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ORIGINAL ARTICLE

# Predicting clinical outcome and length of sick leave after surgery for lumbar spinal stenosis in Sweden: a multi-register evaluation

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## Abstract

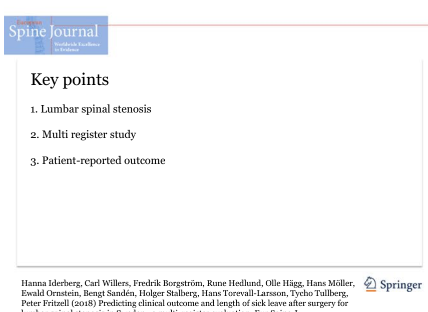
**Purpose** Lumbar spinal stenosis (LSS) can be surgically treated, with variable outcome. Studies have linked socioeconomic factors to outcome, but no nation-wide studies have been performed. This register-based study, including all patients surgically treated for LSS during 2008–2012 in Sweden, aimed to determine predictive factors for the outcome of surgery.

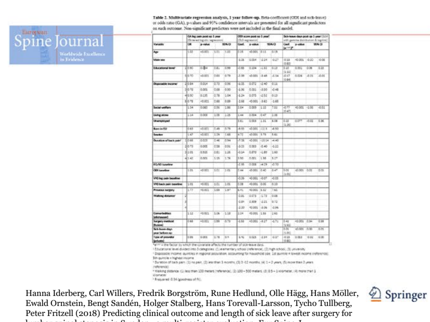
**Methods** Clinical and socioeconomic factors with impact on outcome in LSS surgery were identified in several high-coverage registers, e.g., the national quality registry for spine surgery (Swespine, FU-rate 70–90%). Multivariate regression analyses were conducted to assess their effect on outcome. Two patient-reported outcome measures, Global Assessment of leg pain (GA) and the Oswestry Disability Index (ODI), as well as length of sick leave after surgery were analyzed.

**Results** Clinical and socioeconomic factors significantly affected health outcome (both GA and ODI). Some predictors of a good outcome (ODI) were: being born in the EU, reporting no back pain at baseline, a high disposable income and a high educational level. Some factors predicting a worse outcome were previous surgery, having had back pain more than 2 years, having comorbidities, being a smoker, being on social welfare and being unemployed.

**Conclusions** The study highlights the relevance of adding socioeconomic factors to clinical factors for analysis of patient-reported outcomes, although the causal pathway of most predictors' impact is unknown. These findings should be further investigated in the perspective of treatment selection for individual LSS patients. The study also presents a foundation of case mix algorithms for predicting outcome of surgery for LSS.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary Material.





**Keywords** Lumbar spinal stenosis · Regression analysis · Patient-reported outcome · Sick leave · Prediction algorithms · Spine surgery · Global assessment · Functional disability · Socioeconomic factors · Multi-register study

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s00586-018-5842-3) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

## Introduction

Lumbar spinal stenosis (LSS) is caused by narrowing of the spinal canal and compression of nerve roots as a result of degenerative changes [1]. Initial treatment usually consists of advice and conventional non-surgical therapies such as physiotherapy. Selected patients may receive surgical treatment.

The prevalence of spinal stenosis is rapidly increasing in the world as a result of increasing life expectancy. Surgery for LSS is the most common spine procedure in Sweden with approximately 5000 procedures performed annually [2, 3]. The most common method in Sweden is decompression of the stenosis (expanding the spinal canal), without instrumentation or fusion [4].

Surgical treatment in selected patients may be beneficial and can be superior to non-surgical treatment [3], but results after surgery are not always satisfying, as around 40% of the patients report suboptimal results [2]. The patient's functional status, pain level and quality of life may influence outcome [5], as may attitudes toward the therapy, and the patient's psychological status [6]. In addition, gender, obesity and smoking are essential determinants of health outcome in spine surgery [7–9]. Also, a high educational level has been associated with better health outcome [10]. As such socioeconomic factors may be key determinants for outcome, while problems with LSS are increasing in society, we were prompted to extensively investigate outcome after LSS surgery in a national perspective. In addition to many of the known predictors mentioned above, this study included educational level, income level, unemployment status, marital status, social welfare information and country of birth. To this end, we used several comprehensive national registers which allowed an explorative multivariate evaluation of the effects of a large number of clinical and sociodemographic factors.

## Patients and methods

### Study population and data sources

1. Patients receiving LSS surgery on one or two adjacent levels (L2–L5), during 2008–2012 in Sweden, were identified using ICD-10 codes and procedure codes (used to identify different surgical methods) in the National Patient Register (NPR), which contain information related to all inpatient care consumption in Sweden.
2. All data on healthcare utilization, 1 year prior to (used to calculate comorbidity index), and 2 years after surgery, were linked on patient level to the national quality registry for spine surgery (Swespine) via the patient unique Swedish identification number. Swespine data contain information on the patients' preoperative health status as well as postoperative patient-reported outcome measures (PROM).
3. Data on socioeconomics and sick leave (from Statistics Sweden and the Swedish Social Insurance Agency) were linked through the patient unique Swedish identification number to the database described above.

The Regional Ethical Review Board in Stockholm approved the study protocol (Dnr 2013/2226-31/5).

### Study variables

This study is a retrospective analysis of prospectively collected data. The study variables used were determined by a cross-professional group including spine surgeons, clinical register experts and statisticians.

