



Overweight and smoking promote recurrent lumbar disk herniation after discectomy

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Abstract

Purpose Recurrent lumbar disk herniation (rLDH) following lumbar microdiscectomy is common. While several risk factors for primary LDH have been described, risk factors for rLDH have only sparsely been investigated. We evaluate the effect of Body mass index (BMI) and smoking on the incidence and timing of rLDH.

Methods From a prospective registry, we identified all patients undergoing primary tubular microdiscectomy (tMD), with complete BMI and smoking data, and a minimum 12-month follow-up. We defined rLDH as reherniation at the same level and side requiring surgery. Overweight was defined as BMI > 25, and obesity as BMI > 30. Intergroup comparisons and age- and gender-adjusted multivariable regression were carried out. We conducted a survival analysis to assess the influence of BMI and smoking on time to reoperation.

Results Of 3012 patients, 166 (5.5%) underwent re-microdiscectomy for rLDH. Smokers were reoperated more frequently (6.4% vs. 4.0%, $p = 0.007$). Similarly, rLDH was more frequent in obese (7.5%) and overweight (5.9%) than in normal-weight patients (3.3%, $p = 0.017$). Overweight smokers had the highest rLDH rate (7.6%). This effect of smoking (Odds ratio: 1.63, 95% CI: 1.12–2.36, $p = 0.010$) and BMI (Odds ratio: 1.09, 95% CI: 1.02–1.17, $p = 0.010$) persisted after controlling for age and gender. Survival analysis demonstrated that rLDH did not occur earlier in overweight patients and/or smokers.

Conclusions BMI and smoking may directly contribute to a higher risk of rLDH, but do not accelerate rLDH development. Smoking cessation and weight loss in overweight or obese patients ought to be recommended with discectomy to reduce the risk for rLDH.

Keywords Lumbar disk herniation · Discectomy · Recurrence · Lifestyle · Smoking · Overweight · Obesity

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Introduction

Sciatica due to lumbar disk herniation (LDH) represents one of the most frequent indications for lumbar spine surgery [1]. While patient satisfaction and rates of improvement in pain and functional impairment are usually very high after microdiscectomy, reoperations due to recurrent LDH (rLDH) are not uncommon, with incidences ranging between 2 and 11% [2–8]. Reoperations for rLDH can incur high direct and indirect health care-associated costs, as well as additional complications and morbidity [6, 7, 9].

While risk factors for primary LDH have been relatively well-established, the literature is rather sparse on risk factors for rLDH. Still, several studies have investigated risk factors or potential etiologies for rLDH, however with often inconsistent results, low statistical power, or low effect sizes for certain potential risk factors [3, 7, 10–14]. Knowledge of robust risk factors for reherniation with a clinically relevant

effect size would be clinically beneficial, especially if those risk factors were modifiable, such as “lifestyle” factors like smoking and body weight [15].

Multiple studies have assessed the effect of weight or Body mass index (BMI) on the incidence of rLDH. While some papers were able to detect an association between overweight and higher reoperation rates [14, 16], other studies identified no effect [3, 11–13, 17, 18]. Some investigators have identified a positive association among smoking and reoperation rate [3, 11, 13], while one paper found no difference [12]. However, the main limitation for almost all of these studies investigating the association of “lifestyle” factors smoking and body weight on rLDH demonstrated low sample sizes and consequently low statistical power, which is why additional studies with prospective and larger patient cohorts have been called for [3, 13]. In addition, no studies have assessed the influence of these risk factors on time to recurrence.

Identifying such risk factors and etiologies may not only help to better understand the nature of rLDH, but—in case of modifiable risk factors—may also lead to lower reoperation rates through optimal pre and postoperative patient management. Thus, any robust, modifiable “lifestyle” risk factor for rLDH would be clinically valuable. We evaluate the effect of BMI and smoking on the incidence and timing of rLDH after microdiscectomy.

Materials and methods

Patient population

We identified all patients who underwent primary tubular microdiscectomy (tMD) out of a prospective institutional registry of surgical interventions, as described previously [5]. All patients were operated on by a single neurosurgeon (M.L.S.)—focused solely on minimally invasive degenerative spine surgery—between 2010 and 2019 at a specialized, high-caseload, short-stay spine center [19]. Indications for surgery—whether for index or redo cases—have been reported previously [5, 20]. This report was compiled according to the “Strengthening the reporting of observational studies in epidemiology” (STROBE) guidelines [21].

