of IVDD is associated with the development of ischemic cardiovascular disease [4–6]. Among the factors contributing to ischemic cardiovascular disease, including dyslipidemia and metabolic disorders [7]. Whether dyslipidemia increases the risk of IVDD is not well understood.

It has been reported that dyslipidemia and atherosclerosis (AS) contribute to the development of IVDD [8, 9]. A positive correlation has been found between sciatica and total cholesterol, LDL-C, as well as triglyceride levels [10]. A series of studies have also shown that levels of Triglyceride, TG, LDL-cholesterol, APO B, and lipoprotein contribute to the occurrence of LDH [8–10]. In 2016, the Joint Committee of Guidelines for the Prevention and Treatment of Dyslipidemia in Chinese Adults reported that the overall prevalence of dyslipidemia in Chinese adults was 40.4%. They predicted that the prevalence of dyslipidemia and related disease burden among Chinese adults is expected to increase [11]. Moreover, dyslipidemia in Chinese adults and non-high-density lipoprotein (nonHDL-C) were predicted to be important risk factors of cardiovascular disease [11]. NonHDL-C and nonHDL-C/HDL-C (high-density lipoprotein) are now being studied in relation to their role in dyslipidemia development [12]. The level of nonHDL-C and the ratio of non-HDL-C/HDL-C are independent risk factors of osteoarthritis and AS [12–14]. However, the association of nonHDL-C and nonHDL-C/HDL-C ratios with IVDD is not clear. Intervertebral disc (IVD) is a non-vascular tissue composed of nucleus pulposus, annulus fibrosus, and cartilage endplate (CEP) [15]. CEP degeneration is closely related to IVDD. However, the possible interplay between blood lipid levels and IVDD remains elusive.

This was a cross-sectional case–control study based on frequency matching. Clinical data were collected to analyze serum lipid levels and compare lipoprotein levels among the groups.

Materials and methods

This study was approved by the Third Hospital of Mianyang Ethical Committee and all participants provided written informed consent. This study conformed to the Declaration of Helsinki.

A total of 538 patients were enrolled in our study at our institution (January 2017–November 2022). The patients were assigned into groups as follows: Group 1 (disc herniation, DH group); comprising 269 patients with LDH (176 men and 93 women; mean age: 45.57 ± 9.08 years, range 20–59), with single-level lumbar disc herniation (LDH, Table 1), Group 2 (control group); comprising 269 patients (176 men and 93 women; mean age: 47.04 ± 8.87 years, range 17–59), who underwent surgery for fractures of the spine (TEPS and Pfirrmann Grading Systems of Grade I or II) [16, 17, 33]. A frequency matching was performed between LDH patients and the patients in the control group based on gender (Table 1). This study was performed in accordance with the Declaration of Helsinki.

Inclusion and exclusion criteria

The inclusion criteria for LDH group were: single segment lumbar disc herniation; single nerve palsy or cauda equina palsy; presented with classical symptoms; neurologic impairment symptoms; bladder or rectal disturbance; magnetic resonance imaging (MRI) signs of herniated disc; refractory nerve root pain due to ineffective systemic conservative treatment. Those with recurring or worsening symptoms during conservative treatment were also included. MRI assessment of IVDD was Grade III or VIII using the modified Pfirrmann

Table 1 Baseline characteristics of participants ($N = 538$)

Variables	Disc herniation ($n = 269$)	Control group ($n = 269$)	*P* value
Gender	176 (Male)/93 (Female)	176 (Male)/93 (Female)	
Age (years)	45.57 ± 9.08 (20–59)	47.04 ± 8.87 (17–59)	0.058
BMI (kg/m^2)	24.25 ± 3.17 (16.53–33.80)	24.09 ± 2.64 (18.03–31.25)	0.529
Smoking	29.37	25.28	0.333
Labour intensity			0.507
Light (%)	27.88	31.97	
Moderate (%)	39.03	34.94	
Heavy (%)	33.08	33.09	

BMI body mass index

Grading Systems and Total End Plate Damage Score III–VI grade (the classification of cartilage endplate and intervertebral disc degeneration was determined according to the average grade of each segment of L3/4, L4/5, and L5/S1).The exclusion criteria for the LDH group were: lumbar spinal stenosis, spondylolisthesis, multiple intervertebral disc herniations, spinal tumor, and history of spinal trauma. These patients had no intervertebral space infection or history of previous lumbar disc surgery.

The inclusion criteria for the control group were: clinical and imaging diagnosis of spinal fractures; MRI assessment of IVDD was Grade I or II using the modified Pfirrmann Grading Systems and Total End Plate Damage Score (the classification of cartilage endplate and intervertebral disc degeneration was determined according to the average grade of each segment of L3/4, L4/5 and L5/S1). The excluded criteria for the control group were: history of spinal disorders, trauma, and low back pain; previous surgery on the affected lumbar disc. In both groups, participants who had undergone operations on the spine, infectious diseases, autoimmune disease, hypertension, coronary heart disease or diabetes were excluded.

Collection of blood samples

After fasting for 8 h, blood samples were collected from each eligible patient between 07.00 and 07.30 am. Fresh blood samples were collected into tubes of 5 ml each (Vacutainer System, Becton–Dickinson, NJ, USA). The samples were centrifuged at 3,500 rpm for 10 min. The supernatant was filtered and collected for further analysis using CIBA Corning 550 Express Auto to measure total cholesterol, LDL-C, triglycerides, and HDL-C (SIEMENS AG, Erlangen, Germany).

Hierarchical criteria of lipid levels

Dyslipidemia was determined in line with the 2016 Chinese Guidelines for the Prevention and Treatment of Dyslipidemia in Adults as follows: high-TC $\geq$ 6.2 mmol/L and borderline high-TC $\geq$ 5.2 and $<$ 6.2 mmol/L; high-TG $\geq$ 2.3 mmol/L and borderline high-TG $\geq$ 1.70 and $<$ 2.3 mmol/L; high-LDL-C $\geq$ 4.1 mmol/L and borderline high LDL-C $\geq$ 3.4 and $<$ 4.1 mmol/L; high-nonHDL-C $\geq$ 4.9 mmol/L, borderline high nonHDL-C $\geq$ 4.1 and $<$ 4.9 mmol/L; low HDL-C for levels $<$ 1.0 mmol/L; Apo B levels between 0.8 and 1.1 g/L; Apo A1 levels between 1.2 and 1.6 g/L; In the male participants, Apo B/Apo A1 was of 0.87, whereas in female participants, it was 0.65; and the atherogenic index(AI) $\geq$ 4.