Two primary health outcome variables were assessed: Global assessment (GA) [11] and the Oswestry Disability Index (ODI) [12], both collected in Swespine. The GA is a nonlinear ordinal parameter of perceived leg pain after surgery compared to preoperative pain.[1] ODI measures functional disability on a 0–100 scale.[2] In addition, a third primary outcome, length of sick leave[3] (net days) after surgery, was evaluated. All outcome measures were evaluated both one and 2 years after surgery (2-year follow-up reported in supplemental material).

A large number of baseline characteristics, including clinical (e.g., pain level/duration, health-related quality of life), socioeconomic factors (e.g., education, income, country of birth), surgical method and type of caregiver (clinic), were selected as possible predictive factors.

### Statistical analysis

To assess each factor's effect on outcome, multivariate regression analysis adjusted for clustering of patients within clinics, by correcting the standard errors with a robust cluster estimator, was employed in two steps; [1] stepwise regression with the full set of case mix factors as a variable selection step (10% significance level), [2] regression including significant predictors. Ordered logistic regression was performed for GA, and odds ratios (OR) are reported for

[1] Question: How is your leg/back pain today compared to before surgery? Possible answers: 0 = no pain before surgery (not included in statistical model), 1 = pain free, 2 = much improved, 3 = somewhat improved, 4 = unchanged, 5 = worse.

[2] High score = high disability.

[3] The first 14 days of sick-leave is not reported to the Swedish Social Insurance Agency, hence not accounted for in these analyses.

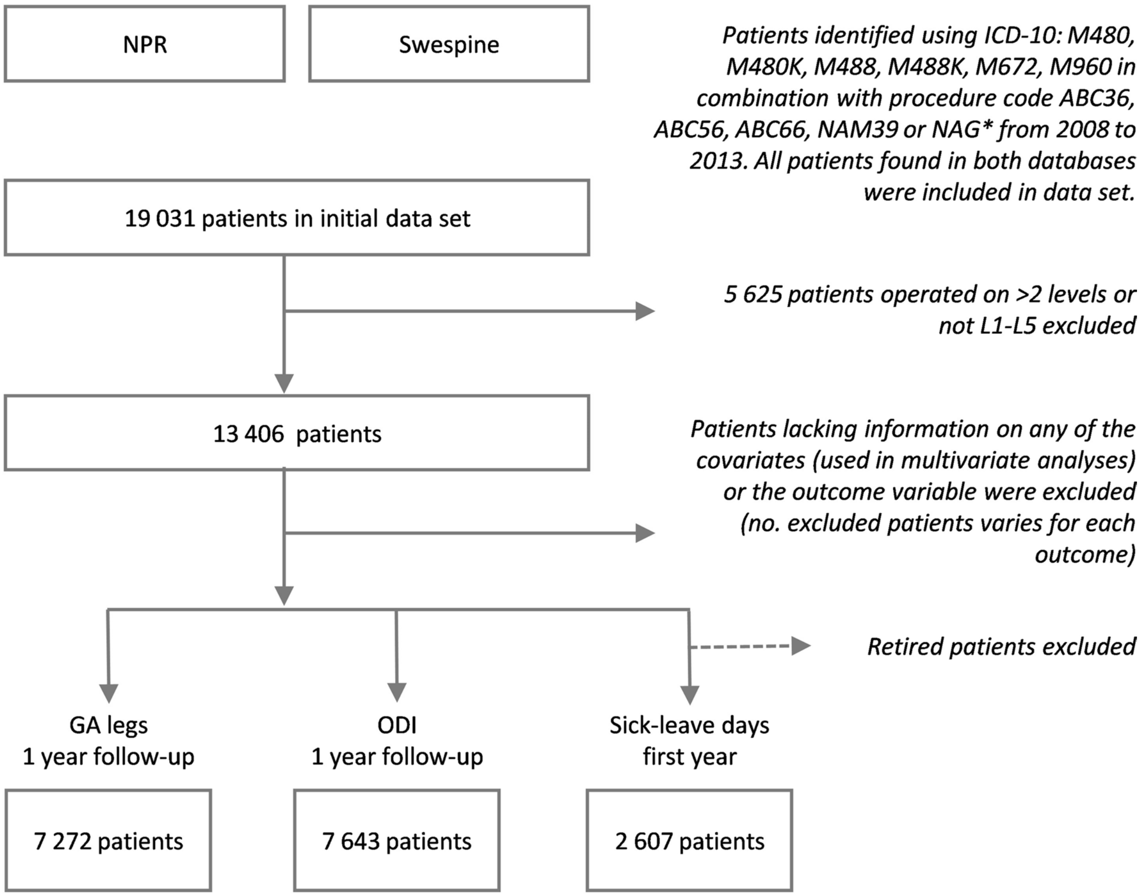



**Fig. 1** Patient population and study samples. Flow diagram showing the number of included patients, and the loss of cases in the different steps of analysis, due to selection steps and missing data. Out of the 19,031 patients identified as being surgically treated for spinal stenosis, 13,406 were operated on 1 or 2 adjacent levels (L2–L5). When fitting the multivariate models for each outcome variable, patients lacking information on any of the used case mix variables were excluded as well as those that had no follow-up reported 1 year after surgery. Out of the 13,406 patients, 54% were included in analysis of GA leg pain and 57% were included in analysis of ODI (postop 1 year). For analysis of sick leave, retired patients not eligible for sick-leave reimbursement ($n=9862$) were first excluded. Out of the eligible patients ($n=3544$), 74% were included in analysis of postoperative sick leave (1 year postoperatively) with the full set of case mix factors reported

each case mix factor and should be interpreted as the odds of a worse outcome on the scale [1–5] as 1 represents the best outcome and 5 the worst outcome. For example, the continuous variable age has an OR of 1.02. This means that the odds for a worse outcome on the scale is 1.02 for every year of higher age. ODI was analyzed using ordinary least squares (OLS) regression, and a GLM regression model with gamma distribution and log-link, suitable for continuous data with skewed distribution, was used for analysis of sick-leave days. All statistical analysis was carried out using STATA 13.1 (Stata Corporation, College Station, TX).