Preoperative inclusion criteria were single-level LDH confirmed using magnetic resonance imaging and failed conservative management for ≥ 8 weeks [22]. Reoperations were performed in patients with a recurrence of disabling pain and/or neurological symptoms, who failed conservative therapy and in whom a MRI showed rLDH. All consecutive cases of first-time tMD for LDH with a follow-up threshold of ≥ 12 months regarding recurrence (surgery at least 12 months before this analysis), as well as complete data on either one or both of (1) preoperative BMI and/or (2)

smoking status were included in our analysis to maximize statistical power with the available prospective registry data. Patients who had received prior surgery at the index level (e.g., those with a previous history of discectomy who were referred to us from another center) were excluded.

Ethical considerations

This institutional registry was approved by the local institutional review board (Medical Research Ethics Committees United, Registration Number: W17.067). Additionally, all individual patients included in the study provided written informed consent, and the study was performed according to the Declaration of Helsinki and its amendments.

Outcomes and data collection

We defined rLDH as a return of preoperative pain symptoms after a pain-free period after primary discectomy, combined with ipsilateral nerve root compression at the same level, visible on magnetic resonance imaging that necessitated surgical revision [4, 5, 23]. Additionally, the period between primary microdiscectomy and reoperation was measured in days for each patient with rLDH. Any reoperations—including reoperation for rLDH—were systematically tracked and entered into the registry.

Weight and height were measured preoperatively and entered into the prospective patient registry. According to the WHO classification, overweight was defined as a BMI of 25.0 kg/m^2 or greater, and obesity was defined as a BMI of 30.0 kg/m^2 or greater [24]. Smoking status was captured preoperatively, although we did not record how long before surgery patients had given up smoking. “Non-smokers” included never-smokers and individuals who had ceased smoking preoperatively.

Statistical analysis

Continuous data are given as mean \pm standard deviation or median (Interquartile range, IQR), and categorical data as numbers (percentages).

Pearson’s χ^2 test was conducted to assess the association of smoking status and body weight classes with rLDH. Median time to recurrence was compared using the exact version of Wilcoxon’s rank-sum test, based on the “shift” algorithm described by Streitberg and Röhmel [25]. In addition, we performed an age- and sex-adjusted multivariable logistic regression analysis to determine the influence of smoking status and BMI on rLDH while controlling for these potential confounders.

The effect of smoking and overweight on recurrence was also determined using an age- and sex-adjusted Cox proportional hazards model. The log-rank test was used to test

for significance in the survival analyses. Patients without reoperation for rLDH were right-censored at the date of last follow-up, and Kaplan–Meier curves were constructed. For all analyses, a $p \leq 0.05$ was considered as statistically significant on two-tailed tests. All analyses were carried out using R version 3.6.1 (The R Foundation for Statistical Computing, Vienna, Austria) [26].

Results

Patient cohort

A total of 3012 patients included in the prospective registry underwent primary tMD for LDH during the study period (Fig. 1). All 3012 patients had a minimum 12-month follow-up with data on reoperations, since all patients were followed clinically for at least a year and since we only include patients who were operated at least one year before the initiation of this analysis according to our inclusion criteria. Overall, 166 of 3012 patients (5.5%) had to undergo reoperation for rLDH, with 798 (31%) active smokers and a mean BMI of $25.5 \pm 3.5 \text{ kg/m}^2$. Detailed baseline patient characteristics are provided in Table 1. From this database we

analyzed 2584 patients with complete smoking data, 1481 patient with complete BMI data, and 1335 with combined smoking and BMI data. Patients had to undergo reoperation at an average of 476 ± 525 days. Baseline characteristics were compared among the subgroups in *Supplementary Tables 1 and 2*.

Association of BMI with recurrence

Rates of rLDH stratified by BMI and by smoking status are provided in Table 2. The incidence of reoperation for rLDH was higher in overweight (5.9%) and obese (7.5%) patients compared to normal-weight patients (3.3%, $p = 0.017$, Fig. 2). After correction for age and gender, the positive relationship among BMI and rLDH persisted (Odds Ratio (OR) = 1.09, 95% confidence interval (CI) = 1.02–1.17, $p = 0.010$, Table 3). A survival analysis adjusted for age and gender also demonstrated this effect (Fig. 3) with a hazard ratio of 1.899 for overweight versus normal-weight patients ($p = 0.011$). Overweight patients experienced rLDH after a similar number of days ($N = 48$, Median = 343 days, IQR = 146 to 661 days) as their normal-weight counterparts ($N = 24$, Median = 245 days, IQR = 142 to 637 days, $p = 0.555$).