Imaging diagnosis

In this study, the spines of patients were examined using a 3.0 T MRI scanner. The evaluation of IVDD was done using T2-weighted images from L1 to S1 by two spine surgeons who had no prior knowledge of the study. The degree of IVDD was assessed using the modified Pfirrmann grading system on MRIs. The severity of damage in the CEP was evaluated using T1-weighted images and classified into six types, based on which a score was assigned to CEP. To calculate the "Total End Plate Damage Score (TEPS)" for each disc, both endplate scores were added together, taking into account the severity of CEPD [18].

Statistical analysis

Using two-sample unpaired t-tests, continuous variables were expressed as mean ± standard deviation. Chi-square test was used to analyze categorical variables, which were expressed as percentages. Before statistical analysis, we checked the normality of continuous variables. All statistical analyses were conducted using SPSS (Version 20.0). According to the normal distribution test, all continuous variables in this study are normal. The adjustment for multiple comparisons was conducted in the study. A statistically significant difference was defined by $P < 0.001$ after adjusting for multiple comparisons ($P < 0.001$). The effects of blood lipids on symptomatic LDH were determined using multivariate logistic regression analysis. The Odds ratio (OR) and 95% confidence interval were used as effect indicators. The correlation data were analyzed using Spearman's correlation analysis. A P value of less than 0.05 indicates statistical significance.

Results

Characteristics of the enrolled patients

In Table 1, the study population was divided into two groups. The disc herniation (DH) group included 269 subjects (176 men and 93 women), 45.57 ± 9.08 years with a BMI of 24.25 ± 3.17 kg/m^2. The control group included 269 subjects (176 men and 93 women), 47.04 ± 8.87 years with a BMI of 24.09 ± 2.64 kg/m^2. There was no significant difference in age, gender, BMI, smoking, and labour intensity between the two groups.

The DH group exhibited significantly elevated levels of total cholesterol, TG, LDL-C, non-HDL-C, Apo B, ApoA1, and atherogenic index

In both groups, serum levels of total cholesterol, TG, LDL-C, non-HDL-C, Apo B, ApoA1, and atherogenic index were measured (Table 2). The levels of TC in the symptomatic LDH group, TG, LDL-C, non-HDL-C, Apo

Table 2 The concentrations of serum lipids and lipoproteins in the two groups (mmol/L)

Serum lipids	Disc herniation	Control group	*t* value	*P* value
TC (mmol/L)	4.67 ± 0.88	4.05 ± 0.84	8.379	< 0.001***
TG (mmol/L)	1.78 ± 1.17	1.38 ± 0.88	4.435	< 0.001***
LDL-C (mmol/L)	2.93 ± 0.81	2.43 ± 0.77	7.738	< 0.001***
HDL-C (mmol/L)	1.25 ± 0.34	1.19 ± 0.32	1.910	0.057
nonHDL-C (mmol/L)	3.42 ± 0.85	2.85 ± 0.80	3.970	< 0.001***
ApoB (g/L)	0.93 ± 0.21	0.82 ± 0.21	6.235	< 0.001***
ApoA1 (g/L)	1.33 ± 0.24	1.25 ± 0.23	3.970	< 0.001***
Atherogenic index (%)	2.96 ± 1.14	2.59 ± 1.06	3.963	< 0.001***

TC Total Cholesterol, *TG* Triglyceride, *LDL-C* Low-density lipoprotein-cholesterol, *HDL-C* High-density lipoprotein-cholesterol level, *nonHDL-C* Non-high-density lipoprotein-cholesterol, *ApoB* Apolipoprotein B, *ApoB A1* Apolipoprotein A1,***$P < 0.001$

Table 3 Incidence of dyslipidemia in the two groups

Serum lipids	Disc herniation (%)	Control *N* (%)	*P* value
TC			
5.2 ~ 6.2 mmol/L	47 (17.47)	12 (4.46)	< 0.001***
≥ 6.2 mmol/L	15 (5.58)	5 (1.86)	0.019*
TG			
1.7 ~ 2.3 mmol/L	38 (14.13)	35 (13.01)	0.401
≥ 2.3 mmol/L	65 (24.16)	25 (9.29)	< 0.001***
LDL-C			
3.4 ~ 4.1 mmol/L	60 (22.30)	17 (6.20)	0.033*
≥ 4.1 mmol/L	16 (5.95)	5 (4.38)	0.012*
nonHDL-C			
4.1 ~ 4.9 mmol/L	32 (11.90)	8 (2.97)	< 0.001***
≥ 4.9 mmol/L	15 (5.58)	5 (1.86)	0.019*
HDL-C (mmol/L)			
< 1.0 mmol/L	59 (21.93)	78 (29.00)	0.037*
ApoA1			
< 1.2 g/L	86 (31.97)	110 (40.89)	0.020*
ApoB			
≥ 1.1 g/L	55 (20.45)	21 (7.81)	< 0.001***
Atherogenic index (%)			
≥ 4	46 (17.10%)	21 (7.81%)	0.025*
ApoB/ApoA1			
> 0.65 or > 0.87	143 (53.16)	73 (27.14)	< 0.001***

TC Total Cholesterol, *TG* Triglyceride, *LDL-C* Low-density lipoprotein-Cholesterol, *HDL-C* High-density lipoprotein-cholesterol level, *nonHDL-C* Non-high-density Lipoprotein Cholesterol, *ApoB* Apolipoprotein B, *ApoB A1* Apolipoprotein A1,*$P < 0.5$,***$P < 0.001$

B, Apo A1, and atherogenic index were higher compared with levels in the control group. There was no significant difference in HDL-C between the two groups ($P = 0.057$).

