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CLINICAL ARTICLE

# Risk Factors for Surgical Treatment of Lumbar Degenerative Disc Disease in Middle-aged and Older Women: A Prospective Case–Control Study of 2370 Subjects

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**Objective:** Given the distinct physiological and societal traits between women and men, we propose that there are distinct risk factors for lumbar degenerative disc disease surgeries, including lumbar disc herniation (LDH) and lumbar spinal stenosis (LSS), in middle-aged and older populations. However, few studies have focused on middle-aged and older women. This study aims to identify these risk factors specifically in this population.

**Methods:** In this case–control study, the study group comprised 1202 women aged ≥ 45 years who underwent operative treatment of lumbar degenerative disc disease (LDH, $n = 825$; LSS, $n = 377$), and the control group comprised 1168 women without lumbar disease who visited a health examination clinic during the same period. The study factors included demographics (age, body mass index [BMI], smoking, labor intensity, and genetic history), female-specific factors (menopausal status, number of deliveries, cesarean section, and simple hysterectomy), surgical history (number of abdominal surgeries, hip joint surgery, knee joint surgery, and thyroidectomy), and systemic diseases (hypercholesterolemia, hypertriglyceridemia, hyper-low-density lipoprotein cholesterolemia, hypertension, diabetes, cardiovascular disease, and cerebrovascular disease). Multivariate binary logistic regression analysis was used to calculate the odds ratio (OR) and 95% confidence interval (95% CI) of associated factors.

**Results:** The risk factors for surgical treatment of LDH in middle-aged and older women included BMI (OR = 1.603), labor intensity (OR = 1.189), genetic history (OR = 2.212), number of deliveries (OR = 1.736), simple hysterectomy (OR = 2.511), hypertriglyceridemia (OR = 1.932), and hyper-low-density lipoprotein cholesterolemia (OR = 2.662). For surgical treatment of LSS, the risk factors were age (OR = 1.889), BMI (OR = 1.671), genetic history (OR = 2.134), number of deliveries (OR = 2.962), simple hysterectomy (OR = 1.968), knee joint surgery (OR = 2.527), hypertriglyceridemia (OR = 1.476), hyper-low-density lipoprotein cholesterolemia (OR = 2.413), and diabetes (OR = 1.643). Cerebrovascular disease was a protective factor against surgery for LDH (OR = 0.267).

**Conclusions:** BMI, genetic history, number of deliveries, simple hysterectomy, hypertriglyceridemia, and hyper-low-density lipoprotein cholesterolemia were independent risk factors for surgical treatment of both LDH and LSS in middle-aged and older women. Two disparities were found: labor intensity was a risk factor for LDH patients, and knee joint surgery and diabetes were risk factors for LSS patients.

**Key words:** Case–control study; Lumbar degenerative disc disease; Lumbar disc herniation; Lumbar spinal stenosis; Middle-aged and older women; Risk factor

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## Introduction

Lumbar degenerative disc disease (LDDD), including lumbar disc herniation (LDH) and lumbar spinal stenosis (LSS), is a common health problem and frequently leads to work disability. LDH refers to protrusion of the nucleus pulposus from the defective annulus fibrosus into the spinal canal.[1] LSS is defined as a narrowing of the lumbar spinal canal with encroachment of neural structures by surrounding bone and soft tissue.[2] Both LDH and LSS are common causes of low back pain, radicular leg pain, and/or leg numbness. Previous studies have shown that risk factors for LDDD include family history, mechanical stress, aging, posture, trauma, occupation, smoking, and obesity.[3] However, the most recent research has mainly examined the relationships of occupation, work, and lifestyle factors with LDDD.[4,5] There is a relative lack of research specifically focusing on the risk factors for surgical treatment of LDDD in women.

Women and men exhibit distinct physiological and social characteristics. In women, the hormones secreted by the hypothalamic–pituitary-ovarian axis have complicated effects on multiple organ systems in the body.[6] Various studies have indicated a correlation between female sex hormone levels and degenerative changes in the lumbar spine. Loss of estrogen leads to decreased skeletal muscle mass, bone and muscle fat accumulation, aggravation of disc degeneration, increased incidence of facet joint osteoarthritis (OA), and lumbar endplate damage.[7–10] A study of 4000 women in China revealed that disc degeneration accelerates after menopause.[11] Moreover, Imada *et al.*[12] demonstrated that women are approximately three to four times more likely than men to develop degenerative lumbar spondylolisthesis. Most of these effects can be significantly improved after estrogen supplementation. In addition, sex disparities manifest as differences in work intensity, occupation type, and lifestyle behaviors, such as smoking, in China. Furthermore, the incidence of LDDD may be influenced by pregnancy and childbirth.[13] Therefore, the spectrum of LDDD-associated risk factors may differ between women and men. However, this population is novel and has not been well studied before.