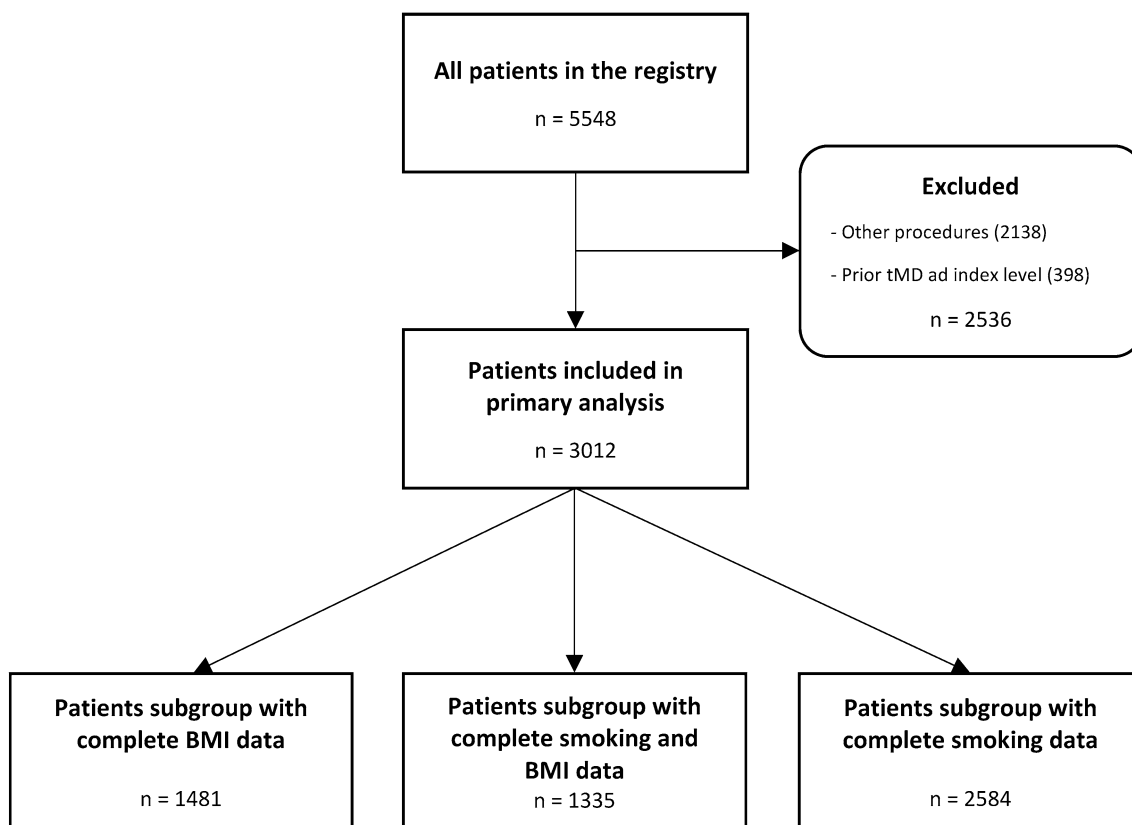


Fig. 1 Flowchart demonstrating the flow of patients throughout this analysis

Table 1 Baseline patient characteristics

Variable	Value N=3012
Age [years]	45 ± 13
Active smoker	798 (31%)
Male gender	1608 (53%)
BMI [kg/m ²]	25.5 ± 3.5
ASA score	
Class I	1762 (64%)
Class II	931 (36%)
Class III	7 (0.2%)
Index level	
L1-L2	4 (0.1%)
L2-L3	44 (1.4%)
L3-L4	187 (6.2%)
L4-L5	1344 (45%)
L5-S1	1433 (48%)
Side	
Right-sided	1493 (49.6%)
Left-sided	1376 (45.7%)
Midline	102 (3.4%)
Bilateral	41 (1.4%)
Reoperation for rLDH	166 (5.5%)
Time to reoperation [days]	476 ± 525