The frequency of dyslipidemia was enhanced in patients with LDH

In Table 3, the prevalence of high-total cholesterol (TC), high triglyceride (TG), high LDL-C, high nonHDL-C, low ApoA1 and low HDL-C in the LDH group was 5.58, 15.58, 5.95, 5.58, 31.97, and the incidence for the control group was 1.86, 9.29, 4.38, 1.86, 40.89, and 29%, respectively. Further analysis showed that high-ApoB, high A1, and high-ApoB/ApoA1 ratio were significantly higher in the DH group compared to the control group. For the 269 patients in the DH group, borderline High-TC was 47 (17.47%), borderline High-TG was 38 (14.13%), borderline High-LDL-C was 60 (22.30%) compared to 12 (4.46%), 35 (13.11%), and 17 (6.20%) in the control group, respectively. Patients in the DH group had a significantly higher incidence of borderline High-TC and borderline High-LDL-C compared to those in the control group. Notably, the incidence of borderline High-TG was not significantly different between the two groups ($P = 0.401$). Analysis of the 269 patients with DH showed that 32 (11.90%) had borderline High-nonHDL-C compared to 8 (2.97%) patients in the control group. The difference in the frequency of borderline High-nonHDL-C between the two groups was significant.

The nonHDL-C/HDL-C, Triglyceride/HDL-C, ApoB/ApoA1, LDL-C/HDL-C, and Total Cholesterol/HDL-C ratios were elevated in the DH group

In DH group, the ratio of total cholesterol/HDL-C, triglyceride/HDL-C, LDL-C/HDL-C, nonHDL-C/HDL-C, and ApoB/ApoA1 was 3.96 ± 1.14, 1.65 ± 1.53, 2.50 ± 0.89, 2.96 ± 1.14, and 0.72 ± 0.22, the ratio for the control group was 3.59 ± 1.06, 1.32 ± 1.12, 2.17 ± 0.84, 2.59 ± 1.06, and 0.67 ± 0.19, respectively. This study showed that the ratios of total cholesterol/HDL-C,triglyceride/HDL-C,ApoB/ApoA1,LDL-C/HDL-C, and nonHDL-C/HDL-C were significantly higher in the DH group compared to the control group (Fig. 1).

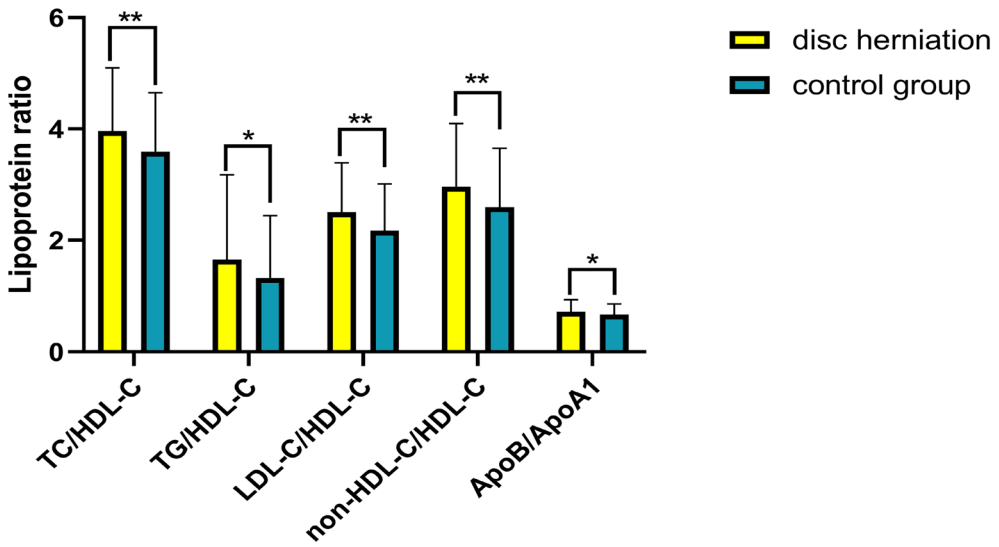

Fig. 1 Lipoprotein ratios in the two groups. The ratios of TC/HDL-C, TG/HDL-C, LDL-C/HDL-C, nonHDL-C/HDL-C and ApoB/ApoA1 were significantly higher in the DH group compared with the control group, *$p < 0.01$ and **$p < 0.001$