In the present study, we compared middle-aged and older women who underwent surgery for LDH or LSS at our hospital with middle-aged and older women who attended our health examination clinic during the same period. The purpose of this case–control study is to investigate the risk factors associated with surgical treatment for LDH or LSS in middle-aged and older women, from four aspects: demographics, female-specific factors, surgical history, and systemic diseases. We hypothesized that female-specific factors, such as a history of hysterectomy and parity, may contribute to the risk of requiring such surgeries.

## Methods

Institutional review board approval was obtained before commencing this study, and informed consent was obtained from all participants prior to their enrollment (KYLL-2021(KS)-055). The medical center where the study was conducted is a large tertiary hospital in an eastern province of China, and the orthopedic department serves approximately 1 million people per year. The investigation followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and was designed and executed accordingly. International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis codes M51.202 and M48.0 were used to identify all patients who underwent surgical procedures for LDH or LSS from April 2019 to June 2021 from our institution's prospectively collected data. LDH and LSS were diagnosed by two or more orthopedic experts based on clinical symptoms, signs, and radiological examinations (computed tomography and magnetic resonance imaging). The diagnostic process was objective and standardized. Experienced data scientists and statisticians extracted the data.

Using the above-mentioned codes, we initially identified 2203 patients for review. After checking the medical record of each patient, 1412 women who had undergone surgery for LDH or LSS were initially identified. Inclusion criteria for this study encompassed female patients who were aged 45 or older, diagnosed with LDH or LSS, had a comprehensive medical history, met the surgical indications, and underwent the surgical intervention at our research institution. The following exclusion criteria were then applied: absence of body mass index (BMI) data, incomplete medical history, diagnosis of other spinal diseases, and history of spinal surgery. Following the application of these criteria, the final study group comprised 1202 patients (LDH, $n = 825$; LSS, $n = 377$). A total of 1362 subjects were randomly selected from women aged 45 and older with a complete medical history, who visited the health examination clinic during the same period. This selection was made using a computer-generated random number sequence. After the exclusion of individuals with a history of LDH, LSS, spinal instability due to trauma, scoliosis, or spondylolisthesis, the remaining 1168 subjects were included in the control group. Both the study and control groups consisted of Chinese patients because the medical institution where the research was conducted primarily serves the Chinese population.

### *Independent Variables*

#### *Demographics*

Demographics including age, BMI, smoking, labor intensity, and genetic history were recorded. Age was categorized into middle-aged and older groups with 60 years as the cutoff point. BMI categories were defined according to the World Health Organization guidelines: underweight ($< 18.5$ kg/m$^2$), normal weight (18.5 to $< 25.0$ kg/m$^2$), overweight (25.0 to $< 30.0$ kg/m$^2$), and obese ($\geq 30.0$ kg/m$^2$).[14] Smoking was defined as $> 1$ cigarette per day for $\geq 1$ year. The labor intensity of all participants was recorded when they visited the hospital, using seven questions constituting the validated labor intensity index by Leijon *et al.*.[15] The labor intensity index was determined by aggregating all responses to questions into a single value. Because no documented threshold for labor intensity exists, we trichotomized the index based on the frequency distribution of the questionnaire replies: low physical work load (index of 7–14), moderate physical work load (index of 15–23), and high physical work load (index of 24–31).[16] The first-degree relatives of patients who met the following two criteria were identified as having a genetic history of LDH/LSS: a history of typical symptoms in the past and diagnosis of LDH/LSS by an orthopedic physician above the county level or at a county-level hospital with imaging (computed tomography or magnetic resonance imaging).

*Female-specific Factors*

Menopausal status, number of deliveries, cesarean section, and simple hysterectomy were documented as female-specific factors. Patients were coded as 0, 1, or 2 based on the number of deliveries (0, 1, or > 1, respectively).

*Surgical History*

To assess the impact of surgical history, we recorded the number of abdominal surgeries (mainly appendectomy, cholecystectomy, subtotal gastrectomy, cesarean section, myomectomy, hysterectomy, rectal tumor resection, splenectomy, and pancreatectomy), hip joint surgery (mainly hip replacement), knee joint surgery (mainly total knee replacement and single condylar replacement), and thyroidectomy (mainly total thyroidectomy and partial thyroidectomy). Patients were coded as 0, 1, or 2 based on the number of abdominal surgeries (0, 1–2, or ≥ 3, respectively).

*Systemic Diseases*

The systemic diseases analyzed in this study were hypercholesterolemia (total cholesterol level of ≥ 6.0 mmol/L), hypertriglyceridemia (triglyceride level of ≥ 1.70 mmol/L), hyper-low-density lipoprotein cholesterolemia (low-density lipoprotein cholesterolemia level of ≥ 3.37 mmol/L), hypertension (grade 1, blood pressure of 140–159/90–99 mmHg; grade 2, blood pressure of 160–179/100–109 mmHg; and grade 3, blood pressure of ≥ 180/≥ 110 mmHg), diabetes (fasting blood glucose of ≥ 7.0 mmol/L and/or blood glucose of ≥ 11.1 mmol/L 2 h after a meal), cardiovascular disease (coronary atherosclerotic heart disease), and cerebrovascular disease (hemorrhagic stroke and ischemic stroke).