BMI, Body mass index; ASA, American society of anesthesiologists; rLDH, Recurrent lumbar disk herniation

Table 2 Confrontation of rLDH rates for active smokers compared to non-smokers, as well as for BMI < 25 (normal-weight) compared to 25–30 (overweight) and > 30 kg/m² (obesity), and for the combination of both potential risk factors

Variable	Number	rLDH	p value
Smoking	N = 2584		0.007*
Non-smoker	1786 (69%)	71 (4.0%)	
Active Smoker	798 (31%)	51 (6.4%)	
BMI	N = 1481		0.017*
< 25 kg/m ²	703 (47%)	23 (3.3%)	
25–29.9 kg/m ²	592 (40%)	35 (5.9%)	
≥ 30 kg/m ²	186 (13%)	14 (7.5%)	
Smoking and BMI	N = 1335		0.038*
Non-smoker and BMI < 25	444 (33%)	14 (3.2%)	
Active smoker or BMI ≥ 25 kg/m ²	693 (52%)	29 (4.2%)	
Active smoker and BMI ≥ 25 kg/m ²	198 (15%)	15 (7.6%)	

*p ≤ 0.05

Association of smoking with recurrence

Smokers had a significantly higher incidence of rLDH

(6.4%) compared to non-smokers (4.0%, $p = 0.007$). In the multivariable logistic regression analysis corrected for age and gender, smoking independently predicted rLDH (OR = 1.63, 95% CI = 1.12–2.36, $p = 0.010$, Table 3). The age- and gender-adjusted survival analysis corroborated this finding (Hazard ratio = 1.591, $p = 0.012$, Fig. 3), and smokers experienced rLDH after a similar duration ($N = 51$, Median = 350 days, IQR = 135 to 781 days) as non-smokers ($N = 71$, Median = 237 days, IQR = 111 to 521 days, $p = 0.129$).

Association of combined smoking and overweight with recurrence

To assess any potential accumulative effect of combined active smoking and overweight, we carried out an additional analysis among the 1335 (44%) patients with complete data on both potential risk factors (Fig. 4). Active smokers with a BMI ≥ 25.0 kg/m² had the highest rate of rLDH (7.6%, Table 4). Patients with both potential risk factors also demonstrated a hazard ratio of 1.91 (95% CI = 1.06–3.45, $p = 0.032$) for development of rLDH requiring reoperation in the adjusted survival analysis. These patients also experienced rLDH after a similar number of days ($N = 15$, Median = 456 days, IQR = 272 to 959 days) than others ($N = 43$, Median = 245 days, IQR = 138 to 613 days, $p = 0.078$).

Discussion

Using a large patient sample from a prospective institutional registry, the association of the two “lifestyle” factors body weight—captured as BMI—and active smoking with the incidence and timing of symptomatic rLDH requiring reoperation was evaluated. Out of all patients, around five percent necessitated reoperation for recurrent herniation. Both active smoking and overweight led to consistent and clinically relevant increases in the incidence of rLDH. Multivariable logistic and survival modeling corroborated these findings. A combination of the two risk factors led to the highest odds of developing rLDH requiring reoperation. However, active smoking and overweight do not appear to influence the timing of rLDH requiring surgical treatment.

Symptomatic recurrent disk herniation is relatively common after primary microdiscectomy, often requires patients to undergo redo surgery which puts them at excess risk for other surgical and medical complications, and also incurs high direct and indirect health care costs [9]. The reoperation rate of 5.5% after primary tubular microdiscectomy conforms with values ranging between 3 and 13% in the contemporary literature [2–8]. Preoperative risk assessment can be beneficial for improved patient counseling and