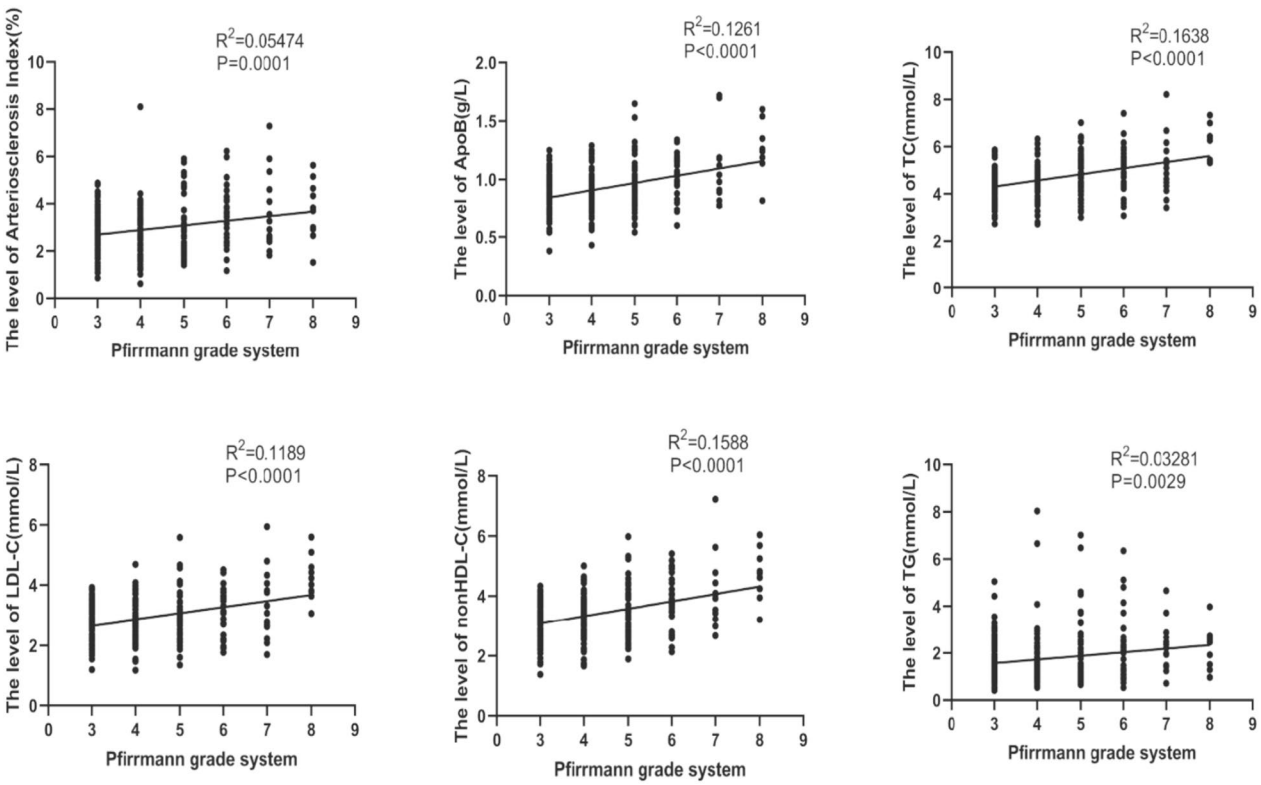

Fig. 2 The degree of IVDD was positively correlated with serum lipid abnormalities

Abnormal serum lipids were correlated with intervertebral disc degeneration (IVDD)

To analyze the relationship between IVDD, we investigated the correlation between them. Figure 2 illustrates that the degree of IVDD was significantly correlated with elevated LDL-C, total cholesterol, TG, nonHDL-C, Apo B, and atherogenic index. The results showed that higher levels of LDL-C, total cholesterol, triglyceride,

nonHDL-C, apolipoprotein B and atherogenic index were associated with IVDD.

Abnormal serum lipids were correlated with CEP degeneration

To analyze the relationship between LDH and CEP degeneration (Total End Plate Damage Score, TEPS), we investigated the correlation between them. Figure 3 illustrates that the degree of CEP degeneration was significantly correlated with elevated LDL-C, total cholesterol, TG, nonHDL-C, Apo B, and atherogenic index (R^2 LDL-C = 0.05915, $P < 0.001$; R^2TC = 0.0745, $P < 0.0001$; R^2 TG = 0.01923, $P = 0.0229$; R^2 Apo B = 0.08841, $P < 0.001$; R^2 nonHDL-C = 0.08456, $P < 0.008$; R^2 atherogenic index = 0.04007, $P = 0.01$). In addition, higher levels of LDL-C, total cholesterol, triglyceride, nonHDL-C, apolipoprotein B and atherogenic index were associated with CEP degeneration.

Patients with elevated levels of age, labour intensity, TG, Apo B/ApoA1 ratio and atherogenic index (AI) had an increased risk of IVDD

In the preliminary phase of our study, we conducted a multicollinearity assessment on the initial dataset ($n = 538$), to ensure the reliability and stability of our subsequent predictive model. We conducted Spearman correlation analysis to identify and eliminate highly correlated features (BMI, ApoA1, ApoB, smoking, nonHDL, gender, LDLHDL, TCHDL, TGHDL, and nonHDLHDL), aiming to mitigate the impact of multicollinearity (Fig. 4). Subsequently, we conducted a multivariate logistic regression analysis to examine the associations between various risk factors and the incidence of IVDD (Fig. 5). The analysis revealed that TG, labour intensity, and the arteriosclerosis index were positively correlated with an increased risk of IVDD, with OR values of 1.4284 (95% CI 1.04161, 1.96), 1.4668 (95% CI 1.08206, 1.99), and 1.3666 (95% CI 1.11323, 1.68), respectively. Conversely, age and the ApoB/ApoA1 exhibited negative correlations with the risk of IVDD, with OR values of 0.9653 (95% CI 0.96302, 0.99) and 0.0054 (95% CI 0.00012, 0.24).

Discussion

Currently, the pathophysiology of IVDD is not well understood [19]. This study demonstrates that the pathomechanism of IVDD mainly involves abnormal mechanical load, lack of nutritional supply, metabolic disorders, cell senescence, apoptosis, matrix metalloproteinases or corresponding inflammatory cytokines activation [19–21]. A previous study postulated that the occurrence of IVDD may be related to age, physical activity and genetic factors [21]. In recent years, there has been increased interest to study the association of dyslipidemia with IVDD occurrence [5, 8, 10].

Numerous studies have demonstrated a close association between dyslipidemia and IVDD [5, 8, 10, 21]. The

