Lumbar spinal stenosis

Body mass index and the patient's perspective

BJÖRN KNUTSSON
Abstract

During recent decades, lumbar spinal stenosis (LSS) has become the most common indication for spine surgery, a change that coincides with a higher worldwide prevalence of overweight and obesity. Thus, surgical treatment of LSS in the overweight and obese population is common and increasing in scope.

The overall aim of this thesis was to investigate whether body mass index (BMI) is related to the development of LSS, and whether BMI is linked to outcome after surgery for LSS. We further evaluated whether there are specific experiences of LSS from a patient perspective.

Data were obtained for all patients registered in the Swedish Spine Register who had undergone surgery for LSS between January 1, 2006 and June 30, 2008. After adjusting for differences in baseline characteristics, patients with obesity showed both poorer results after surgery and a higher rate of dissatisfaction than patients with normal weight (odds ratio 1.73; 95% confidence interval, CI, 1.36-2.19).

Furthermore, patients with obesity in the cohort reported modest weight loss at follow-up (2.0 kg; 95% CI, 1.5-2.4), and only 8% reported a clinical important weight loss 2 years after surgery. Our analysis of 389,132 construction workers, showed that overweight (incidence rate ratio, IRR 1.68; 95% CI, 1.54-1.83) and obesity (IRR 2.18; 95% CI, 1.87-2.53) were associated with an increased future risk in developing LSS when compared with patients with normal weight.

To gain insight into the patients' perspective of LSS, we performed interviews with 18 patients who were on a waiting list for LSS surgery. The transcripts, analyzed with content analysis, revealed that living with LSS is a physical, mental and social challenge in which resources to cope with the condition are of major importance.

In summary, obesity is associated with poorer results after surgery, and patients with obesity report modest weight loss during follow-up. In addition, obesity is associated with an increased risk to develop LSS. Our findings revealed that being a patient with LSS, naturally involves considerable suffering and pain, but it also implies being a person with his or her own resources who is able to cope with these adverse conditions.

Keywords: Antonovsky, back pain, BMI, body mass index, Bygghalsan, cohort study, coping, EQ-5D, excess weight, leg pain, LSS, lumbar spinal stenosis, obesity, ODI Oswestry disability index, overweight, patient-centered, patient-physician relationship, patient-perspective, patient-related-outcome-measure, PROMs, qualitative study, spinal stenosis, salutogenesis, salutogenic, sciatica, spine surgery, suffering, Swedish spine register, Swespine, VAS, weight loss, weight change

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To my family
List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I  Knutsson B, Michaëlsson K, Sandén B. 
Obesity is associated with inferior results after surgery for lumbar spinal stenosis: a study of 2633 patients from the Swedish spine register. 

II  Knutsson B, Michaëlsson K, Sandén B. 
Obese patients report modest weight loss after surgery for lumbar spinal stenosis: a study from the Swedish spine register. 

III  Knutsson B, Sandén B, Sjödén G, Järvholm B, Michaëlsson K. 
Body mass index and risk for clinical lumbar spinal stenosis: a cohort study. 

IV  Knutsson B, Jong M, Sjödén G, Augutis M. 
Waiting for lumbar spinal stenosis surgery: suffering, resources to cope and expectations. 
Submitted.

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<td>CI</td>
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<td>CIWL</td>
<td>Clinically important weight loss</td>
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<td>CSA</td>
<td>Cross-sectional area</td>
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<td>Directed acyclic graph</td>
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<td>EQ-5D</td>
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<td>GLM</td>
<td>Generalized linear model</td>
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<td>General resources of resistance</td>
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<td>Health-related quality of life</td>
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<td>International consortium for health outcomes measures</td>
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<td>IRR</td>
<td>Incidence rate ratio</td>
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<td>Kilogram</td>
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<td>Sense of coherence</td>
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<td>Spine patient outcomes research trial</td>
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<td>Self-reported walking ability</td>
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<td>Visual analogue scale</td>
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<td>World Health Organization</td>
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Introduction

Definition and classification of lumbar spinal stenosis

Lumbar spinal stenosis (LSS) is defined as a narrowing of the lumbar spinal canal that is caused by facet joint arthrosis, thickened and shrunken ligamentum flavum, bulging disc, thickened lamina and in some cases spondylolisthesis. These spondylotic changes diminish the space for neural and vascular structures.\(^1\) Spinal stenosis can further be divided into central, lateral or foraminal.\(^1\)\(^,\)\(^2\) All patients included in this study have central spinal stenosis with or without spondylolisthesis as the main diagnosis, although combined types can exist. LSS can also be classified according to etiology into two main categories, namely congenital/developed and acquired.\(^1\)\(^,\)\(^2\) The most common type is degenerative acquired LSS with predominance in the lower lumbar levels.\(^1\)

![Figure 1. Lumbar spinal stenosis with images of a cross-sectional (A) and a sagittal plane (B). In the sagittal plane, the minor slip between L4 (lumbar vertebrae 4) and L5 (lumbar vertebrae 5) is a spondylolisthesis. Arrows indicate stenosis. Picture C and D shows a normal spine.](image)
History
During the 19th and beginning of the 20th century several descriptions of neurogenic claudication as a differential diagnosis to vascular claudication and syphilis were described. Thomson measured the diameter of the spinal canal in 1913, the same year Elsberg surgically decompressed a lumbar nerve root. During the following decades, methods for surgical treatment of LSS as well as morphological and radiological classification of LSS developed.