## Results

### Study population

A total of 19,031 patients were identified in NPR and Swespine, of which 13,406 patients fulfilled the study criteria (Fig. 1). For sick-leave analysis, patients above age of 65 years[4] as well as prematurely retired patients were omitted (3544 patients included). Individuals with missing values on any variable were excluded for each analysis. The analysis sample (and % of total study population included) amounted to 7272 individuals (54%) for GA (1 year) and 7643 individuals (59%) for ODI (1 year). The analysis sample for sick-leave analyses was 2607 (74%

[4] Retirement age in Sweden.

**Table 1** Descriptive statistics of study sample

| Variable | Possible values | Percentage (%) | Observations | Mean | SD | CI | Min | Max |
|---|---|---|---|---|---|---|---|---|
| Demographic and socioeconomic profile | | | | | | | | |
| Age | 18–92 | | | 66.2 | 10.7 | 66.0–66.5 | 18 | 92 |
| Male sex | | 47 | 4052 | | | | | |
| Educational level, elementary | | 28 | 2161 | | | | | |
| Educational level, high school | | 44 | 3353 | | | | | |
| Educational level, college/university | | 28 | 2129 | | | | | |
| Disposable income, 1st 20% | | 17 | 1326 | | | | | |
| Disposable income, 2nd 20% | | 19 | 1430 | | | | | |
| Disposable income, 3rd 20% | | 20 | 1526 | | | | | |
| Disposable income, 4th 20% | | 21 | 1615 | | | | | |
| Disposable income, 5th 20% | | 23 | 1746 | | | | | |
| Social welfare | | 1 | 113 | | | | | |
| Living alone | | 38 | 2869 | | | | | |
| Unemployed | | 2 | 163 | | | | | |
| Born in EU | | 97 | 246 | | | | | |
| Smoker | | 12 | 897 | | | | | |
| Health status before spine surgery | | | | | | | | |
| Duration of leg pain, no leg pain | | 3 | 255 | | | | | |
| Duration of leg pain, less than 3 months | | 3 | 235 | | | | | |
| Duration of leg pain, 3–12 months | | 26 | 1981 | | | | | |
| Duration of leg pain, 1–2 years | | 28 | 2116 | | | | | |
| Duration of leg pain, more than 2 years | | 40 | 3009 | | | | | |
| Duration of back pain, no back pain | | 6 | 444 | | | | | |
| Duration of back pain, less than 3 months | | 2 | 147 | | | | | |
| Duration of back pain, 3–12 months | | 18 | 1408 | | | | | |
| Duration of back pain, 1–2 years | | 22 | 1661 | | | | | |
| Duration of back pain, more than 2 years | | 52 | 3983 | | | | | |
| EQ-5D baseline | −0.59 to 1.0 | | | 0.37 | 0.32 | 0.363–0.377 | −0.59 | 1 |
| ODI baseline | 0–100 | | | 42.9 | 15.5 | 42.6–43.3 | 0 | 100 |
| VAS leg pain baseline | 0–100 | | | 66.3 | 23.8 | 62.8–63.9 | 0 | 100 |
| VAS back pain baseline | 0–100 | | | 55.6 | 26.1 | 55.1–56.2 | 0 | 100 |
| Previous surgery | | 18 | 1407 | | | | | |
| Walking distance, less than 100 m | | 39 | 2978 | | | | | |
| Walking distance, 100–500 m | | 30 | 2292 | | | | | |
| Walking distance, 0.5–1 km | | 15 | 1125 | | | | | |
| Walking distance, more than 1 km | | 16 | 1248 | | | | | |
| Comorbidities (any) | | 33 | 2544 | | | | | |
| Surgery method (fusion) | | 19 | 1483 | | | | | |
| Sick-leave days year before surgery* | 0–366 days | | | 53.4 | 97.2 | 50.1–56.7 | 0 | 366 |
| Type of provider (private) | | 46 | 3526 | | | | | |

Baseline characteristics for subjects included in the analysis of ODI 1 year following surgery ($n = 7643$)

*Only patients under the age of 66 and retired patients

of total population under 65 years) (Fig. 1). There were small differences in baseline characteristics between the analyzed population and the patients excluded (supplemental Table S1). A full description of missing values for each factor used is included in the supplement (Table S2).

For the largest study sample used (ODI 1 year), the baseline characteristics are presented in Table 1. The average age was 66.2 years, and most patients had a high-school diploma (44%). Most patients were born in the EU (97%), 12% were smokers, 1% were on social welfare payments and 2% unemployed (Table 1). A majority of the patients had endured leg pain more than 1 year (68%). On average, health-related quality of life (EQ-5D) [13] at baseline was 0.37 (range −0.59 to 1) and ODI 42.9. Pain levels on the visual analogue scale (VAS; 0–100) [14] were 66.3 (leg pain) and 55.6 (back pain), respectively. Most patients (69%) could walk less than 500 m because of leg pain/weakness (100–500 m: 30%; less than 100 m: 39%). In all, 18% of all patients had had a previous surgery and 34% suffered from one or more comorbidities[5] [15]. Decompression without fusion was the most common surgical procedure (81%). The average patient had 53 sick-leave days the year prior to surgery.