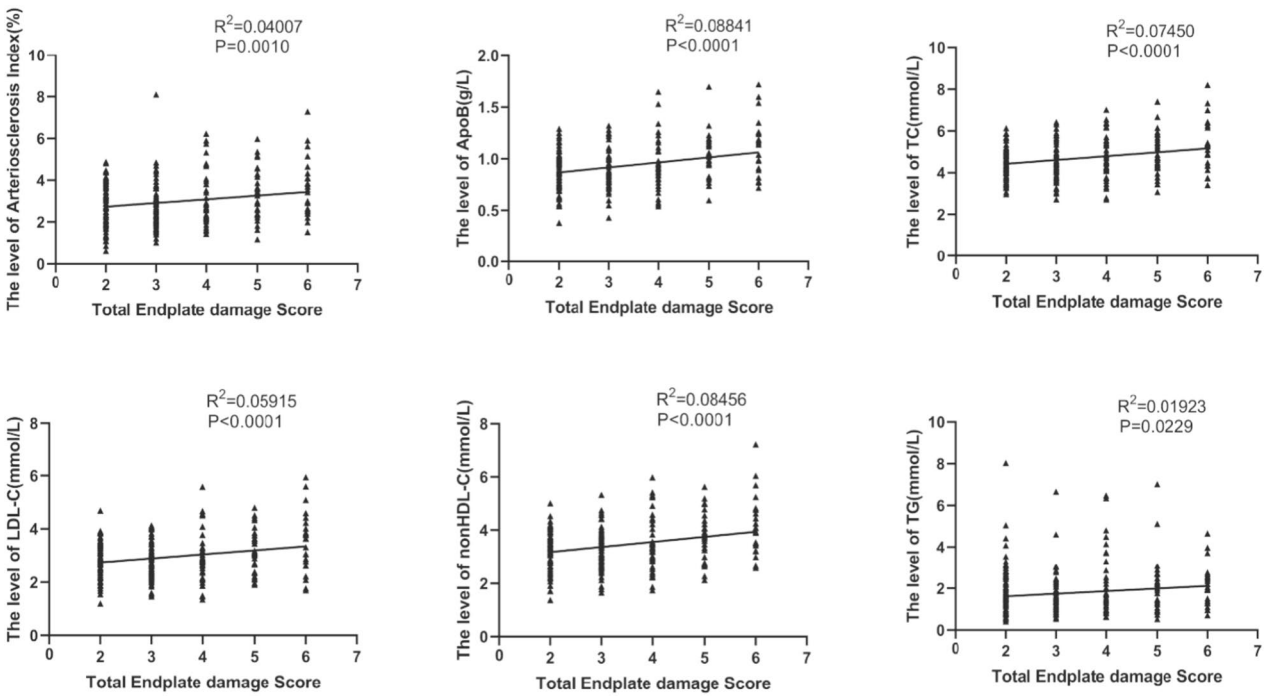

Fig. 3 The degree of CEP degeneration was positively correlated with serum lipid abnormalities

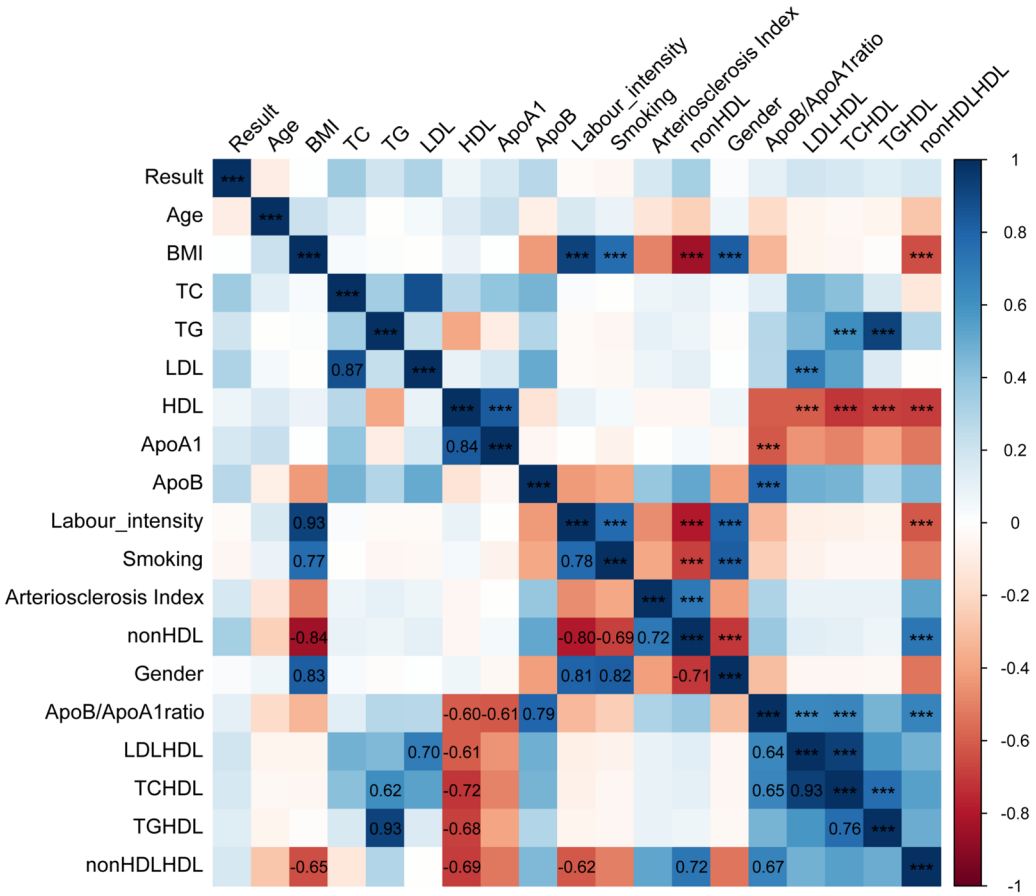

Fig. 4 Correlation coefficient matrix heatmap of the feature variables

level of TC, TG, LDL-C, and lipoprotein has also been shown to influence the development of sciatica, low back pain, and LDH [5, 8, 16, 22]. The results are consistent with our findings. In particular, we found that TC, TG, LDL-C, and Apo B levels were increased in the DH group compared with the control group. However, the level of HDL-C was significantly different between the two cohorts. The proportions of high-TC, high-TG, high-LDL-C, high-ApoB, and high Apo B/ApoA1 were significantly increased in the DH group. Moreover, a positive correlation was found between TC, triglyceride, LDL-C, LDL-C/HDL-C, ApoB/ApoA1, and LDH. The age, labour intensity, TG, ApoB/ApoA1 ratio and atherogenic index (AI) may increase the risk of IVDD. The ratios of TC/HDL-C, TG/HDL-C, LDL-C/HDL-C, and ApoB/ApoA1 were significantly increased in the DH group. In their study, Chen et al. [10] found no significant differences in TG/HDL-C ratios between the DH and control groups. However, in this study, the DH group had a significantly higher ratio of TG/HDL-C and borderline High-TG compared with the control group ($P > 0.05$). The discrepancies observed among studies may have been caused by differences in sample sizes and inclusion criteria for the enrolled cases. A previous study explored the impact of dyslipidemia on disc degeneration by comparing DH with lower limb fracture or articular cartilage injury. However, the study was limited by the fact that the patients in the control group did not undergo MRI examination, which would weaken the validity of the results, especially for individuals with LDH. To overcome this challenge, we included spine fracture MRIT2-weighted images of lumbar intervertebral discs with modified Pfirrmann I and II grades in the study as controls. Our results demonstrated that ApoA1 levels were higher in serum from LDH patients relative to the controls. Among the major components of HDL-C, APO plays a role in the transport of cholesterol. The relationship between HDL-C and the risk of cardiovascular disease is not linear. Studies have suggested that an increase in HDL-C levels beyond 1.5 mmol/L may not confer any further improvement in cardiovascular disease. In severe cases of dyslipidemia, elevated levels of apolipoprotein A1 (APO A1) may also be observed [17]. Due to this, the relationship between HDL-C and ApoA1 and symptomatic LDH deserve