In 1949, Verbiest introduced the term spinal stenosis. His case report included seven patients with clinical and radiological features of spinal stenosis. The development of computed tomography (CT) increased the understanding of LSS. However, the diagnosis and treatment of LSS have been debated for decades and was not classified in the International classification of disease (ICD) until 1987.

Clinical presentation
Clinical degenerative LSS is typically diagnosed in the 6th and 7th decade of life. Even if back pain were common among patients with LSS it is considered a non-specific symptom. The typical symptoms include leg pain, especially during walking, associated with numbness and paraesthesia, and sometimes loss of motor control and bladder disturbances. In addition these symptoms should be induced or exacerbated during standing or walking and relieved by lumbar flexion.

Clinical findings are often scarce. Even if some kind of motor or sensory deficit is common, the findings are typically mild.

Differential or coexisting diagnosis is hip osteoarthritis, trochanteric bursitis, vascular claudication, restless legs and neuropathy, but also more severe conditions like neoplasia and normal pressure hydrocephalus.

Radiological criteria and relation to symptoms
Examination with CT, CT myeolography or magnetic resonance imaging (MRI) is traditionally used to diagnose LSS. MRI is the modality of choice today with high sensivity and specificity. There are at least sixteen different radiological criteria for diagnosis of LSS. An expert group recommended qualitative methods for classification of LSS in clinical practice, and quantitative measures for research. Recommended qualitative measures are the compromise of the central zone and the relation between fluid and the cauda equina. Furthermore, the cross-sectional area (CSA) of the dural sac were the recommended quantitative method for clinical outcome studies, with fair to excellent reproducibility. The expert group considered the CSA method difficult during the daily working routine. However, today
most spine units in Sweden have computerized software for MR images, and measurement of the CSA is implemented in the daily routine. Schönström et al. measured the CSA in 7 cadavers. They concluded that once 60-80 mm² is reached, further compression of the dural sac increases the pressure on the nerve roots. Anthiwiaram et al found an association between CSA<70mm² and preoperative function among surgically treated patients. Whether there is a linear correlation between CSA and clinical symptoms once the critical area is reached is uncertain. Ogikubo et al. reported a positive correlation between preoperative symptoms and CSA, which is in contrast to Sigmundsson et al who found no relation between symptoms and the CSA. Both studies included patients before surgical treatment for LSS, where the majority of the patients demonstrated an CSA≤80 mm².

Sirvanci et al. found no correlation between CSA and function in the Oswestry Disability Index (ODI). Similar to Sigmundsson et al., their retrospective study comprised a high proportion of patients with multi-level stenosis (MLS). The number of patients with MLS in Ogikubo's study was not shown. MLS and coexisting degenerative features of the spine are common which is a limitation of the one level CSA method.

Radiographic LSS without symptoms is common. For instance, Boden et al performed MRI on 67 asymptomatic persons and found radiological spinal stenosis in 21% of the participants over 60 years old. Finally, even if asymptomatic radiological LSS were common among elderly, Ishimoto et al. observed a correlation between severe stenosis and clinical symptoms in a cross-sectional study on a Japanese population.

Pathophysiology

The pathophysiology hypothesis for these LSS symptoms is a combination of direct pressure on neural elements and vascular structures, but also an increased pressure inside the dural sac, a condition that disturbs nutrition to the neural elements. Postural positions, such as extension of the back and standing can potentially increase both the direct and indirect pressure.

Epidemiology

Prevalence

Few studies have described the prevalence of LSS in the general population. The prevalence is highly dependent of the age of the studied population and definition of spinal stenosis. Kalichman et al noted a prevalence of 24% (45/191) of CT-evaluated LSS in a subgroup analysis in the Framingham cohort. The mean age was 53 years (range 32-79), the prevalence of LSS showed similar sex distribution. The authors used the axial diameter of the
spinal canal as the definition of LSS. In a recent cross-sectional study on the prevalence of radiological and clinical LSS, moderate to severe LSS was common (78%, 731/938), although symptoms were uncommon (13%, 94/731). A qualitative evaluation based on MRI imaging was used for diagnosis. The mean age was 67 years (range, 40-93) and the prevalence of radiographic LSS increased from 64% in people 50 to 59 years to 93% in people 80 to 89 years. The prevalence of symptomatic and asymptomatic LSS was similar in male and female persons.

Incidence for surgically treated LSS

During recent decades, the most common indication for spine surgery in many countries is LSS. In Sweden the incidence of LSS surgery increased from 4.7 to 13.2 per 100 000 inhabitants per year from 1987 to 1999, and the annual number of registered surgical procedures for LSS is continuously on the rise. We have also observed a similar trend in Europe and the United States. Increasing age in the population, increased use of MRI and systematic differences in health care are major factors to account for this trend, although the impact of biological factors might also be relevant.

Risk factors for LSS

A recent study on 598 Finish male twins described radiographic LSS as a highly genetic condition that is to some degree mediated by disc degeneration. However, the degree of hereditability also depend on the definition of LSS and lumbar level: the environmental influence increases with decreasing lumbar level (from L1 to S1).