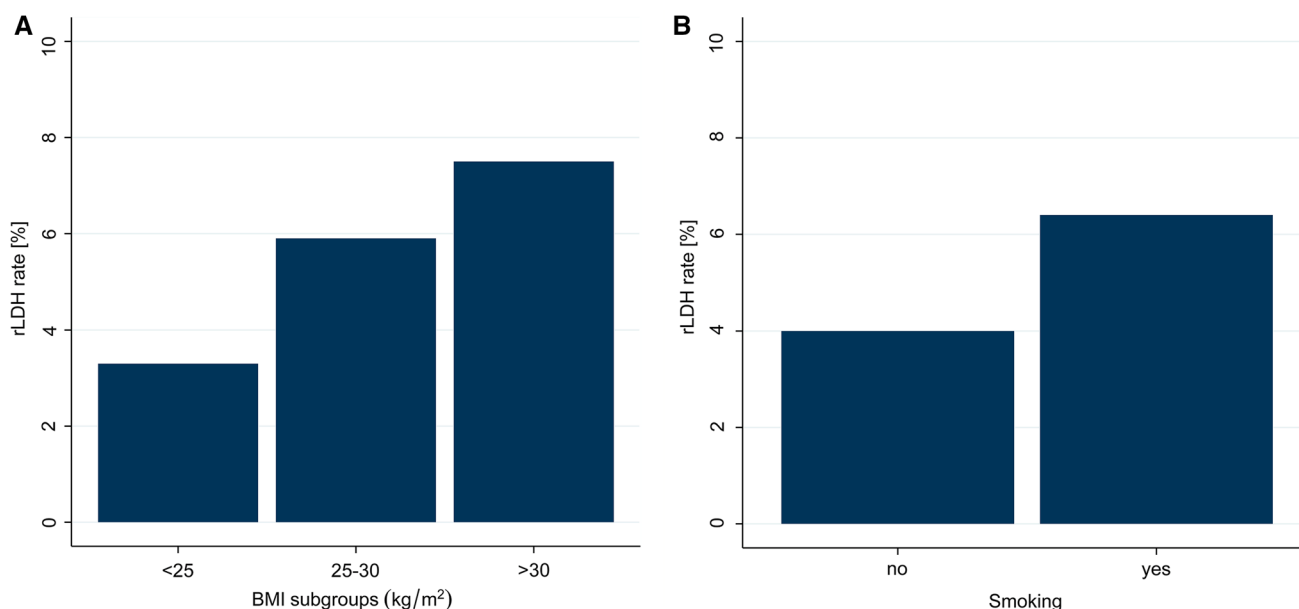


Fig. 2 Rates of recurrent lumbar disk herniation (rLDH) among the studied subgroups. Panel A demonstrates rLDH rates for normal-weight, overweight, and obese patients. Panel B shows rLDH rates for non-smokers and smokers

Table 3 Logistic regression values with rLDH as dependent variable and BMI or smoking, respectively, as well as age and gender as independent variables. Each one-step increase in BMI led to a 1.09-fold increased odds of rLDH, and active smokers had 1.63-fold higher odds of rLDH compared to non-smokers

Variable	Odds Ratio (<i>N</i> = 1481)	95% CI	<i>P</i> value
BMI subgroup			
BMI	1.09	1.02–1.17	0.010*
Male gender	1.16	0.72–1.88	0.553
Age	1.00	0.98–1.01	0.603
Smoking subgroup			
Active smoker	1.63	1.12–2.36	0.010*
Male gender	1.19	0.82–1.73	0.362
Age	1.00	0.98–1.01	0.899

**p* ≤ 0.05

rLDH, Recurrent lumbar disk herniation; BMI, body mass index; CI, Confidence interval

individualized risk–benefit discussion [15, 27], although patient-specific risk factors for reherniation would only very rarely dissuade from surgery once a clear indication for surgery is given. This is why—apart from potentially contributing to the understanding of the etiopathology of recurrence—risk factors are the most clinically relevant if they are modifiable [15].

Several studies have investigated the effect of BMI or smoking on rLDH, with conflicting results. Most of these studies have included smaller cohorts of less than 300

patients and correspondingly even fewer patients with rLDH, with consequently less powerful effect estimates [3, 11, 14, 18]. A meta-analysis conducted by Huang et al. [13] demonstrated an increased risk for rLDH in smokers (OR = 1.99, 95% CI = 1.53–2.58), and no effect of overweight (OR = 1.11, 95% CI = 0.57–2.16) based on only two studies, with relatively low heterogeneity. Our findings demonstrate a recurrence-promoting effect of both overweight and active smoking with higher statistical power and prospective data, which corresponds to the results of the majority of studies [3, 11, 13, 18]. Furthermore, the accumulative effect of the two risk factors observed in our data further corroborates their potential to causatively promote rLDH (“biological gradient”) [28].