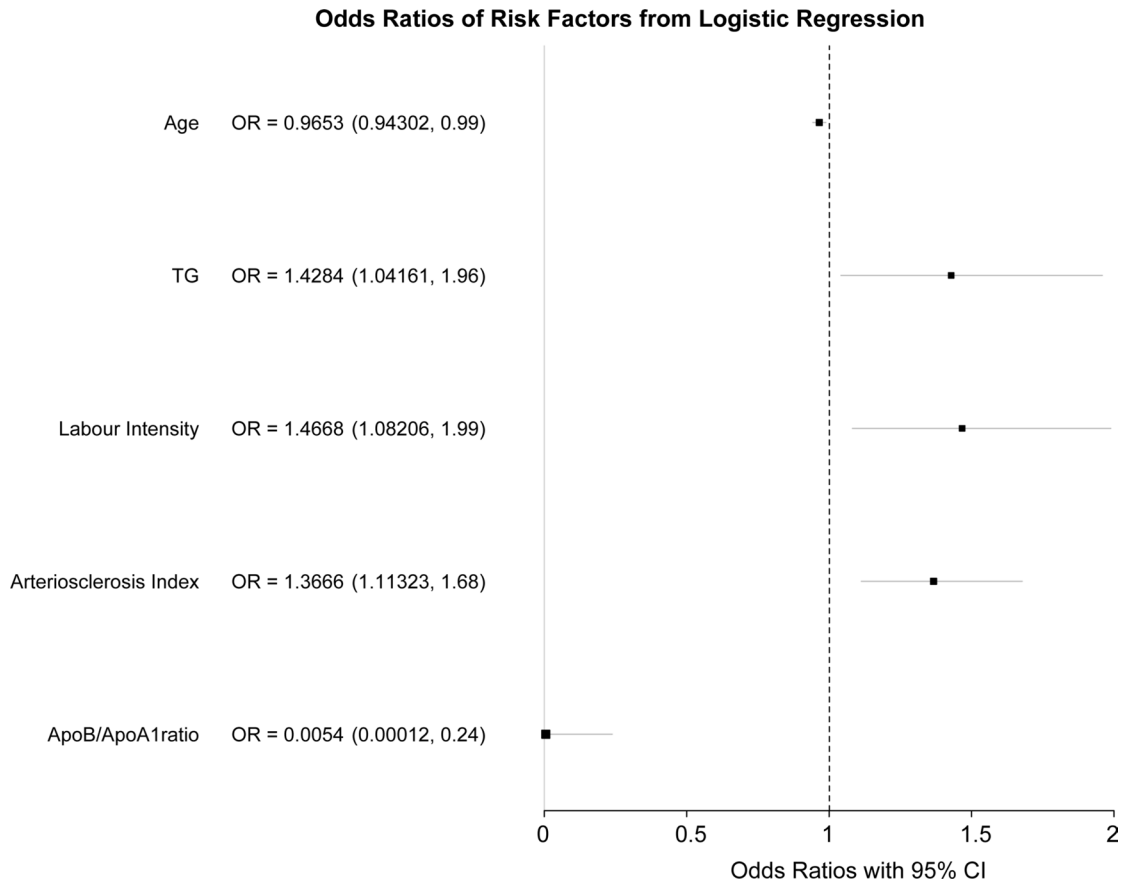

Fig. 5 Association of serum lipid abnormalities with the risk of IVDD

further assessment. Studies have shown that total cholesterol (TC)/HDL-C, ApoB/ApoA1, LDL-C/HDL-C and Triglyceride/HDL-C are more accurate indicators of the transport capacity of cholesterol to peripheral tissues, and plasma cholesterol level can accurately indicate dyslipidemia because it is based on the level of cholesterol in the blood [23].

NonHDL-C refers to the sum of very LDL (VLDL-C), intermediate density lipoprotein (IDL), and LDL-C [24]. NonHDL-C is a robust marker of cholesterol content in all types of atherosclerotic lipoprotein particles and has demonstrated superior predictive accuracy for cardiovascular disease compared to other lipid measures. On the other hand, the AS index is a well-established tool used by the international medical community to quantify the extent of arteriosclerosis development. The arteriosclerosis index = (total cholesterol high-density lipoprotein-cholesterol)/high-density lipoprotein-cholesterol, which is an independent risk factor for arteriosclerosis [25]. Some studies have shown that NonHDL-C and arteriosclerosis index are risk factors for cardiovascular disease, osteoarthritis, rheumatoid arthritis etc. [25, 26]. However, whether the levels of nonHDL-C and arteriosclerosis index are associated with LDH is unclear. In this study, nonHDL-C and arteriosclerosis index levels were correlated with LDH. Our findings showed a significant increase in nonHDL-C and arteriosclerosis index levels in the LDH patients (Table 1). NonHDL-C and arteriosclerosis index levels were positively correlated with LDH. Arteriosclerosis index may be independent risk factors for IVDD. Measuring non-HDL cholesterol levels is an effective strategy to identify individuals at high risk of developing cardiovascular disease. It is a reliable predictor of future events and can be easily measured, representing the total cholesterol content in atherogenic lipoprotein particles. Using non-HDL cholesterol can aid in implementing appropriate prevention and treatment strategies [25, 26]. However, compared with LDL-C, non-HDL-C has received little attention. In the current guidelines, non-HDL-C is an equally important therapeutic target, similar to LDL-C. It is a more accurate indicator of atherosclerotic particles than LDL-C, and may reduce the nutritional supply to the intervertebral disc through AS, leading to IVDD. Studies have shown that AS is

closely related to IVDD, and AI is the most direct indicator of AS [27, 28]. AI is closely related to the occurrence of IVDD. Compared to the control group, the IDH group had higher levels of nonHDL-C and AI.