Older age is a risk factor for degenerative LSS, and the majority of the patients included in studies on degenerative LSS are ≥50 years old. The results from a Swedish incidence study found a low proportion of patients (13%) with LSS who were <49 years of age. The causality between age and LSS could be low grade inflammation, immunosenescence and impaired repair pathways both genetically and environmentally.

Smoking and strenuous work are not established risk factors for LSS, although they are reported as risk factors for spondylosis and disc degeneration which could develop into clinical LSS.

Research on sex differences has produced diverse and inconsistent results. Several reports on surgically treated LSS showed a higher proportion of female participants, especially LSS that was due to spondylolisthesis. In contrast, male predominance or equal sex distribution is also presented in the literature. To my knowledge, there were no studies that have examined the links between body mass index (BMI) and the incidence rate for LSS.
Treatment for LSS

The natural course versus non-surgical treatment

The natural course of LSS is poorly documented. Johnsson et al. selected 32 patients for non-surgical treatment of LSS. Of these 32 patients, 27 were followed for 4 years. The majority of the patients reported unchanged or decreased symptoms during follow-up (70-85%); severe deterioration was not found in these patients.39

The first choice of treatment is non-surgical including bed rest, bracing, painkillers, epidural injections and physical therapy.40, 41 Although the evidence for non-surgical treatment is poor, several studies have reported unchanged or decreased symptoms at follow-up in patients selected for non-surgical treatment.40-42 Simotas et al. followed 40 patients with an active treatment algorithm, including physical and pharmacologic treatment, with a mean follow-up of 33 months (range, 16-55). Of the 40 patients, 77% (n=31) reported unchanged or decreased symptoms. The results also indicated that neurologic deterioration was rare.40 Although epidural injections could have a short-term benefit; epidural injections with steroids have minimal or no treatment effect compared to epidural injections with local anesthetics.43-45

Surgical treatment

Several studies have compared surgical with non-surgical treatment, some of which have been randomized controlled trials (RCTs). Although, the results from these studies, have shown conflicting results; surgical treatment is considered superior over non-surgical treatment for strictly selected patients.34, 37, 38, 41, 46-49

The golden standard and most common method for surgery is decompression of the osseous and soft tissue elements that compress the spinal canal with conventional laminectomy.50

The indication for adding a fusion to decompression remains unclear, but is associated to increased risk for complications compared with the decompression procedure alone.20, 21, 35, 51

Micro-decompression surgery is a procedure that entails minimal skin incision and preserves the supraspinous process and interspinous ligaments. The rationale for this procedure is that preserving the posterior structures enhances rehabilitation and improves the outcomes compared with standard decompression. A Norwegian register study compared micro and standard decompression, and found no clinical important differences in outcomes or complication rates 12 months after surgery.52 Similar results were reported in a recent Cochrane review.53 The authors compared techniques that preserved the posterior structures with conventional laminectomy and found equal results regardless of surgical technique.
Because of comorbidities, many patients are not eligible for decompression procedures. Accordingly, a new minimalistic technique with an interspinous device has been introduced. Through distraction between the supraspinous processes, the patients’ symptoms can decrease owing to indirect decompression of the dural sac. Moojen et al. employed a sample of 205 patients in a multicenter RCT. The interspinous process device was compared with standard decompression in a 1-year follow-up. The methods showed equal improvement in patient-reported outcome measures (PROMs), but the reoperation rate in the interspinous process device group was 29% (21/73) which was more than threefold compared with the standard decompression group (8%, 6/72).

Mortality, complications and re-operation rate related to surgery for LSS

Jansson et al. studied the mortality and re-operation rate in Sweden between 1987 and 1999. The case fatality rate was 3.5 per 1000 operations within 30 days. Age >75 years, fusion procedures and male sex were associated with a higher risk for postoperative mortality. The re-operation rate was 5% after 2 years and 11% after 10 years.

The registration of complication rates is often poor. Surgeons tend to underreport, while patients often overreport the complications. Earlier studies on posterior lumbar fusion on obese patients have shown an increased risk for complications compared with normal-weight patients, especially postoperative infections.

A recent North American register study that included over 49 000 elective surgical procedures of the spine showed that obesity, particularly obesity class II and III, was associated with minor and major complications. However, elevated BMI was not associated with an increased mortality. In a sensitivity analysis, cohorts were matched for comorbidities. The results from the analysis indicated that differences between the BMI groups diminished, but BMI was still a risk factor in the obese class III group compared with the normal-weight group. The following complication rates were reported in patients with normal weight: minor complications (2.1%), major complications (3.8%), 30-day return to operation room (2.3%) and 30-day mortality (0.1%).

Outcome predictors after LSS surgery

This section is limited to PROMs, including health related quality of life (HRQoL), function, pain, walking capacity, use of analgesics and satisfaction with treatment. A predictor can be associated with inferior (negative) or superior (positive) outcome. It is important to emphasize that all predictors
may be outcome-specific, which is a limitation especially in studies using one or few outcome measures.61

A meta-analysis comprised of 74 studies reported a good to excellent outcome in 64% of the patients after LSS surgery.62 Consequently, a substantial proportion of the patients were not satisfied with the outcome after surgery, probably because of residual symptoms, complications associated with surgery and unrealistic expectations of the surgical outcome. Aalto et al. performed a systematic review on preoperative predictors for postoperative outcome in LSS. Totally, 885 abstracts were assessed and only 21 of acceptable quality were included in the study.61 A summary of these studies and more recent research are presented below.