Still, the nature of the effect of smoking on rLDH pathophysiology remains poorly understood. In an experimental biological study with mice, smoking has been shown to lead to misalignment and lesions of the annulus fibrosus [29]. In addition, the vasoconstrictor effect of nicotine may also inhibit the synthesis of proteoglycans, consequently leading to a more vulnerable disk [30, 31]. Lastly, chronic cough as a consequence of smoking was also shown to increase intradiscal pressure and therefore potentially lead to recurrent disk herniations, especially when also considering the effects of smoking on wound healing in other domains [32–34].

The effect of overweight on rLDH in the literature remains more unclear [3, 4, 11, 13, 14, 16–18]. Overweight and especially obesity have been well-described to be an independent risk factor for degenerative disease, including disk herniation as well as degenerative disk disease

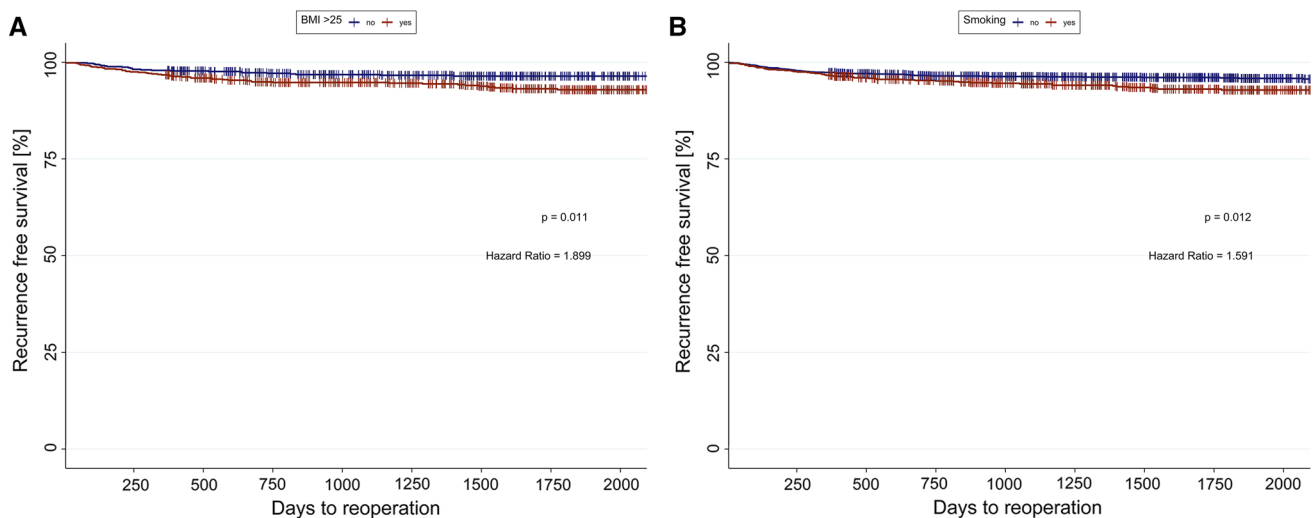


Fig. 3 Kaplan–Meier estimates for recurrence-free survival are shown for normal-weight versus overweight patients (Panel A), as well as for non-smokers versus smokers (Panel B). Data are right-censored (vertical lines) according to the duration of clinical follow-

and spondylolysis [35–39]. These effects may be partially explained by the elevated mechanical load on the spine that comes along with obesity, especially with abdominal obesity [40]. Obese patients also tend to undergo changes in posture and flexibility of the thoracolumbar spine, resulting in postures that increase the mechanical load on the spine [41]. On the other hand, adipose tissue produces and releases adipokines such as leptin and adiponectin, which in turn induce inflammatory and degrading processes leading to disk degeneration [42, 43]. A study investigating glycosaminoglycan (GAG) concentration in the nucleus pulposus found decreased GAG levels in obese patients [44], which may correspond to morphological finding in degenerated intervertebral disk [44, 45]. Overall, obese patients also empirically appear to be less likely to experience clinically meaningful symptomatic improvement after discectomy [46, 47].

While several studies have previously investigated factors associated with rLDH, none have analyzed the timing of recurrence. In our study, active smokers and overweight patients did not significantly differ in the speed of their progression to rLDH compared to their non-smoking and normal-weight counterparts.