Additionally, the exact mechanisms by which dyslipidemia stimulates LDH and IVDD development are not well understood. LDH and disc degeneration caused by lipid metabolism disorder are primarily attributed to vascular sclerosis and plaque formation resulting from AS. These changes may lead to a reduced blood supply to the intervertebral disc, leading to IVDD. The intervertebral disc is a vascular tissue, which relies on the CEP and the capillaries of the annulus fibrosus for nutrient support. AS can be caused by elevated levels of TG, total cholesterol, LDL-C, Atherogenic Index, Apolipoprotein B, and non-HDL-C. AS and vascular sclerosis decrease the blood supply to the disc, leading to the occurrence of LDH or IVDD. Some studies have shown that AS may be an independent risk factor for LDH [27–29]. Metabolic factors, inflammatory cell activation, and inflammatory factors associated with lipid metabolism disorders may also contribute to the development of LDH or IVDD. CEP is a thin layer of transparent cartilage between the intervertebral disc and the vertebral body through which nutrients diffuse from the vertebral body to the IVD through CEP [15]. Therefore, CEP modulates the nutritional supply and biomechanical balance of the IVD. Williams et al. [30] showed that CEP defects are significantly and independently associated with IVDD, and the degeneration of CEP is the initial factor in the pathogenesis of IVDD. Some studies have shown that oxidized low-density lipoprotein (ox-LDL) and lectin-like low-density lipoprotein receptor 1 (LOX-1), the most common pathogenic factors of hyperlipidemia, are highly expressed in degenerative intervertebral discs, especially in the CEP [31, 32]. Although most of the abnormal metabolites in the blood enter the intervertebral disc through the CEP, there are no data to support the relationship between dyslipidemia and CEP degeneration. Our study found that dyslipidemia was positively correlated with cartilage endplate degeneration.Some studies have shown that lipid levels are positively correlated with the degree of IVDD, this is consistent with our findings [8–10].

This study found a positive association of LDL-C, total cholesterol, TG, nonHDL-C, Apolipoprotein B, and atherogenic index levels with the degree of CEP degeneration. Dyslipidemia-related substances may potentially initiate cartilage degeneration (such as aging or calcification) by affecting the CEP, impairing its ability to provide nutrients to the intervertebral disc. This may ultimately result in a reduction in nutritional support to the disc, leading to the development of LDH or IVDD [31, 32, 34]. Our study was to select patients with discogenic low back pain as the experimental group, because patients with discogenic low back pain were mostly treated conservatively in the outpatient department, and many patients did not undergo blood lipid testing, so patients with discogenic low back pain could not be used as the experimental group. It is, therefore, necessary to conduct further experiments to validate our findings.

Our study suggests a significant correlation between elevated blood lipid levels and LDH, with high blood lipid levels indicating a higher incidence of IVDD. Furthermore, there is a positive association between the degree of CEP degeneration and blood lipid levels. These findings shed new light on the mechanism of lipid metabolism disorder and its potential role in IVDD. The causal relationship between dyslipidemia and LDH or IVDD remains unclear because this was a retrospective case–control study. In future, large-scale, longitudinal follow-up observations, animal experiments, and interventional studies should be conducted to define the causal relationship and find effective IVDD/LDH prevention and treatment methods.

Conclusions

Taken together, our study demonstrates that age,labour intensity, TG, ApoB/ApoA1 ratio, and atherogenic index (AI) may increase the risk of IVDD. The levels of TC, TG, LDL-C, nonHDL-C, Apo B, and atherogenic index (AI) may be related to the degree of cartilage endplate (CEP) and intervertebral disc degeneration (IVDD).This study provides new evidence supporting the association between dyslipidemia and the risk of LDH disease, and suggests that controlling blood lipid levels may be a new approach to reduce IVDD. Additionally, this study provides new ideas for investigating the mechanism of IVDD induced by dyslipidemia.

Author contributions

Conception and design: Bing Tan, Nian Zhou. Development of methodology: Bing Tan, Shanlin Xiang. Acquisition of data: Yuhao Zheng,Jianyuan Ouyang. Analysis and interpretation of data:Bing Tan,Jianyuan Ouyang.Writing and review of manuscript: Bing Tan, Nian Zhou.Bing Tan prepared Figs. 1, 2, 3, 4, and 5. All authors reviewed the manuscript.

Funding

The study is supported by the National Natural Science Foundation of China (Project No. 82102556) and Sichuan Medical Youth Innovation Research Project Plan (No.Q23072). A commercial party has not received or will not receive any benefits related directly or indirectly to this manuscript.

Availability of data and materials

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethics Review Committee of Mianyang The Third People's Hospital. The Approval number is 2023-9.

Competing interests
The authors declare no competing interests.

Received: 12 January 2024 Accepted: 11 March 2025
Published online: 21 March 2025