*Statistical Analysis*

Continuous variables are presented as mean and standard deviation, and categorical variables are presented as number and percentage. Student's *t* test was used for normally distributed continuous variables, and the chi-square test, Fisher's exact test, or Mann–Whitney U test was used for categorical variables or non-normally distributed variables. Variables considered clinically significant with *p*-values of < 0.10 were entered into univariate conditional logistic regression analyses to obtain unadjusted odds ratios (ORs) and 95% confidence intervals (95% CIs). Variables with *p*-values of < 0.10 from the univariate analysis were entered in a step-wise manner into multivariate binary logistic regression analyses to calculate adjusted ORs and 95% CIs. The variance inflation factor (VIF) was used for collinearity diagnosis of the variates in the model. The statistical analysis was performed using SPSS version 27 (IBM Corp., Armonk, NY, USA). A two-tailed *p*-value of < 0.05 was considered statistically significant.

## Results

The study included 2370 patients, of whom 825 were diagnosed with LDH, 377 were diagnosed with LSS, and 1168 comprised the control group.

Compared with the control group, patients with LDH showed significantly higher BMI, labor intensity, number of deliveries, and number of abdominal surgeries as well as significantly higher prevalences of a genetic history, simple hysterectomy, hypercholesterolemia, hypertriglyceridemia, and hyper-low-density lipoprotein cholesterolemia ($p < 0.05$). Patients with LDH had a significantly lower occurrence of cerebrovascular disease ($p < 0.05$). There were no significant differences in the other variables ($p > 0.05$) (Table 1).

Relative to the control group, patients with LSS exhibited a significantly higher proportion of individuals aged >60 years ($p < 0.05$); higher BMI, number of deliveries, and number of abdominal surgeries; and higher prevalences of a genetic history, simple hysterectomy, hip and knee surgeries, hypercholesterolemia, hypertriglyceridemia, hyper-low-density lipoprotein cholesterolemia, hypertension, and diabetes ($p < 0.05$). No significant differences were observed in the remaining variables ($p > 0.05$) (Table 1).

***Univariate Conditional Logistic Regression Analysis***

As presented in Table 2, variables showing significant associations with LDH surgery in middle-aged and older women were BMI category (OR = 1.754, 95% CI = [1.534–2.006], $p < 0.001$), labor intensity (OR = 1.225, 95% CI = [1.086–1.381], $p = 0.001$), genetic history (OR = 2.140, 95% CI = [1.669–2.745], $p < 0.001$), number of deliveries (OR = 1.824, 95% CI = [1.517–2.191], $p < 0.001$), simple hysterectomy (OR = 2.694, 95% CI = [1.893–3.832], $p < 0.001$), number of abdominal surgeries (OR = 1.297, 95% CI = [1.058–1.590], $p = 0.012$), hypercholesterolemia (OR = 2.931, 95% CI = [2.114–4.064], $p < 0.001$), hypertriglyceridemia (OR = 2.215, 95% CI = [1.772–2.769], $p < 0.001$), and hyper-low-density lipoprotein cholesterolemia (OR = 3.235, 95% CI = [2.540–4.121], $p < 0.001$). Cerebrovascular disease was inversely associated (OR = 0.363, 95% CI = [0.233–0.566], $p < 0.001$). Hypertension showed no significant association (OR = 1.049, 95% CI = [0.950–1.157], $p = 0.344$).

Table 3 shows significant associations between LSS surgery in middle-aged and older women and age category (OR = 2.267, 95% CI = [1.787–2.874], $p < 0.001$), BMI category (OR = 1.712, 95% CI = [1.456–2.014], $p < 0.001$),