## Regression analysis

In the multivariate models, several baseline variables were significantly associated with outcome (the *R*-squared of the ODI model was 0.34) (Table 2). The factors describing preoperative health profile including comorbidity, pain level/duration and functional disability, quality of life or walking distance (all of which were significant in, at least, the ODI model) were associated with both GA and ODI outcome. In addition, socioeconomic variables such as a high educational level, a high income, being born in the EU, being a non-smoker, not being on social welfare, not being unemployed or living alone were associated with a better outcome. Using these socioeconomic variables alone to predict outcome rendered an *R*-squared of 0.07. Surgical method and previous surgical treatment also proved to be statistically significant predictors.

Diploma university degree (OR:0.70), high disposable income (OR:0.78) and born in the EU (OR:0.63) were associated with better outcome (GA), while social welfare (OR:1.34), living alone (OR:1.14) and smoking (OR:1.47) had a negative impact on GA (Table 2). The functional status (ODI) 1 year after surgery was positively affected by a high educational level ($\beta = -2.4$), a high income ($\beta = -2.6$) and being born in the EU ($\beta = -9.3$), while being on social welfare ($\beta = 3.6$), living alone ($\beta = 1.4$), unemployment ($\beta = 3.6$) and smoking ($\beta = 4.7$) were factors associated with a higher ODI (worse outcome) (Table 2).

Some socioeconomic factors were associated with postoperative length of sick leave. Social welfare payment was associated with fewer sick-leave days, while unemployment was associated with a longer sick leave (Table 2).

[5] Elixhauser index, method for measuring patient comorbidity based on diagnosis codes in administrative data (includes mental disorders, drug and alcohol abuse, obesity, coagulopathy, weight loss and fluid and electrolyte disorders).

Results regarding the second postoperative year were consistent with the results of the 1-year follow-up for all three outcome measures (same predictors with similar effects) and are reported in the supplemental material (Table S3).

## Simulation of predicted outcome

To visualize the association to some of the socioeconomic attributes, the regression algorithms were used to simulate outcome for patients with varying case mix. Figure 2 shows the predicted probability of GA (A) and ODI score (B) 1 year after surgery. Predicted levels and their 95% confidence intervals are reported in the supplemental material (Tables S4, S5). However, it should be noted that the individual error of prediction is higher than a confidence interval based on grouped data.

According to the algorithms for GA (leg pain), a non-smoking patient with university education and high disposable income, born in the EU, stood a 72% chance of being substantially improved, 1 year after surgery, while a smoking patient with elementary education and low income, born outside the EU and living alone stood a 28% chance of becoming substantially improved during the same period of time (Fig. 2a). Correspondingly, a non-smoking patient with university education and high income, born in the EU with no comorbidities, was predicted to have a postoperative ODI score of 18 (good result), while a smoking patient with low income, unemployed, living alone, born outside the EU, on social welfare, and with comorbidities, was predicted to have a postoperative ODI score of 48 (bad result) (Fig. 2b).

Furthermore, unemployment was associated with a higher number of sick-leave days (79 days) than a patient on social welfare (32 days, Fig. 3a). High-school education was associated with a larger amount of sick leave compared to elementary education (64 net days).

# Discussion

This study demonstrates how patient baseline factors are associated with outcomes of surgery for LSS. When considering a large number of patient characteristics in the same statistical model, the results point to some socioeconomic factors, e.g., country of birth, educational level, social welfare and employment status, as being relevant predictors of outcome. Studying ODI and GA simultaneously is also important; ODI is a well-known commonly used primary outcome measure of functional disability, used in recent studies evaluating outcome from LSS surgery [16, 17]. The GA (patient-reported, carefully validated outcome measure [18, 19]), is based on pain but has potential drawbacks as it disregards impairment in balance and general weakness which are important symptoms of LSS. This multi-register