**Radiologic predictors**

In a study following 109 patients for 2 years, Sigmundsson et al. found that a narrow preoperative CSA was related to greater improvement in back and leg pain.63

Another study divided a cohort (n=47) based on preoperative CSA and, found an association between a CSA <70 mm² and better postoperative function as measured by the ODI.64 Jönsson et al described similar findings as those in Sigmundsson i.e. a severe encroachment in the sagittal plane (<6mm) was associated with better improvements in leg pain and walking ability.65

Degenerative spondylolisthesis (DS) is discussed as a predictor for outcome after LSS surgery. However, a recent cohort study included 5390 patients with and without DS; no significant differences in outcomes were found during follow-up.35 LLS is also associated with degenerative scoliosis which is reported as a negative predictor for back pain in a group of 90 patients followed for 2 years after surgery.66

**Health, comorbidities, walking ability, pain and function**

Katz et al. analyzed the predictors for postoperative outcome in LSS in 272 participants. He found that self-rated health was moderately correlated to preoperative function and pain. Self-rated health was also a positive predictor for better walking ability and satisfaction.67 A sense of coherence (SOC) and ability to cope were associated with self-rated health, as well as with quality of life (QoL), function and outcomes after LSS surgery.68, 69 Somatic and emotional health are positive predictors, and comorbidities especially cardiovascular comorbidities and depression, predict worse outcome.61, 67

Predominant leg pain is associated with better improvement in leg pain and walking ability,63 but long duration of pain is associated with poor outcomes.63, 70, 71

Not surprisingly, good preoperative walking ability predicts better postoperative walking ability. Additionally, in a systematic review, disorders affecting the walking ability were found to be associated with worse postop-
ervative walking ability and pain. Furthermore, low preoperative score in EuroQol group five dimensions of health (EQ-5D), high levels of pain and preoperative use of analgesics are predictors of poor outcome. Earlier back surgery is also a negative predictor of outcome probably related to residual symptoms, complications, low function, high levels of pain and long pain duration.

**High income and educational level**

High income is associated with better walking ability, a higher degree of improved symptoms and satisfaction. Correlations also exist between high educational level and improved back pain, leg pain, ODI and the short form (36) health survey (SF-36).

**Expectations**

Iversen et al. followed 257 patients for 6 months. The authors found that more ambitious expectations of physical function are associated with better function and satisfaction. In contrast, a great number of expectations of pain relief proved to be a negative predictor for postoperative pain. Another study that included 184 patients reported affirmative expectations as a positive predictor for ODI and leg pain.

**Age, sex and life style factors**

The majority of the studies that included age or sex as a predictor show no difference associated with either age or sex.

In a recent cohort study, Sandén et al. showed that smoking is associated with dissatisfaction and poorer outcomes. The cohort study, which included 4555 surgically treated patients, found inferior results in smokers compared to non-smokers in all outcome measures: EQ-5D, SF-36, ODI, back pain, leg pain, use of analgesics, walking ability and return to work. Cobo Soriano et al also demonstrated that smoking is a negative predictor for pain relief.

The results of earlier studies on BMI as a predictor for outcome after surgery are inconsistent. Several studies have reported no significant effect of BMI on outcome. In contrast, Athiviraham et al. found a correlation between BMI and poorer outcome on the Roland Morris Score. This study, however, has several important limitations; the study was not designed to specifically evaluate BMI, it included a small number of patients (n=89) and no BMI data were provided.

**Obesity and weight loss**

Obesity is a condition of excessive fat accumulation in adipose tissue, and was an important determinant for survival among our prehistoric ancestors.
For thousands of years obesity was rare, and even indicating wealth and status in some cultures. Even if there were several historical monographs and case reports on obesity and related morbidity, obesity as a major public health problem was not appreciated until the end of the 1940s. During the recent decades, obesity has become a growing epidemic with no cessation in sight. Indeed, a majority of the adult population in many developed and developing countries is overweight or obese.

Obese individuals have a higher rate of death from cardiovascular diseases, as well as a significantly elevated risk for diabetes and many specific cancers. Overweight and obesity are also associated with higher risk for lumbar disc disease, hospitalization for low back pain (LBP), several types of osteoarthritis and pain.

Weight loss in patients with obesity could be an important issue. Further, patients reduced activity secondary to LSS is cited as an important factor for weight gain and inability to lose weight. Postoperative weight loss in obese individuals could reduce back pain and leg pain, improve function, and enhance HRQoL. However, weight loss after spine surgery may not positively correlate with better results.

Body Mass Index

In clinical practice and epidemiological research, BMI is a widely accepted proxy to classify underweight, normal weight, overweight and obesity in adults. Although BMI is an established measure of overweight and obesity in both a clinical and research setting, the measure has admittedly a major limitation because it cannot differentiate lean mass from adipose tissue. In addition, age, sex, self-reported weight and height might bias the estimates. Nevertheless, a BMI $\geq 30$ demonstrates high specificity and positive predictive value for excessive fat. Moreover, women do tend to increase their BMI by an increase in fat mass and not by higher lean mass.