In combination with the literature, our findings suggest that both overweight—especially obesity—and active smoking independently promote symptomatic rLDH requiring reoperation. The effect sizes, which were reproduced through multiple analytical methods, further corroborate the potential clinical relevance of our findings: Active smoking led to approximately 1.6-fold increased absolute risk of recurrence, while overweight and obesity led to approximately

1.8-fold and 2.3-fold increased absolute risks of recurrence, respectively. Reoperations for recurrence are inconvenient and costly, and any preventative measures to prevent recurrence requiring redo surgery ought to be considered. In recent years, even implantable devices have been trialed to reduce the risk of symptomatic reherniation requiring surgery, with mixed results [23]. Lifestyle risk factors that are modifiable and that have a robust and clinically relevant effect could be very valuable in reducing the incidence of rLDH. Further studies evaluating structured interventions for weight loss and smoking cessation before discectomy should be carried out to assess if these measures can be truly clinically impactful.

Strengths and limitations

The main strengths of this analysis are that its source data originate from a prospective institutional registry, and that the statistical power is very high due to available sample size with complete data. Furthermore, reoperations were systematically tracked. Moreover, we observed large and consistent effect sizes for the associations of BMI and smoking with rLDH, among multiple statistical methods, and there is at least some biological plausibility to support the main findings [28].

The main limitation however remains the retrospective nature of this specific analysis, as selection bias cannot be ruled out, although all data was collected prospectively and all patients with sufficient data were included. Even though we examined a large prospective cohort, the sample