**Table 2** Multivariate regression analysis, 1-year follow-up

| Variable | GA leg pain post op 1 year (ordered logistic regression) | | | | ODI score post op 1 year[e] (OLS regression) | | | | Sick-leave days post op 1 year (GLM with gamma distribution and log-link) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OR | *p* value | 95% CI | | Coef. | *p* value | 95% CI | | Coef. ($e^{Coef.}$)* | *p* value | 95% CI | |
| Age | 1.02 | < 0.001 | 1.01 | 1.02 | 0.15 | < 0.001 | 0.11 | 0.19 | | | | |
| Male sex | | | | | − 1.05 | 0.014 | − 2.24 | − 0.27 | − 0.19 (0.83) | < 0.001 | − 0.20 | − 0.08 |
| Educational level[a] | | | | | | | | | | | | |
| 2 | 0.90 | 0.034 | 0.81 | 0.99 | − 0.65 | 0.104 | − 1.32 | 0.13 | 0.10 (1.11) | 0.001 | 0.06 | 0.23 |
| 3 | 0.70 | < 0.001 | 0.63 | 0.79 | − 2.39 | < 0.001 | − 3.49 | − 1.14 | − 0.17 (0.84) | 0.026 | − 0.21 | − 0.01 |
| Disposable income[b] | | | | | | | | | | | | |
| 2 | 0.84 | 0.014 | 0.73 | 0.96 | − 1.05 | 0.072 | − 2.40 | 0.11 | | | | |
| 3 | 0.78 | 0.001 | 0.68 | 0.90 | − 1.96 | 0.011 | − 3.50 | − 0.48 | | | | |
| 4 | 0.90 | 0.135 | 0.78 | 1.04 | − 1.24 | 0.075 | − 2.52 | 0.13 | | | | |
| 5 | 0.78 | < 0.001 | 0.68 | 0.89 | − 2.58 | < 0.001 | − 3.62 | − 1.68 | | | | |
| Social welfare | 1.34 | 0.083 | 0.96 | 1.86 | 3.64 | 0.009 | 1.15 | 7.51 | − 0.77 (0.47) | < 0.001 | − 1.06 | − 0.51 |
| Living alone | 1.14 | 0.003 | 1.05 | 1.25 | 1.44 | 0.004 | 0.47 | 2.35 | | | | |
| Unemployed | | | | | 3.61 | 0.003 | 1.31 | 6.08 | 0.23 (1.26) | 0.077 | − 0.02 | 0.36 |
| Born in EU | 0.63 | < 0.001 | 0.49 | 0.79 | − 9.33 | < 0.001 | − 12.3 | − 6.50 | | | | |
| Smoker | 1.47 | < 0.001 | 1.29 | 1.68 | 4.72 | < 0.001 | 3.73 | 5.61 | | | | |
| Duration of back pain[c] | | | | | | | | | | | | |
| 1 | 0.66 | 0.023 | 0.46 | 0.94 | − 7.08 | < 0.001 | − 10.14 | − 4.40 | | | | |
| 2 | 0.73 | 0.005 | 0.58 | 0.91 | − 3.03 | 0.003 | − 5.40 | − 1.22 | | | | |
| 3 | 1.01 | 0.926 | 0.81 | 1.26 | − 0.14 | 0.870 | − 1.89 | 1.60 | | | | |
| 4 | 1.42 | 0.001 | 1.15 | 1.76 | 3.50 | 0.001 | 1.56 | 5.27 | | | | |
| EQ-5D baseline | | | | | − 2.35 | 0.008 | − 4.29 | − 0.70 | | | | |
| ODI baseline | 1.01 | < 0.001 | 1.01 | 1.01 | 0.44 | < 0.001 | 0.40 | 0.47 | 0.01 (1.01) | < 0.001 | 0.01 | 0.01 |
| VAS leg pain baseline | | | | | − 0.06 | < 0.001 | − 0.07 | − 0.05 | | | | |
| VAS back pain baseline | 1.01 | < 0.001 | 1.01 | 1.01 | 0.08 | < 0.001 | 0.06 | 0.10 | | | | |
| Previous surgery | 1.77 | < 0.001 | 1.59 | 1.97 | 6.41 | < 0.001 | 5.32 | 7.61 | | | | |
| Walking distance[d] | | | | | | | | | | | | |
| 2 | | | | | − 0.81 | 0.073 | − 1.73 | 0.08 | | | | |
| 3 | | | | | − 0.84 | 0.309 | − 2.21 | 0.72 | | | | |
| 4 | | | | | − 2.00 | < 0.001 | − 3.06 | − 0.96 | | | | |
| Comorbidities (elixhauser) | 1.12 | < 0.001 | 1.06 | 1.18 | 2.04 | < 0.001 | 1.55 | 2.61 | | | | |
| Surgery method (fusion) | 0.66 | < 0.001 | 0.59 | 0.73 | − 2.53 | < 0.001 | − 3.27 | − 1.71 | 0.41 (1.51) | < 0.001 | 0.34 | 0.59 |
| Sick-leave days year before op | | | | | | | | | 0.01 (1.01) | < 0.001 | 0.00 | 0.01 |
| Type of provider (private) | 0.86 | 0.001 | 0.78 | 0.4 | − 1.42 | 0.025 | − 2.34 | − 0.17 | − 0.15 (0.86) | 0.053 | − 0.32 | 0.00 |

Beta-coefficient (ODI and sick leave) or odds ratio (GA), *p* values and 95% confidence intervals are presented for all significant predictors on each outcome. Nonsignificant predictors were not included in the final model

*$e^{Coef}$ = the factor by which the covariate affects the number of sick-leave days

[a]Educational level divided into 3 categories: (1) elementary school (reference), (2) high school, (3) university

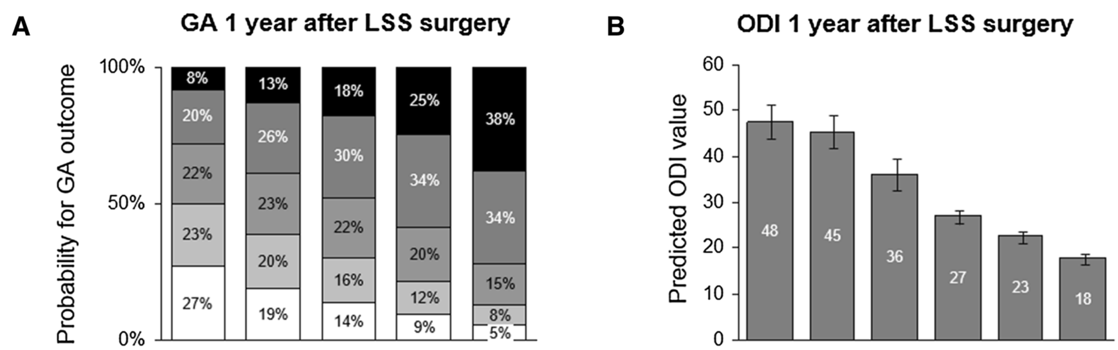
[b]Disposable income: quintiles in regional population, accounting for household size. 1st quintile = lowest income (reference), 5th quintile = highest income