**TABLE 1 Independent variables of women in study group and control group.**

| Characteristic | Study group: LDH ($n = 825$) | Study group: LSS ($n = 377$) | Control group ($n = 1168$) | *p*-value[d]: LDH | *p*-value[d]: LSS |
|---|---|---|---|---|---|
| Age (years)[b] | | | | | |
| 45–60[a] | 586 (71.0%) | 191 (50.7%) | 817 (69.9%) | 0.602 | < 0.001[c] |
| >60[a] | 239 (29.0%) | 186 (49.3%) | 351 (30.1%) | | |
| BMI (kg/m$^2$)[b] | 25.7 ± 3.3 | 25.7 ± 3.5 | 24.7 ± 3.9 | | |
| < 18.5[a] | 5 (0.6%) | 7 (1.9%) | 50 (4.3%) | < 0.001[c] | < 0.001[c] |
| 18.5-24.9[a] | 350 (42.4%) | 160 (42.4%) | 687 (58.8%) | | |
| 25–29.9[a] | 390 (47.3%) | 158 (41.9%) | 345 (29.5%) | | |
| ≥ 30 | 80 (9.7%) | 52 (13.8%) | 86 (7.4%) | | |
| Smoking[a] | 5 (0.6%) | 2 (0.5%) | 8 (0.7%) | 0.829 | 0.745 |
| Labor intensity[a] | | | | | |
| Low physical work load | 234 (28.4%) | 126 (33.4%) | 432 (37.0%) | < 0.001[c] | 0.127 |
| Moderate physical work load | 388 (47.0%) | 177 (46.9%) | 479 (41.0%) | | |
| High physical work load | 203 (24.6%) | 74 (19.6%) | 257 (22.0%) | | |
| Genetic history[a] | 172 (20.8%) | 80 (21.2%) | 128 (11.0%) | < 0.001[c] | < 0.001[c] |
| Menopausal status[a] | 603 (73.1%) | 280 (74.3%) | 841 (72%) | 0.592 | 0.391 |
| Number of deliveries[a] | | | | < 0.001[c] | < 0.001[c] |
| 0 | 0 | 0 | 4 (0.3%) | < 0.001[c] | < 0.001[c] |
| 1 | 274 (33.2%) | 81 (21.5%) | 550 (47.1%) | | |
| 2 | 551 (66.8%) | 296 (78.5%) | 614 (52.6%) | | |
| Cesarean section[a] | 43 (5.8%) | 16 (4.2%) | 68 (5.2%) | 0.559 | 0.240 |
| Simple hysterectomy[a] | 92 (11.2%) | 31 (8.2%) | 52 (4.5%) | < 0.001[c] | 0.005[c] |
| Number of abdominal surgeries[a] | | | | 0.011[c] | 0.037[c] |
| 0 | 599 (72.6%) | 273 (72.4%) | 910 (77.9%) | 0.004[c] | 0.033[c] |
| 1 | 226 (27.4%) | 100 (26.5) | 254 (21.7%) | | |
| 2 | 0 | 4 (1.1%) | 4 (0.3%) | | |
| Hip joint surgery[a] | 8 (1.0%) | 10 (2.7%) | 10 (0.9%) | 0.792 | 0.007[c] |
| Knee joint surgery[a] | 10 (1.2%) | 15 (4%) | 10 (0.9%) | 0.432 | < 0.001[c] |
| Thyroidectomy[a] | 17 (2.1%) | 9 (2.4%) | 14 (1.2%) | 0.126 | 0.098 |
| Hypercholesterolemia[a] | 113 (13.7%) | 48 (12.7%) | 60 (5.1%) | < 0.001[c] | < 0.001[c] |
| Hypertriglyceridemia[a] | 226 (27.4%) | 94 (24.9%) | 170 (14.6%) | < 0.001[c] | < 0.001[c] |
| Hyper-low-density lipoprotein cholesterolemia[a] | 226 (27.4%) | 101 (26.8%) | 122 (10.4%) | < 0.001[c] | < 0.001[c] |
| Hypertension[a] | 729 (46.8%) | 206 (54.6%) | 503 (43.1%) | 0.100 | < 0.001[c] |
| Grade 0 | 439 (53.2%) | 171 (45.4%) | 665 (56.9%) | 0.257 | < 0.001[c] |
| Grade 1 | 249 (30.2%) | 100 (26.5%) | 307 (26.3%) | | |
| Grade 2 | 82 (9.9%) | 51 (13.5%) | 122 (10.4%) | | |
| Grade 3 | 55 (6.7%) | 55 (14.6%) | 74 (6.3%) | | |
| Diabetes[a] | 122 (14.8%) | 81 (21.5%) | 158 (13.5%) | 0.425 | < 0.001[c] |
| Cardiovascular disease[a] | 58 (7.0%) | 35 (9.3%) | 110 (9.4%) | 0.059 | 0.938 |
| Cerebrovascular disease[a] | 26 (3.2%) | 32 (8.5%) | 96 (8.2%) | < 0.001[c] | 0.869 |

Abbreviations: BMI, body mass index; LDH, lumbar disc herniation; LSS, lumbar spinal stenosis.; [a] Data are presented as number of patients with percentage in parentheses.; [b] Data are presented as mean ± standard deviation of continuous variables with a normal distribution.; [c] Statistically significant.; [d] *p*-values were calculated by comparing the patients with LDH and LSS with the patients in the control group.