Being a patient with lumbar spinal stenosis

From a patients perspective LSS can be experienced as a world of suffering and despair, with an impaired QoL comparable to stroke, heart-related diseases and diabetes. Illness-suffering that is due to pain, impaired function or from being on a waiting list for surgery is obvious, but also "caring suffering" and life-suffering may be important forms of suffering. Caring-suffering refers to suffering that is due to care, e.g. by patients experiencing feelings of not being believed or not being taken seriously. Life-suffering comprises experiences of a threatened life situation such as uncertainty of the world and loneliness.
Individuals attempt to manage suffering and demands created by one or several stressors, are often referred to as coping strategies. These efforts seek to manage, master, tolerate, reduce or minimize the demands of a stressful environment. Furthermore, Antonovsky's salutogenic model that includes but is not restricted to coping abilities, delineates the importance of general resources of resistance (GRRs) for dealing with stressors. Through strong GRRs, life stressors can be comprehensible, manageable and meaningful, all which produce a high SOC. This capacity is relatively stable over time, but increases with age. Depending on context, stressors and available GRRs, SOC can be dynamic, at least in the short term. A strong SOC is associated with life satisfaction, perceived health, mental health, high QoL, and also better function after surgery for LSS.68, 69, 103-106

Development of the salutogenic model

The Israeli-American medical sociologist Aaron Antonovsky first described his theory of salutogenesis in his book "Stress, Health and Coping" 1979, and further developed it in the work "Unraveling the mystery of health".103, 104 His theory originated from interviews with female survivors from the Holocaust. A subgroup of the interviewees showed good mental and physical health, despite their experiences of violence and traumatic events. He concluded that stress is a natural part of life and raised the question: How can we survive despite all chaos and stress? 107

With support from earlier research he developed, in contrast to disease (pathogenesis), a concept that focuses on health (salutogenesis). The theory has been developed to become an important tool both for quantitative and qualitative research.68, 105-113

Between 2005 and 2007 Lindström and Eriksson published several systematic reviews on the salutogenic model. The authors concluded that SOC was a valid measure and a health-promoting resource.68, 105, 106

Rationale for the studies

During recent decades, LSS has become the most common indication for spine surgery, a change that coincides with a higher prevalence of obesity. Thus, surgical treatment of LSS in the overweight and obese population is common and increasing in scope and number.

We hypothesized that an elevated BMI would decrease the success rate after surgery for LSS (study I) and increase the rate of clinical LSS through similar metabolic and biomechanical pathways (study III).

Because the results from previous studies on BMI as a predictor for outcome after LSS were inconsistent and because they included a limited number of patients as well as other limitations we performed study I.
The incidence rate in relation to BMI has not been amply described. Whether an increased BMI is a risk factor for the development of a clinical LSS was unknown. Therefore, we performed study III.

Furthermore, weight loss can be important in patients with obesity. Because of the limited evidence on weight change after surgery for LSS, and whether weight loss after spine surgery correlates with better results we performed study II. Finally, qualitative studies exclusively for patients with LSS who are waiting for surgery are scarce. Study IV describes the experience of being a person waiting for LSS surgery from a patient's perspective.
Aims

The overall aim of this thesis was to investigate whether BMI is related to the development of LSS or with outcome after surgery for LSS. A further aim was to examine weight change after surgery for LSS and if weight loss were associated with the reported outcomes. A final aim was to study whether there are specific experiences of LSS from a patient's perspective.

Specific aims

I To determine the association between BMI and outcome of lumbar spine surgery for spinal stenosis (study I).

II To determine the extent of weight change 1 and 2 years after surgery in obese LSS patients, as well as to define the proportion of obese patients who reported a clinically important weight loss (CIWL) and whether this change is related to improvement in PROMs 2 years after surgery (study II).

III To assess the relation between BMI and later development of clinically overt LSS (study III).

IV To describe the experience of being a person waiting for LSS surgery, and how everyday life and suffering are managed under the influence of the disease (study IV).
Patients and Methods

Data sources

Swespine (Study I and II)
The National Swedish Register for Spine Surgery (Swespine) is a prospective registry of patients who have undergone surgery for spinal disorders, including LSS. The definition of LSS in Swespine is based on the surgical record from the surgeon. More than 80% of the total number of surgical procedures for degenerative lumbar spine disorders in Sweden are included. The patients complete a preoperative questionnaire and postal follow-up questionnaires at 1, 2, 5 and 10 years after surgery. The surgeon records surgical data, including diagnosis, without having access to the patient questionnaires. Preoperative data completed by the patient include age, sex, smoking habits, consumption of analgesics (regular use, intermittent or no use), weight, height, back pain, leg pain, walking ability, duration of symptoms, the EQ-5D and the ODI. Walking ability is recorded as one of four categories (<100m, 100-500m, 500-1000m and >1000m). Back and leg pain are measured on a visual analog scale (VAS). Patient self-reported satisfaction with surgery is recorded as one of three categories: satisfied, uncertain and dissatisfied.