[c]Duration of back pain: (1) no pain, (2) less than 3 months, (3) 3–12 months, (4) 1–2 years, (5) more than 2 years (reference)

[d]Walking distance: (1) less than 100 m (reference), (2) 100–500 m, (3) 0.5–1 km, (4) more than 1 km

[e]*R*-squared: 0.34 (goodness of fit)

study comprises a larger set of predictors than previous studies, including socioeconomic factors, and results reflect nation-wide data, with potentially high generalisability. Surgery for LSS is not associated with a 100% success rate. Around 64% of the patients report a good outcome (GA score 1 or 2) 1 year after surgery [20]. A future application




| A | | | | | |
|---|---|---|---|---|---|
| Educational level[1] | 1 | 1 | 1 | 1 | 3 |
| Disposable income[2] | 1 | 1 | 1 | 1 | 5 |
| Social welfare | Yes | Yes | Yes | No | No |
| Living alone | Yes | Yes | Yes | No | No |
| Born in the EU | No | Yes | Yes | Yes | Yes |
| Smoker | Yes | Yes | No | No | No |

1: pain free
2: much improved
3: somewhat improved
4: unchanged
5: worse

| B | | | | | | |
|---|---|---|---|---|---|---|
| Educational level[1] | 1 | 1 | 1 | 1 | 1 | 3 |
| Disposable income[2] | 1 | 1 | 1 | 1 | 1 | 5 |
| Social welfare | Yes | Yes | Yes | No | No | No |
| Living alone | Yes | Yes | Yes | No | No | No |
| Unemployed | Yes | Yes | Yes | No | No | No |
| Born in the EU | No | No | Yes | Yes | Yes | Yes |
| Smoker | Yes | Yes | Yes | Yes | No | No |
| Comorbidities | Yes | No | No | No | No | No |

[1] Educational level: (1) elementary, (2) high school, (3) university
[2] Disposable income (1-5), categorized into quintiles base on the county's distribution. 1 is low income and 5 is high income.

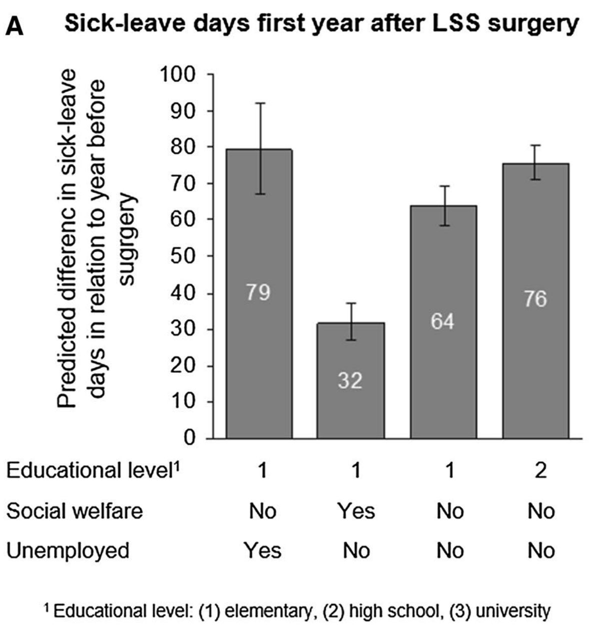
**Additional covariates of model, kept constant at average values**

| | | | |
|---|---|---|---|
| Age | 64 | ODI baseline | 40 |
| Male sex | Yes | Previous surgery | No |
| Unemployed | No | Walking distance | 100-500 meters |
| Duration of back pain | 1–2 years | Comorbidities | No |
| EQ-5D baseline | 0.30 | Surgery method (fusion) | No |
| VAS leg pain baseline | 60 | | |
| VAS back pain baseline | 60 | | |

**Fig. 2** Simulation of patients to predict outcome on GA and ODI based on prediction algorithms. **a** The predicted probability of GA outcome 1 year after surgery, given different case mix with varying socioeconomic status and smoking habits. **b** The predicted ODI score 1 year after surgery given differences in case mix. Error bars indicate the 95% confidence intervals (for details see supplemental table S4 and S5). Additional significant predictors (not specifically modulated in these simulations, but included in model) were kept at constant values representing the average patient (gray box)

could be using case mix algorithms, like the ones developed here, as assessment tools for predicting patient outcome, when discussing treatment options. Importantly, use of such a tool must focus on improving preoperative and postoperative interventions for risk patients rather than excluding surgery as an option for therapy. In addition, the fact that the model does not consider factors like diagnostic imaging and detailed psychological status of patients must be recognized as a drawback of the model.

Factors like smoking and obesity have previously been shown to affect outcome of surgery [7, 8]. This study showed that also socioeconomic indicators seem to affect outcome. Higher educational level and higher disposable income were associated with a 72% likelihood of successful outcome (GA), while a less "privileged" person had a probability of 28% to reach the same result (Fig. 2a). Unemployment, social welfare and living alone negatively affected the improvement in ODI (potential difference of 30 points, Fig. 2b). The simulations performed in Figs. 2 and 3 illustrate the effect of the predictors on health outcome and sick leave. It should be noted though that the rather extreme example of a patient with low income, low educational level, on social welfare, living alone, born outside the EU and being a smoker is a rare profile which in this population occurs in only one single patient (who reported becoming worse after surgery). Furthermore, the explanatory value of socioeconomic variables alone for predicting variation in outcome was far lower (7%) than when including clinical variables as well (34%). In order to better understand to what extent socioeconomic factors play a role for health outcomes and sick leave after surgery, and to enable drawing generalisable conclusions, further investigation is needed. This study does not explain




| Covariates of model, kept constant at average values | |
|---|---|
| Male sex | Yes |
| ODI baseline | 40 |
| VAS back pain baseline | 52 |
| Surgery method (fusion) | No |
| Sick-leave days year before | 51 |
| Type of provider (private) | No |