genetic history (OR = 2.189, 95% CI = [1.609–2.977], $p < 0.001$), number of deliveries (OR = 3.292, 95% CI = [2.512–4.314], $p < 0.001$), simple hysterectomy (OR = 1.92s3, 95% CI = [1.213–3.048], $p = 0.005$), number of abdominal surgeries (OR = 1.362, 95% CI = [1.057–1.756], $p = 0.036$), number of hip surgeries (OR = 3.155, 95% CI = [1.303–7.640], $p = 0.011$), number of knee surgeries (OR = 4.798, 95% CI = [2.137–10.773], $p < 0.001$), hypercholesterolemia (OR = 2.694, 95% CI = [1.808–4.015], $p < 0.001$), hypertriglyceridemia (OR = 1.950, 95% CI = [1.467–2.591], $p < 0.001$), hyper-low-density lipoprotein cholesterolemia (OR = 3.138, 95% CI = [2.336–4.215], $p < 0.001$), hypertension (OR = 1.375, 95% CI = [1.225–1.542], $p < 0.001$), and diabetes (OR = 1.749, 95% CI = [1.299–2.355], $p < 0.001$). However, cerebrovascular disease showed no significant association (OR = 1.036, 95% CI = [0.682–1.573], $p = 0.869$).

### *Multivariate Binary Logistic Regression Analysis*

#### *Association between Surgery for LDH/LSS and Demographics*

Although there were no significant statistical differences in age category between the LDH group and the control group, and in labor intensity between the LSS group and the control group; we adjusted for age category and labor intensity

**TABLE 2 Univariate conditional logistic regression analyses for the association of LDH patients and study factors.**

| Factors | Unadjusted odds ratio[a] | p-value |
|---|---|---|
| BMI category | 1.754 (1.534–2.006) | < 0.001[b] |
| Labor intensity | 1.225 (1.086–1.381) | 0.001[b] |
| Genetic history | 2.140 (1.669–2.745) | < 0.001[b] |
| Number of deliveries | 1.824 (1.517–2.191) | < 0.001[b] |
| Simple hysterectomy | 2.694 (1.893–3.832) | < 0.001[b] |
| Number of abdominal surgeries | 1.297 (1.058–1.590) | 0.012[b] |
| Hypercholesterolemia | 2.931 (2.114–4.064) | < 0.001[b] |
| Hypertriglyceridemia | 2.215 (1.772–2.769) | < 0.001[b] |
| Hyper-low-density lipoprotein cholesterolemia | 3.235 (2.540–4.121) | < 0.001[b] |
| Hypertension | 1.049 (0.950–1.157) | 0.344 |
| Cerebrovascular disease | 0.363 (0.233–0.566) | < 0.001[b] |

Abbreviations: BMI, body mass index; LDH, lumbar disc herniation.; [a] The values are given as the odds ratio, with the 95% CI in parentheses.; [b] Significant.

**TABLE 3 Univariate conditional logistic regression analyses for the association of LSS patients and study factors.**

| Factors | Unadjusted odds ratio[a] | p-value |
|---|---|---|
| Age category | 2.267 (1.787–2.874) | < 0.001[b] |
| BMI category | 1.712 (1.456–2.014) | < 0.001[b] |
| Genetic history | 2.189 (1.609–2.977) | < 0.001[b] |
| Number of deliveries | 3.292 (2.512–4.314) | < 0.001[b] |
| Simple hysterectomy | 1.923 (1.213–3.048) | 0.005[b] |
| Number of abdominal surgeries | 1.362 (1.057–1.756) | 0.017[b] |
| Hip joint surgery | 3.155 (1.303–7.640) | 0.011[b] |
| Knee joint surgery | 4.798 (2.137–10.773) | < 0.001[b] |
| Hypercholesterolemia | 2.694 (1.808–4.015) | < 0.001[b] |
| Hypertriglyceridemia | 1.950 (1.467–2.591) | < 0.001[b] |
| Hyper-low-density lipoprotein cholesterolemia | 3.138 (2.336–4.215) | < 0.001[b] |
| Hypertension | 1.375 (1.225–1.542) | < 0.001[b] |
| Diabetes | 1.749 (1.299–2.355) | < 0.001[b] |
| Cerebrovascular disease | 1.036 (0.682–1.573) | 0.869 |

Abbreviations: BMI, body mass index; LSS, lumbar spinal stenosis.; [a] The values are given as the odds ratio, with the 95% CI in parentheses.; [b] Significant.

respectively in the LDH model and the LSS model, considering the possible confounding effects of age category and labor intensity. This way, we could obtain more accurate and precise ORs and 95% CIs of the other variables. Multivariate logistic regression analyses revealed that the following variables were associated with LDH surgery in middle-aged and older women after adjusting for age category: BMI category (OR = 1.603, 95% CI = [1.389–1.850], $p < 0.001$), labor intensity (OR = 1.189, 95% CI = [1.044–1.355], $p = 0.009$), and genetic history (OR = 2.212, 95% CI = [1.693–2.891], $p < 0.001$) (Table 4). Similarly, the following were associated