Bygghälsan cohort (Study III)
The Bygghälsan cohort consists of Swedish construction workers who participated in a nationwide occupational health surveillance program, that was initiated through a trade agreement between employers and unions. The workers were invited to participate in health examinations (participation rate was at least 80%). At inclusion, weight was measured with a scale and height with a stadiometer. The workers' job title (22 categories) and smoking habits were also registered. From 1971 the data were computerized. The examinations ended in early 1993 and the computerized register contains 389 132 persons. The proportion of females was 5%, of which 42% were office workers.
National Patient Register (Study III)
The National Patient Register (NPR) started in 1964, covered 83% of the Swedish population in 1972 and all inpatient care in Sweden since 1987. The completeness of ascertainment and the accuracy of diagnostic classification in the NPR are both high. The completeness for spinal diagnosis and surgical procedures in the NPR was on average 86% in 2001-2012.116 117

Body Mass Index
Weight and height were self-reported in study I, II and IV and measured in study III. BMI was calculated as bodyweight in kilograms (kg) divided by the square of height in meters (m). We used BMI both as a continuous and categorical variable.
Because self-reported BMI might bias the estimates, we performed a sensitivity analysis in study II using a correction algorithm described by Nyholm et al.118

Table 1. Body Mass Index (BMI) categories defined by the World Health Organization (WHO)

<table>
<thead>
<tr>
<th>BMI category</th>
<th>BMI range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.5</td>
</tr>
<tr>
<td>Normal weight</td>
<td>18.5-24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25-29.9</td>
</tr>
<tr>
<td>Obese Class 1</td>
<td>≥30-34.9</td>
</tr>
<tr>
<td>Obese Class 2</td>
<td>35-39.9</td>
</tr>
<tr>
<td>Obese Class 3</td>
<td>≥40</td>
</tr>
</tbody>
</table>

Outcome measures
EQ-5D, ODI and VAS (Study I and II)
The EQ-5D, ODI and VAS are PROMs with good validity, reliability and responsiveness for spine surgery. All three measures reflect how patients perceive their treatment.119-121

The EQ-5D is a generic instrument of HRQoL, that contains five dimensions of health: mobility, self-care, activities of daily life, pain and depression. Each dimension has three levels and the measure includes 243 different health states. Respondents' answers are transformed to a numeric score, (range -0.594-1): lower scores indicating inferior HRQoL.120

The ODI is a disease-specific functional score and HRQoL instrument that contains 10 items related to limitations in daily life activities (Pain Intensity, Personal Care, Lifting, Walking, Sitting, Standing, Sleeping, Sex...
Life, Social Life and Traveling). Each question has five points and the summary is transformed to percentage scored from 0 to 100; higher scores indicate more severe symptoms.\textsuperscript{120,121}

VAS consists of a 100 mm line, with 0 at one end indicating no pain at all and 100 at the other end indicating worst possible pain.\textsuperscript{119}

Self-reported walking ability and use of analgesics (Study I)

In study I, we used patients' self-reported walking ability (SRWA) and use of analgesics as outcome measures. Walking ability was dichotomized into "improved walking ability" or "not improved walking ability" (unchanged or impaired walking ability). Although there is a correlation between estimated and measured walking distance, overestimation is common and hence could lead to inaccurate estimates.\textsuperscript{122,123}

Self-reported use of analgesics was dichotomized into "use" (regular or intermittent use) or "no use".

Patient satisfaction with surgery (Study I)

In study I, patients' satisfaction with surgery at the 2-year follow-up was dichotomized into "satisfied" or "not satisfied" (uncertain and dissatisfied). This measure of satisfaction is associated with PROMs in Swespine.\textsuperscript{63} In contrast, the definition of satisfaction can differ between studies, not necessarily reflecting the treatment effect.\textsuperscript{124}

Weight change and clinically important weight loss, (Study II)

In study II, the weight change in kilograms 1 and 2 years after surgery was our main outcome measure. Further, we analyzed any associations between CIWL and outcomes. A weight loss of $\geq 10\%$ was considered a CIWL.\textsuperscript{125} The cohort was divided into three subclasses depending on weight change from time of inclusion to the 2-year follow-up: weight stable (9% weight reduction to 9% increased weight), weight loss ($\geq 10\%$ weight loss) and weight gain ($\geq 10\%$ weight gain). Additionally, weight loss is associated with improvements in EQ-5D, ODI and pain (VAS).\textsuperscript{92-95}

Definition of LSS and surgically treated LSS (Study III)

In study III, primary LSS diagnosis was defined by the ICD-9 codes 724, 724.0 or 724.00 and ICD-10 codes M48.0 or M48.0K. In addition, a sensitivity analysis was performed using as outcome a diagnosis of LSS combined with a surgical procedure of the lumbar spine.
Population

Study I and II

Data were obtained for all patients registered in Swespine who had undergone surgery for LSS between January 1, 2006 and June 30, 2008. Figure 2 is a flow diagram for inclusion in study I and II.

Table 2. Baseline characteristics of the patients in study I divided by categories of Body mass index. Continuous variables given as means with standard deviations (SD).