**Fig. 3** Simulation of patients to predict number of sick-leave days the first year after surgery based on prediction algorithms. The predicted number of sick-leave days during the first (**a**) postoperative year given differences in case mix regarding educational level, social welfare and unemployment. Error bars indicate the 95% confidence intervals. Additional significant predictors (not specifically modulated in these simulations, but included in model) were kept at constant values representing the average patient (gray box)

why or how socioeconomic factors influence surgical outcome which should also be a topic for further research.

Although subtle differences in case mix may imply significant differences in outcome, it is important to consider the minimally clinical important difference (MCID), the smallest difference a patient would perceive as relevant [21]. MCID varies depending on clinical or demographic characteristics, and on how it is calculated. Previously reported MCID for ODI varies in the interval 10–18 units [22]. Indeed, the effect of single parameters may not reach the MCID; however, a combination of several patient factors may imply large differences beyond MCID, as in Figs. 2 and 3.

The study population included patients being treated for LSS regardless of surgical technique used. When adjusting for socioeconomic factors, better outcome appeared when fusion was added to decompression (Table 2). Historically, combining decompression with fusion has been considered a better alternative in patients with spondylolisthesis to avoid postoperative "instability" and to achieve better clinical outcome [23, 24]. However, new data indicate that fusion is, in general terms, unnecessary in these patients [4, 25], which may explain why the percentage of LSS surgeries with fusion in Sweden decreased from 21% in 2008 to 15% in 2012 (data not shown). Interestingly, two recent studies comparing the techniques [4, 25] showed no clinically significant differences in postoperative ODI, VAS or EQ-5D after decompression surgery with or without fusion. It is possible that the discrepancy between results reported in different Swedish register studies (covering different time periods) may be a result of a development over time toward more restricted use of fusion, whereby the smaller group of patients with combined fusion and decompression may have been better selected to receive fusion than patients in the previous time period.

The analysis of sick leave the first postoperative year is complex and likely affected by unspecified factors that were not adjusted for, such as regional recommendations and local routines. Several predictors had a significant effect on sick leave, e.g., educational level, where an elementary education unexpectedly was associated with shorter sick leave than was high-school education. This is different from what has been reported from previous research [26]. Accordingly, the highest educational level was indeed associated with a shorter sick leave than elementary education (Table 2), probably coupled to higher incentives of going back to work. Being on social welfare was associated with shorter sick leave, and unemployment was associated with longer sick leave, potentially explained by different financial incentives to stay on sick leave depending on what type of benefit a patient had before surgery. This may be of interest to investigate in future studies.

Register studies imply some limitations, such as difficulties in controlling for missing or incorrect data. For registries included here, follow-up rates are high (Swespine is rated at the highest Swedish national level regarding data quality and coverage), but as the multivariate statistical models used in this study included several relevant variables with varying rate of missing information this consequently brought about a higher rate of missing data for final analysis. There were small but significant differences in baseline characteristics between patients ultimately included or excluded in final models (Table S1). For example, excluded patients were slightly older, had a higher incidence of comorbidity, higher preoperative ODI score, but a lower preoperative VAS leg pain score as well as lower preoperative EQ-5D score (Table S1). One study showed that a loss to follow-up in clinical registries of 22% did not bias conclusions on the effects of treatment [27]. In this study, 24–29% of the patients (depending on outcome measure) were excluded due to loss to follow-up 1 year after surgery (data in supplement, Table S2); hence, a potential bias due to missing data must be considered in the interpretation of data. A larger proportion of the patients were excluded in the 2-year follow-up analysis (Table S2).

Our study highlights the relevance of adding socioeconomic factors to clinical factors for analysis of clinical outcomes. It has previously not been studied to this extent, i.e., including multiple socioeconomic parameters together with clinical factors as explanatory variables for both health outcomes and postoperative sick leave. The results, however, also raise general questions about how to assess outcome. For example, cultural differences potentially compromise the objectivity of the results.

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## Compliance with ethical standards

**Conflict of interest** HI, CW and FB are employees at Ivbar Institute (a healthcare research consultancy), which has received research grants from Sveus (county council consortium) for the submitted work. FB holds shares in Ivbar Institute. The other authors declare that they have no conflict of interest.