**TABLE 4 Multivariate logistic regression analyses for the association of LDH patients and study factors**

| Factors | Adjusted odds ratio[a] | p-value |
|---|---|---|
| BMI category | 1.603 (1.389–1.850) | < 0.001[b] |
| Labor intensity | 1.189 (1.044–1.355) | 0.009[b] |
| Genetic history | 2.212 (1.693–2.891) | < 0.001[b] |
| Number of deliveries | 1.736 (1.426–2.113) | < 0.001[b] |
| Simple hysterectomy | 2.511 (1.718–3.670) | < 0.001[b] |
| Number of abdominal surgeries | – | 0.870 |
| Hypercholesterolemia | – | 0.188 |
| Hypertriglyceridemia | 1.932 (1.510–2.473) | < 0.001[b] |
| Hyper-low-density lipoprotein cholesterolemia | 2.662 (2.047–3.462) | < 0.001[b] |
| Cerebrovascular disease | 0.267 (0.164–0.434) | < 0.001[b] |

*Notes*: Adjusted for age.; Abbreviations: BMI, body mass index; LDH, lumbar disc herniation.; [a] The values are given as the odds ratio, with the 95% CI in parentheses.; [b] Significant.

with LSS surgery after adjustment for labor intensity: age category (OR = 1.889, 95% CI = [1.458–2.448], $p < 0.001$), BMI category (OR = 1.671, 95% CI = [1.402–1.992], $p < 0.001$), and genetic history (OR = 2.134, 95% CI = [1.523–2.991], $p < 0.001$) (Table 5).

### *Association between Surgery for LDH/LSS and Female-Specific Factors*

Tables 4 and 5 indicate that the following variables significantly increased the risk of LDH/LSS surgery in middle-aged and older women: number of deliveries (OR = 1.736, 95% CI = [1.426–2.113], $p < 0.001$ for LDH; OR = 2.962, 95% CI = [2.221–3.952], $p < 0.001$ for LSS) and a history of simple hysterectomy (OR = 2.511, 95% CI = [1.718–3.670], $p < 0.001$ for LDH; OR = 1.968, 95% CI = [1.178–3.286], $p = 0.010$ for LSS).

### *Association between Surgery for LDH/LSS and Surgical History*

A history of surgery did not influence the likelihood of undergoing LDH surgery in middle-aged and older women. However, a history of knee surgery was significantly associated with the incidence of LSS surgery (OR = 2.527, 95% CI = [1.031–6.198], $p = 0.043$).

### *Association between Surgery for LDH/LSS and Systemic Diseases*

Table 4 shows that after adjusting for age category, the following variables were significantly associated with LDH surgery in middle-aged and older women: hypertriglyceridemia (OR = 1.932, 95% CI = [1.510–2.473], $p < 0.001$), hyper-low-density lipoprotein cholesterol (OR = 2.662, 95% CI = [2.047–3.462], $p < 0.001$), and cerebrovascular disease (OR = 0.267, 95% CI = [0.164–0.434], $p < 0.001$). After adjusting for labor intensity, the following variables were significantly associated with LSS surgery: hypertriglyceridemia

**TABLE 5 Multivariate logistic regression analyses for the association of LSS Patients and study factors**

| Factors | Adjusted odds ratio[a] | p value |
|---|---|---|
| Age category | 1.889 (1.458–2.448) | < 0.001[b] |
| BMI category | 1.671 (1.402–1.992) | < 0.001[b] |
| Genetic history | 2.134 (1.523–2.991) | < 0.001[b] |
| Number of deliveries | 2.962 (2.221–3.952) | < 0.001[b] |
| Simple hysterectomy | 1.968 (1.178–3.286) | 0.010[b] |
| Number of abdominal surgeries | – | 0.286 |
| Hip joint surgery | – | 0.379 |
| Knee joint surgery | 2.527 (1.031–6.198) | 0.043[b] |
| Hypercholesterolemia | – | 0.231 |
| Hypertriglyceridemia | 1.476 (1.064–2.049) | 0.020[b] |
| Hyper-low-density lipoprotein cholesterolemia | 2.413 (1.733–3.359) | < 0.001[b] |
| Hypertension | – | 0.140 |
| Diabetes | 1.643 (1.185–2.277) | 0.003[b] |

*Notes*: Adjusted for labor intensity.; Abbreviations: BMI, body mass index; LSS, lumbar spinal stenosis.; [a] The values are given as the odds ratio, with the 95% CI in parentheses.; [b] Significant.