<table>
<thead>
<tr>
<th></th>
<th>Normal weight n=819</th>
<th>Overweight n=1208</th>
<th>Obese n=606</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex</td>
<td>63% (n=518)</td>
<td>52% (n=628)</td>
<td>58% (n=352)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>19% (n=152)</td>
<td>14% (n=169)</td>
<td>11% (n=69)</td>
</tr>
<tr>
<td>Previous surgery</td>
<td>17% (n=138)</td>
<td>17% (n=204)</td>
<td>17% (n=106)</td>
</tr>
<tr>
<td>Analgesics</td>
<td>51% (n=416)</td>
<td>51% (n=611)</td>
<td>54% (n=327)</td>
</tr>
<tr>
<td>Age</td>
<td>70 (9)</td>
<td>69 (8)</td>
<td>67 (8)</td>
</tr>
<tr>
<td>EQ-5D</td>
<td>0.38 (0.32)</td>
<td>0.39 (0.32)</td>
<td>0.34 (0.31)</td>
</tr>
<tr>
<td>ODI</td>
<td>42 (16)</td>
<td>43 (16)</td>
<td>46 (14)</td>
</tr>
<tr>
<td>Back pain (VAS)</td>
<td>52 (28)</td>
<td>52 (28)</td>
<td>57 (26)</td>
</tr>
<tr>
<td>Leg pain (VAS)</td>
<td>60 (26)</td>
<td>60 (26)</td>
<td>61 (26)</td>
</tr>
</tbody>
</table>

Table 3. Baseline characteristics of the patients in study II, divided by categories of weight change during follow-up. Continuous variables given as means with standard deviation (SD).

<table>
<thead>
<tr>
<th></th>
<th>Weight stable n=483</th>
<th>Weight loss n=45</th>
<th>Weight gain n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex</td>
<td>56%</td>
<td>64%</td>
<td>80%</td>
</tr>
<tr>
<td>Current smoker</td>
<td>11%</td>
<td>23%</td>
<td>0%</td>
</tr>
<tr>
<td>Age</td>
<td>66 (8)</td>
<td>66 (9)</td>
<td>63 (12)</td>
</tr>
<tr>
<td>EQ-5D</td>
<td>0.35 (0.31)</td>
<td>0.34 (0.32)</td>
<td>0.23 (0.32)</td>
</tr>
<tr>
<td>ODI</td>
<td>46 (15)</td>
<td>47 (13)</td>
<td>51 (10)</td>
</tr>
<tr>
<td>Back pain (VAS)</td>
<td>56 (27)</td>
<td>65 (19)</td>
<td>55 (30)</td>
</tr>
<tr>
<td>Leg pain (VAS)</td>
<td>61 (26)</td>
<td>62 (22)</td>
<td>46 (31)</td>
</tr>
</tbody>
</table>

Study III

389 132 constructions workers were registered from 1971 through 1992, while the observation period was from cohort entry until December 31, 2011, death, emigration or the occurrence of first diagnosis that was due to LSS, whichever occurred first. Figure 3 is a flow diagram for inclusion in study III.
Table 4. Characteristics of the study group at baseline divided by categories of body mass index.

<table>
<thead>
<tr>
<th></th>
<th>Underweight n=5795</th>
<th>Normal weight n=235,247</th>
<th>Overweight n=106,730</th>
<th>Obese n=16,695</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex</td>
<td>15% (n=846)</td>
<td>5% (n=12,888)</td>
<td>3% (n=3665)</td>
<td>7% (n=1147)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>46% (n=2654)</td>
<td>39% (n=90,924)</td>
<td>35% (n=37,810)</td>
<td>33% (n=5584)</td>
</tr>
<tr>
<td>Former smoker</td>
<td>7% (n=407)</td>
<td>13% (n=29,533)</td>
<td>19% (n=20,048)</td>
<td>20% (n=3270)</td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>25 (9)</td>
<td>31 (12)</td>
<td>39 (13)</td>
<td>42 (13)</td>
</tr>
</tbody>
</table>

Study IV

During the study period (October-December, 2013), 18 consecutive patients on the waiting list for LSS surgery at a Swedish county hospital were recruited into the study. All patients asked agreed to participate.

Our inclusion criterion were age ≥18 and good knowledge in the Swedish language. Patients with dementia were not eligible for the study. A few days after the patient were scheduled for surgery, a specific research nurse, not involved in the care of the patients, gave information about the study.

Table 5. Characteristics of the 18 interviewees at baseline.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese</td>
<td>n=6 (33%)</td>
</tr>
<tr>
<td>Overweight</td>
<td>n=6 (33%)</td>
</tr>
<tr>
<td>Female sex</td>
<td>n=11 (61%)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>n=2 (11%)</td>
</tr>
<tr>
<td>Age mean (SD)</td>
<td>66 years (11)</td>
</tr>
<tr>
<td>Employed</td>
<td>n=5 (28%)</td>
</tr>
<tr>
<td>Retired</td>
<td>n=8 (44%)</td>
</tr>
<tr>
<td>Disability pension</td>
<td>n=5 (28%)</td>
</tr>
<tr>
<td>Partnership</td>
<td>n=14 (78%)</td>
</tr>
<tr>
<td>One or several comorbidities*</td>
<td>n=15 (83%)</td>
</tr>
</tbody>
</table>

*One patient could have several comorbidities. Number of comorbidities at inclusion hypertension (n=11), heart disease (n=2), Lung disease (n=3), diabetes (n=7), depression (n=1), rheumatiod arthritis (n=1), muscle rheumatism (n=1), osteoporosis (n=1), prostatism (n=2), ulcerative colitis (n=1).
Statistical methods (Study I, II and III)

Proper choice of statistical methods is essential to achieve high internal and external validity. The choice not only depends on the research question, but also on the nature and distribution of the exposure and outcome.