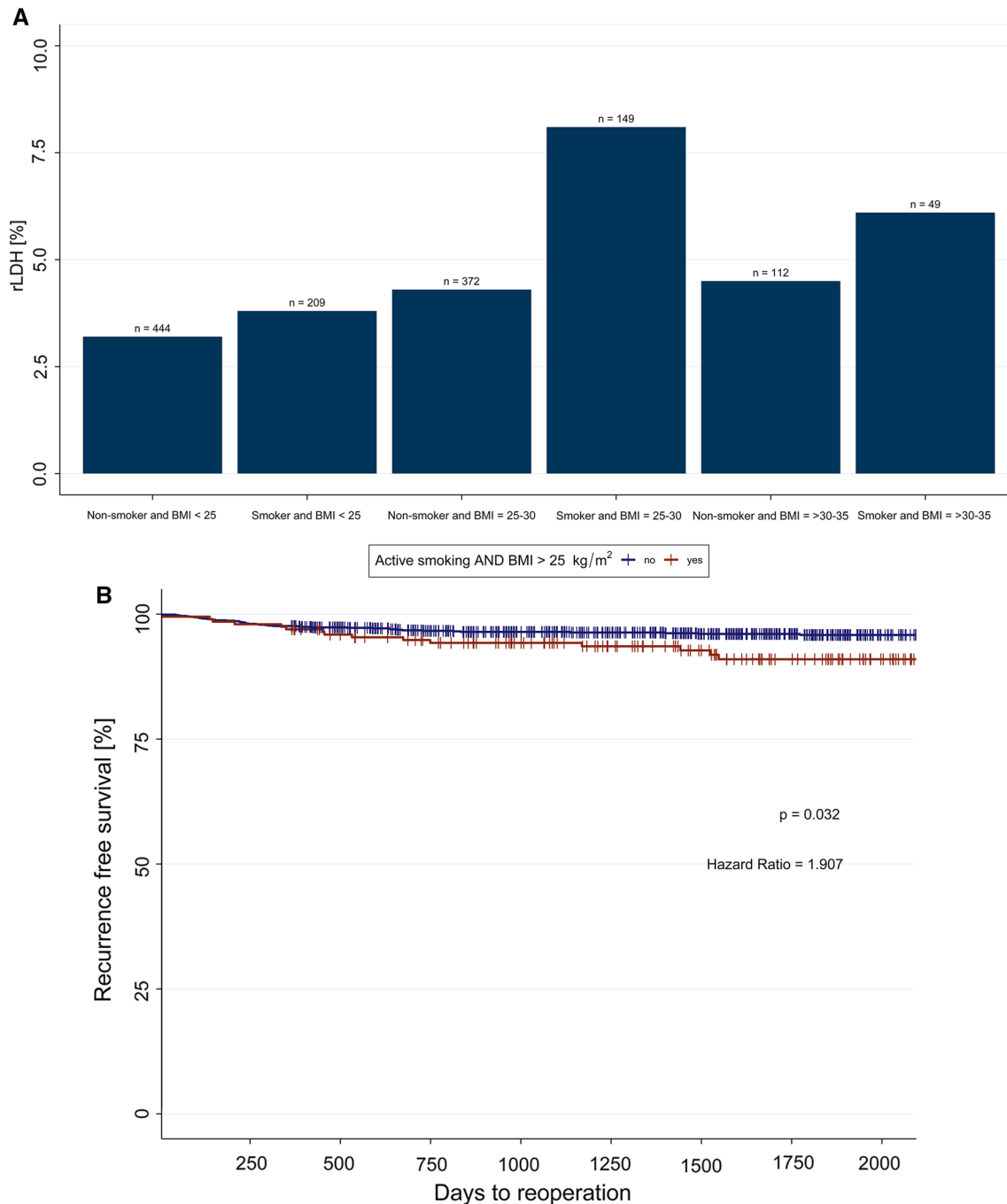


Fig. 4 Panel A demonstrates rates of recurrent lumbar disk herniation (rLDH) for patients with different combination of the two studied risk factors. Kaplan–Meier estimates for recurrence-free survival are shown for patients who are both active smokers and overweight ver-

sus others (Panel B). Data are right-censored (vertical lines) according to the duration of clinical follow-up. Additionally, statistical results of the age- and sex-adjusted survival analysis of time to rLDH are provided

size and consequently power for analysis of time to recurrence was comparatively low. All data stem from a single center, therefore center bias cannot be ruled out. On the other hand, single-surgeon or single-institution study designs eliminate variability in indications or techniques as factors contributing to recurrence. For example, out of

surgeon preference, our cohort includes only tubular discectomy cases, which however have been demonstrated to lead to equal outcomes compared to conventional microdiscectomy [48]. Because of local insurance regulation restrictions, patients aged > 80, with an American Society of Anesthesiologists (ASA) score > 2 or with a body

Table 4 Logistic regression values with rLDH as dependent variable and the combination of active smoking with overweight, age and gender as independent variables. Active smokers who were also overweight or obese had 1.99-fold higher odds of rLDH compared to others

Variable	Odds Ratio (N = 1335)	95% CI	P value
Active smoker and BMI \geq 25 kg/m ²	1.99	1.05–3.59	0.027*
Male gender	1.39	0.81–2.43	0.235
Age	0.99	0.97–1.01	0.481

* $p \leq 0.05$

rLDH, Recurrent lumbar disk herniation; BMI, Body mass index; CI, Confidence interval

mass index (BMI) > 35 were not allowed to be operated on in such a setting. Because of these local insurance regulations, patients with very severe comorbidities or very elderly patients were not included in this study, thus our findings concerning obesity can not be extrapolated to patients suffering from class II or III obesity. Because Gadolinium was not routinely used in patients with a clinical suspicion of LDH recurrence, it may be possible that some clinically judged rLDHs had a scar tissue component. To assess the incidence of the modifiable risk factors in a “non-regulated” environment we looked at 100 consecutive spine surgeries in a random time period by one of the authors (JPM), and found a higher incidence of smoking (36%) and a much higher BMI (mean 33.7 ± 7.7 , range 21–54, median 32). We also did not study the effects of smoking cessation or smoking quantity on LDH recurrence, nor those of diabetes mellitus or other potentially relevant variables such as disk height or type of job. Lastly, as with primary LDH, many recurrent herniations are asymptomatic [10], but we did not track patients with recurrent pain in whom redo surgery was not deemed indicated. Consequently, our findings may not necessarily extrapolate to those asymptomatic cases, but can instead only be applied to patients with symptomatic rLDH.

Conclusions

In an analysis of a large prospective institutional registry, we found that both overweight and active smoking likely contribute to a higher incidence of symptomatic rLDH requiring reoperation, but not necessarily to a more rapid development of reherniation. Modification of risk factors—through lifestyle interventions such as smoking cessation and weight loss in overweight or obese patients—may help reduce the incidence of reoperation for rLDH.

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Declarations

Conflict of interest The authors declare that the article and its content were composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics approval W17.067, approved on 17.05.2019 by *Medical Research Ethics Committees United*.

Informed consent All patients provided written informed consent.

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