**TABLE 6 Collinearity diagnosis of independent variables in multivariate binary logistic regression model.**

| Independent variables in LDH model[a] | VIF | Independent variables in LSS model[b] | VIF |
|---|---|---|---|
| BMI category | 1.027 | Age category | 1.042 |
| Labor intensity | 1.009 | BMI category | 1.015 |
| Genetic history | 1.005 | Genetic history | 1.005 |
| Number of deliveries | 1.013 | Number of deliveries | 1.044 |
| Simple hysterectomy | 1.016 | Simple hysterectomy | 1.015 |
| Hypertriglyceridemia | 1.076 | Knee joint surgery | 1.023 |
| Hyper-low-density lipoprotein cholesterolemia | 1.086 | Hypertriglyceridemia | 1.124 |
| Cerebrovascular disease | 1.012 | Hyper-low-density lipoprotein cholesterolemia | 1.119 |
| | | Diabetes | 1.018 |

Abbreviations: BMI, body mass index; LDH, lumbar disc herniation; LSS, lumbar spinal stenosis; VIF, variance inflation factor.; [a] Multivariate binary logistic regression model between independent variables and surgical treatment for LDH in middle-aged and older women.; [b] Multivariate binary logistic regression model between independent variables and surgical treatment for LSS in middle-aged and older women.

(OR = 1.476, 95% CI = [1.064–2.049], $p = 0.020$), hyper-low-density lipoprotein cholesterol (OR = 2.413, 95% CI = [1.733–3.359], $p < 0.001$), and diabetes (OR = 1.643, 95% CI = [1.185–2.277], $p = 0.003$).

### *Collinearity Diagnosis*

The VIF was used for collinearity diagnosis of the variates in the model. As shown in Table 6, the VIFs between the independent variables in the models were < 3. Therefore, no covariance between the variables was assumed.

## Discussion

To the best of our knowledge, this is the first study to specifically examine the associations of demographics, female-specific factors, surgical history, and systemic diseases with surgical treatment for LDDD in middle-aged and older women. This study found that within demographics, BMI and genetic history, within female-specific factors, the number of deliveries and simple hysterectomy, and within systemic diseases, hypertriglyceridemia and hyper-low-density lipoprotein cholesterolemia, are independent risk factors for surgical treatment of both LDH and LSS in middle-aged and older women. The disparities were found between two conditions: labor intensity was a risk factor for LDH patients, whereas knee joint surgery and diabetes were risk factors for LSS patients.

For several reasons, this study focused on middle-aged and older women who underwent surgical treatment of LDDD. First, the physiological characteristics of women are distinct from those of men. Numerous studies have substantiated that the rate of lumbar degeneration is markedly accelerated in perimenopausal and menopausal women.[10] Furthermore, it is important to note that pregnancy and childbirth could potentially harm the core muscle group. This damage may result in lower back pain and could speed up the development of LDDD.[13] Moreover, women display different lifestyle characteristics and societal roles compared with men, such as smaller proportions of women than men are engaged in strenuous physical labor and smoking. In addition, our clinical experience has shown that the age at onset of degenerative lumbar disease is significantly higher in women than in men, and we believe this may be related to the different risk factors that exist between men and women. However, to date, there has been no relevant research that has taken middle-aged and elderly women as the subject of study. Furthermore, surgical treatment poses a significant burden on families and society; thus, it is crucial to examine patients who undergo such procedures. Taking into account these aspects, our study was conducted to examine the risk factors for surgical treatment of LDDD specifically in middle-aged and older women.

### ***Relationship between Demographics and Surgical Treatment of LDDD***

Age, BMI, smoking, labor intensity, and genetic history were examined as demographics in this study. BMI, smoking, labor intensity, and genetic history are widely recognized risk factors for degenerative lumbar disease. Wahlström *et al.*[17] found that high biomechanical loads and smoking were independent risk factors for LDH. In a study involving 4180 Chinese subjects, Zhang *et al.*[1] found that family history and high work intensity were the main risk factors for LDH in the Chinese population. In the present study, there were no significant differences in age category and the proportion of patients who smoked between the LDH and control groups. This phenomenon may be associated with the extremely low prevalence of smoking among women in China. Similar to previous studies, the BMI category, labor intensity, and genetic history were found to potentially increase the risk of surgical treatment in women with LDH. In addition to the risk factors for LSS, Knutsson *et al.* found in their analysis of 331,941 workers that smoking was a risk factor for LSS.[18] Furthermore, research has shown that the development of LSS may also be linked to heavy manual work. In the present study, however, no significant differences were found in either labor intensity or the proportion of patients who smoked between the LSS and control groups. The study revealed a significantly higher proportion of patients aged >60 years in the LSS group than in the control group. The age category was entered into the multivariate binary logistic regression analysis, which helps to control for the potential confounding effect of age when assessing the impact of other variables. BMI category and genetic history were also associated with surgical treatment in women with LSS. Few studies to date have focused on the relationship between BMI and LSS, but some studies have shown that obesity may cause LSS because high mechanical loads promote ligamentum flavum hypertrophy.[18] Research has also shown that LSS is a highly genetic condition.[19]