References

1. Yang S, Zhang F, Ma J, et al. Intervertebral disc ageing and degeneration: the anti-apoptotic effect of oestrogen. Ageing Res Rev. 2020;57:100978.
2. Wu PH, Kim HS, Jang IT. Intervertebral disc diseases PART 2: a review of the current diagnostic and treatment strategies for intervertebral disc disease. Int J Mol Sci. 2020;20(21):21–35.
3. Yuan C, Wen B, Lin H. Clinical analysis of minimally invasive percutaneous treatment of severe lumbar disc herniation with UBE two-channel endoscopy and foraminal single-channel endoscopy technique. Oxid Med Cell Longev. 2022;2022:9264852.
4. Tezuka F, Sakai T, Nishisho T, et al. Variations in arterial supply to the lower lumbar spine. Eur Spine J. 2016;25(12):4181–7.
5. Longo UG, Denaro L, Spiezia F, et al. Symptomatic disc herniation and serum lipid levels. Eur Spine J. 2011;20(10):1658–62.
6. 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.
7. Doi T, Langsted A, Nordestgaard BG. Elevated remnant cholesterol reclassifies risk of ischemic heart disease and myocardial infarction. J Am Coll Cardiol. 2022;79(24):2383–97.
8. Ruiz-Fernández C, Francisco V, Pino J, et al. Molecular relationships among obesity, inflammation and intervertebral disc degeneration: are adipokines the common link? Int J Mol Sci. 2019;20(8):2030.
9. Hemingway H, Shipley M, Stansfeld S, et al. Are risk factors for atherothrombotic disease associated with back pain sickness absence? The Whitehall II Study. J Epidemiol Community Health. 1999;53(4):197–203.
10. Chen F, Wu T, Bai C, et al. Serum apolipoprotein B/apolipoprotein A1 ratio in relation to intervertebral disk herniation: a cross-sectional frequency-matched case-control study. Lipids Health Dis. 2021;20(1):79.
11. Zhu JR, Gao RL, Zhao SP, et al. Chinese Guidelines for the Prevention and Treatment of Dyslipidemia in Adults (2016 Revision). Chin J Cardiol. 2016;44(10):25–30.
12. Wang G, Jing J, Wang A, China National Stroke Registry II Investigators, et al. Non-high-density lipoprotein cholesterol predicts adverse outcomes in acute ischemic stroke. Stroke. 2021;52(6):2035–42.
13. Eliasson B, Gudbjörnsdottir S, Zethelius B, Eeg-Olofsson K, Cederholm J, National Diabetes Register (NDR). LDL-cholesterol versus non-HDL-to-HDL-C ratio and risk for coronary heart disease in type 2 diabetes. Eur J Prev Cardiol. 2014;21(11):1420–8.
14 Xie B, He J, Liu Y, et al. A meta-analysis of HDL cholesterol efflux capacity and concentration in patients with rheumatoid arthritis. Lipids Health Dis. 2021;20(1):18.
15. Ashinsky BG, Bonnevie ED, et al. Intervertebral disc degeneration is associated with aberrant endplate remodeling and reduced small molecule transport. J Bone Miner Res. 2020;35(8):1572–81.
16. Shi S, Zhou Z, Liao JJ, et al. The impact and distinction of "lipid healthy but obese" and "lipid abnormal but not obese" phenotypes on lumbar disc degeneration in Chinese. J Transl Med. 2020;18(1):211.
17. März W, Kleber ME, Scharnagl H, et al. HDL cholesterol: reappraisal of its clinical relevance. Clin Res Cardiol. 2017;106(9):663–75.
18. Rajasekaran S, Venkatadass K, Naresh Babu J, et al. Pharmacological enhancement of disc diffusion and differentiation of healthy, ageing and degenerated discs: results from in-vivo serial post-contrast MRI studies in 365 human lumbar discs. Eur Spine J. 2008;17(5):626–43.
19 Gullbrand SE, Ashinsky BG, Bonnevie ED, et al. Long-term mechanical function and integration of an implanted tissue-engineered intervertebral disc. Sci Transl Med. 2018;10(468):eaau0670.
20. Novais EJ, Tran VA, Johnston SN, et al. Long-term treatment with senolytic drugs Dasatinib and Quercetin ameliorates age-dependent intervertebral disc degeneration in mice. Nat Commun. 2021;12(1):5213.
21 Zehra U, Tryfonidou M, Iatridis JC, et al. Mechanisms and clinical implications of intervertebral disc calcification. Nat Rev Rheumatol. 2022;18(6):352–62.
22. Shiri R, Karppinen J, Leino-Arjas P, et al. Cardiovascular and lifestyle risk factors in lumbar radicular pain or clinically defined sciatica: a systematic review. Eur Spine J. 2007;16(12):2043–54.
23. Gregersen I, Hoibraaten E, Holven KB, et al. Effect of hormone replacement therapy on atherogenic lipid profile in postmenopausal women. Thromb Res. 2019;184:1–7.
24 Idris I, Tate H, Ahmad A, McCormack T. Concordance between plasma apolipoprotein B levels and cholesterol indices among patients receiving statins and nonstatin treatment: Post-hoc analyses from the U.K. In Practice study. J Clin Lipidol. 2011;5(4):316–23.
25. Zhou W, Li S, Sun G, et al. Early warning of ischemic stroke based on atherosclerosis index combined with serum markers. J Clin Endocrinol Metab. 2022;107(7):1956–64.
26. Yang XY, Zhong DY, Wang GL, et al. Effect of walnut meal peptides on hyperlipidemia and hepatic lipid metabolism in rats fed a high-fat diet. Nutrients. 2021;13(5):1410.
27 Kauppila LI. Atherosclerosis and disc degeneration/low-back pain–a systematic review. Eur J Vasc Endovasc Surg. 2009;37(6):661–70.
28. Kauppila LI, Penttilä A, Karhunen PJ, et al. Lumbar disc degeneration and atherosclerosis of the abdominal aorta. Spine. 1994;19(8):923–9.
29 Kauppila LI, McAlindon T, Evans S, et al. Disc degeneration/back pain and calcification of the abdominal aorta. A 25-year follow-up study in Framingham. Spine. 1997;22(14):1642–7.
30. Rade M, Määttä JH, Freidin MB, et al. Vertebral endplate defect as initiating factor in intervertebral disc degeneration: strong association between endplate defect and disc degeneration in the general population. Spine. 2018;43(6):412–9.
31. Li X, Wang X, Hu Z, et al. Possible involvement of the oxLDL/LOX-1 system in the pathogenesis and progression of human intervertebral disc degeneration or herniation. Sci Rep. 2017;7(1):7403.
32. Wu W, Jing D, Huang X, et al. Drp1-mediated mitochondrial fission is involved in oxidized low-density lipoprotein-induced AF cella poptosis. J Orthop Res. 2021;39(7):1496–504.
33. Griffith JF, Wang YX, Antonio GE, et al. Modified Pfirrmann grading system for lumbar intervertebral disc degeneration. Spine. 2007;32(24):E708–12.
34. Barreto J, Karathanasis SK, Remaley A, Sposito AC. Role of LOX-1 (Lectin-Like Oxidized Low-Density Lipoprotein Receptor1) as a cardiovascularrisk predictor: mechanistic insight and potential clinical use. Arterioscler Thromb Vasc Biol. 2021;41(1):153–66.

Publisher's Note