## References

1. Amundsen T, Weber H, Lilleas F, Nordal HJ, Abdelnoor M, Magnaes B (1995) Lumbar spinal stenosis. Clinical and radiologic features. Spine (Phila Pa 1976) 20(10):1178–1186
2. Stromqvist B, Fritzell P, Hagg O, Jonsson B, Sanden B, Swedish Society of Spinal S (2013) Swespine: the Swedish spine register: the 2012 report. Eur Spine J 22(4):953–974
3. Weinstein JN, Tosteson TD, Lurie JD, Tosteson AN, Blood E, Hanscom B et al (2008) Surgical versus nonsurgical therapy for lumbar spinal stenosis. N Engl J Med 358(8):794–810
4. Försth P, Olafsson G, Carlsson T, Frost A, Borgström F, Fritzell P et al (2016) A randomized controled trial of fusion surgery for lumbar spinal stenosis. N Engl J Med 374(15):1413–1423
5. Iversen MD, Daltroy LH, Fossel AH, Katz JN (1998) The prognostic importance of patient pre-operative expectations of surgery for lumbar spinal stenosis. Patient Educ Couns 34(2):169–178
6. Abbott AD, Tyni-Lenne R, Hedlund R (2010) The influence of psychological factors on pre-operative levels of pain intensity, disability and health-related quality of life in lumbar spinal fusion surgery patients. Physiotherapy 96(3):213–221
7. Knutsson B, Michaelsson K, Sanden B (2013) Obesity is associated with inferior results after surgery for lumbar spinal stenosis: a study of 2633 patients from the Swedish spine register. Spine (Phila Pa 1976) 38(5):435–441
8. Sanden B, Forsth P, Michaelsson K (2011) Smokers show less improvement than nonsmokers two years after surgery for lumbar spinal stenosis: a study of 4555 patients from the Swedish spine register. Spine (Phila Pa 1976) 36(13):1059–1064
9. Stromqvist F, Ahmad M, Hildingsson C, Jonsson B, Stromqvist B (2008) Gender differences in lumbar disc herniation surgery. Acta Orthop 79(5):643–649
10. Cobo Soriano J, Sendino Revuelta M, Fabregate Fuente M, Cimarra Diaz I, Martinez Urena P, Deglane Meneses R (2010) Predictors of outcome after decompressive lumbar surgery and instrumented posterolateral fusion. Eur Spine J 19(11):1841–1848
11. Fritzell P, Hagg O, Wessberg P, Nordwall A, Swedish Lumbar Spine Study G (2001) Volvo Award Winner in Clinical Studies: lumbar fusion versus nonsurgical treatment for chronic low back pain: a multicenter randomized controlled trial from the Swedish Lumbar Spine Study Group. Spine (Phila Pa 1976) 26(23):2521–2532 **(discussion 32-4)**
12. Fairbank JC, Couper J, Davies JB, O'Brien JP (1980) The Oswestry low back pain disability questionnaire. Physiotherapy 66(8):271–273
13. EuroQol G (1990) EuroQol—a new facility for the measurement of health-related quality of life. Health Policy 16(3):199–208
14. Huskisson EC (1974) Measurement of pain. Lancet 2(7889):1127–1131
15. Elixhauser A, Steiner C, Harris DR, Coffey RM (1998) Comorbidity measures for use with administrative data. Med Care 36(1):8–27
16. Hermansen E, Romild UK, Austevoll IM, Solberg T, Storheim K, Brox JI et al (2017) Does surgical technique influence clinical outcome after lumbar spinal stenosis decompression? A comparative effectiveness study from the Norwegian Registry for Spine Surgery. Eur Spine J 26(2):420–427
17. Mobbs RJ, Li J, Sivabalan P, Raley D, Rao PJ (2014) Outcomes after decompressive laminectomy for lumbar spinal stenosis: comparison between minimally invasive unilateral laminectomy for bilateral decompression and open laminectomy: clinical article. J Neurosurg Spine. 21(2):179–186
18. Hagg O, Fritzell P, Oden A, Nordwall A, Swedish Lumbar Spine Study G (2002) Simplifying outcome measurement: evaluation of instruments for measuring outcome after fusion surgery for chronic low back pain. Spine (Phila Pa 1976) 27(11):1213–1222
19. Hedlund R, Johansson C, Hagg O, Fritzell P, Tullberg T, Swedish Lumbar Spine Study G (2016) The long-term outcome of lumbar fusion in the Swedish lumbar spine study. Spine J 16(5):579–587
20. Gunzburg R, Szpalski M (2003) The conservative surgical treatment of lumbar spinal stenosis in the elderly. Eur Spine J 12(Suppl 2):S176–S180
21. King MT (2011) A point of minimal important difference (MID): a critique of terminology and methods. Expert Rev Pharmacoecon Outcomes Res 11(2):171–184
22. Parker SL, Adogwa O, Mendenhall SK, Shau DN, Anderson WN, Cheng JS et al (2012) Determination of minimum clinically important difference (MCID) in pain, disability, and quality of life after revision fusion for symptomatic pseudoarthrosis. Spine J 12(12):1122–1128
23. Ghogawala Z, Benzel EC, Amin-Hanjani S, Barker FG 2nd, Harrington JF, Magge SN et al (2004) Prospective outcomes evaluation after decompression with or without instrumented fusion for lumbar stenosis and degenerative Grade I spondylolisthesis. J Neurosurg Spine 1(3):267–272
24. Herkowitz HN, Kurz LT (1991) Degenerative lumbar spondylolisthesis with spinal stenosis. A prospective study comparing

decompression with decompression and intertransverse process arthrodesis. J Bone Joint Surg Am 73(6):802–808

25. Forsth P, Michaelsson K, Sanden B (2013) Does fusion improve the outcome after decompressive surgery for lumbar spinal stenosis?: a two-year follow-up study involving 5390 patients. Bone Joint J 95-B(7):960–965
26. Piha K, Laaksonen M, Martikainen P, Rahkonen O, Lahelma E (2010) Interrelationships between education, occupational class, income and sickness absence. Eur J Public Health 20(3):276–280
27. Solberg TK, Sorlie A, Sjaavik K, Nygaard OP, Ingebrigtsen T (2011) Would loss to follow-up bias the outcome evaluation of patients operated for degenerative disorders of the lumbar spine? Acta Orthop 82(1):56–63

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