### *Relationship between Female-specific Factors and Surgical Treatment of LDDD*

In this study, we investigated four female-specific factors (menopausal status, number of deliveries, cesarean section, and simple hysterectomy) and found that the number of deliveries and simple hysterectomy increased the risk of surgical treatment for LDH and LSS in middle-aged and older women. Previous studies have shown that an increased number of deliveries is a risk factor for LSS and degenerative lumbar spondylolisthesis, with researchers postulating that changes in the spinal curvature and hormone levels during pregnancy play a significant role.[20,21] However, no studies have found a correlation between the number of deliveries and LDH. Furthermore, there is currently a lack of literature and data on correlation of simple hysterectomy with LDH/LSS. This study fills a gap in the relevant field. Simple hysterectomy may lead to a decline in ovarian function, resulting in changes in hormone levels; this may subsequently accelerate lumbar degeneration, thereby increasing the risk of surgical treatment for LDDD.[22]

### *Relationship between Surgical Histories and Surgical Treatment of LDDD*

We also evaluated various surgical histories and found that a history of knee joint surgery was a relevant risk factor for surgical treatment of LSS in middle-aged and older women. Total knee replacement and single condylar replacement are common procedures for knee OA. Both knee OA and LSS are common diseases leading to disability. One study showed that LSS and comorbid knee OA are very common,[23] a conclusion supported by this study. There may be an indirect association mediated by confounding factors between knee OA and undergoing surgical treatment for LSS. In addition, knee OA can affect the sagittal parameters of the spine, and LSS can in turn increase the load on the knee joint. This indicates a reinforcement interaction between these two diseases.

### *Relationship between System Diseases and Surgical Treatment of LDDD*

In this study, the patients' systemic diseases were entered into the multivariate logistic regression analysis. The diagnosis of dyslipidemia was based on the patients' laboratory test results and medical history, and hypertension was classified according to the patients' blood pressure measurements. The analysis revealed a significant association between hypertriglyceridemia, hyper-low-density lipoprotein cholesterolemia, and surgical treatment of LDH or LSS in middle-aged and older women. This study is the first to find a connection between hypertriglyceridemia, hyper-low-density lipoprotein cholesterolemia, and both LDH and LSS in middle-aged and older women. Previous studies have shown that hyperlipidemia may induce atherosclerosis, leading to insufficient blood supply to the intervertebral discs and accelerating the occurrence of lumbar degenerative disease.[24] Furthermore, the results indicated that diabetes is a risk factor for surgical treatment of LSS in middle-aged and older women. This may be due to the fact that diabetes can cause microvascular dysfunction, which in turn affects the blood supply to the lumbar spine and accelerates lumbar degeneration.[5] Moreover, cerebrovascular disease was shown to be a protective factor against surgery for LDH in the present study. We believe that cerebrovascular disease may play a protective role in lumbar degeneration by reducing the patient's level of physical labor and daily activities. We hypothesize that the reduced physical activity in patients with cerebrovascular disease may delay the onset of lumbar degeneration caused by lumbar pressure. Furthermore, a lower level of physical activity may enhance the patient's tolerance of lumbar disease.

### *Limitations*

This study had two main limitations. First, because this study was conducted in a single center, a meticulously designed multicenter study is necessary to validate the results of this study. Second, the study population comprised only Chinese women; thus, our findings may not be universally applicable to all patients.

## Conclusion

In conclusion, this study has shed light on the risk factors associated with the need for surgical treatment of LDDD in middle-aged and older women, a previously under-studied population. Beyond the well-studied risk factors of BMI and genetic history, this study—which took into account demographics, female-specific factors, surgical history, and systemic diseases—has led to the identification of several novel risk factors. These include the number of deliveries, a history of simple hysterectomy, knee joint surgery, hypertriglyceridemia, and hyper-low-density lipoprotein cholesterolemia. Furthermore, we found that labor intensity was a risk factor for patients with LDH, whereas knee joint surgery and diabetes were risk factors for patients with LSS. These findings not only enhance our understanding of the disparities between LDH and LSS but also underscore the need for a reevaluation of the various risk factors for LDH/LSS surgery. In clinical practice, it is crucial to enhance preventive management for individuals with these risk factors, which could include recommending targeted exercises for strengthening the paravertebral muscles and advising a reduction in heavy physical labor. This study, therefore, provides valuable insights for the prevention of surgical treatment of LDDD in middle-aged and elderly women.

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## Conflict of Interest Statement

The authors declare that there is no conflict of interest.

## Ethical Statement

This study was approved by the Ethics Committee of Qilu hospital, Shandong University and was conducted in accordance with the principles of the Helsinki Declaration. Informed consent was obtained from all participants prior to enrollment.

## Author Contributions

YCZ, SMY and XC are responsible for data collection, statistical analysis and writing the main manuscript text. ZQZ, XRY, SW and YHT are responsible for statistical analysis and revising article. LLW and XYL proposed the concept and revised the article.

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