Data, including a number of categories, are referred to as categorical data and further divided into nominal data (not ordered categories) and ordinal (ordered categories) data. Numerical values are defined as numerical data, divided into discrete and continuous data.\textsuperscript{126} p14
The Chi-squared test and Fisher’s test are commonly used to determine whether there are statistically significant differences between categorical data. The T-test or ANOVA, referred to as parametric tests are often used to test whether there are significant differences between numerical data. However, the validity of these tests are dependent upon certain assumptions, i.e. the variable in question should be normally distributed with an equal variance. However, if the sample size were reasonably large parametric tests are fairly robust to departures from the assumption of normality.

When the assumptions for parametric tests are not fulfilled non-parametric tests are a viable option. The non-parametric Kruskal-Wallis test is comparable with one-way ANOVA, and the non-parametric Mann-Whitney U-test with the Student's t-test.

Linear regression models can describe any linear effect of an independent variable (X) on a dependent variable (Y). The residuals should be normally distributed with constant variance. The influence of covariates can be considered by multivariable linear regression.

To use a mathematical model that best describes relation between one or several exposures and outcomes we used different regression models. The generalized linear model (GLM) can be expressed in the form.

\[ g(Y) = a + b_1x_1 + b_2x_2 + b_kx_k \]

\( g(Y) \) is called the link function and the dependent variable in simple and multiple regression. In logistic regression the link function is the \( \log_e \) of the odds and the \( \log_e \) of the rate in Poisson regression.

Model for logistic regression: \( \ln (\text{odds}) = a + b_1x_1 + b_2x_2 + b_kx_k \)

Model for Poisson regression: \( \ln (\text{rate}) = a + b_1x_1 + b_2x_2 + b_kx_k \)

To gain insight into potential nonlinearity, we modeled restricted cubic spline curves in study I and III. We used knots placed at recommended percentiles of 5 (21.3 kg/m\(^2\)), 35, 65 and 95 (34.4 kg/m\(^2\)).

Study I

For continuous outcome variables in study I, adjusted means for each BMI category were estimated using the procedure GLM in the SAS package system. For dichotomous dependent variables, multivariable logistic regression was applied to assess odds ratios (ORs) with 95% confidence intervals (CIs). The models were adjusted for age, sex, smoking, use of analgesics, previous back surgery, duration of symptoms and the baseline values of the variable.
under investigation. We modeled the nonlinear trend in the risk of dissatisfac-
tion by a restricted cubic-spline logistic regression analysis using knots placed at percentiles of 5 (21.3 kg/m²), 35, 65 and 95 (34.4 kg/m²), with 25.0 kg/m² as the reference.

Study II
In study II, paired t-tests were used to assess weight change 1 and 2 years post-surgery. Because of unequal group sizes and because of the non-normal distribution of our outcome variables (PROMs), Kruskal-Wallis tests were conducted. Post-hoc tests were performed with Mann-Whitney U-tests and a Bonferroni-adjusted significance level of 0.017 was calculated (α-level 0.05). Lehr's formula was applied to calculate a necessarily group size of 26-41 patients for a power of 80%, using a minimal detectable change of 0.2 in the EQ-5D, 10 in the ODI and 18 in the VAS.

Study III
Poisson regression models were used in study III to estimate age- and multi-variable adjusted incidence rate ratios (IRRs) with 95% CIs. The latter model included age (continuous), sex, smoking status (never, former, moderate current, heavy current, unknown) and occupation (22 categories). Non-linear trends of risk were displayed using restricted cubic spline curves estimated by a multivariable-adjusted Poisson regression model. We used knots placed at the 5th, 35th, 65th and 95th percentiles of the cumulative BMI distribution. The reference level was set to 20 kg/m². Finally, we performed stratified analysis by sex.

Qualitative methods (Study IV)
The qualitative inductive approach
Inductive analysis involves discovering categories, themes and patterns from a large amount of information. Inductive analysis involves discovering categories, themes and patterns from a large amount of information. With an inductive approach extensive raw material can be condensed into a summary, as well as establish relevant links between the study participants and the findings. The findings can further develop a model or theory. However, in this study we exam our data using the salutogenic model as a sensitizing concept instead of developing a new theory.
Interviews as method of data collection

The purpose of qualitative interviewing with open questions is to capture the interviewees' experiences and perceptions. The individual interviews with open questions provide a framework for the patients in study IV to describe their experiences in their own words from an individual perspective. The individual face-to-face interviews started with structured questions on socio-demographic and medical information. This phase was followed by open-ended questions designed to stimulate a dialogue on the topic under study. An interview checklist was used to compromise broad domains i.e. care, patient perspective on experiences and feelings from LSS and expectations before surgery. Interviews were digitally recorded and later transcribed verbatim. The interviews lasted from 60-90 minutes and were conducted by the first author (BK).

Content analysis

The interview transcripts were analyzed by content analysis, an approach that aims to capture the core of the interviews and explore differences and similarities in the transcribed text. All interview transcripts were read by all authors, with first impressions were discussed and documented. The next step was to condense (shorten but still preserving the core concepts) the transcripts into meaningful units, further aggregated (interpretation on a higher logical level) into codes. These codes were aggregated into categories, which further created themes.

Theoretical framework

To explain the patterns in the data we need a framework. Several descriptions of coping mechanisms, GRRs and description of the patients own resources were found in the interviews. Therefore, the study is framed within the context of Antonovsky's salutogenic theory. Hence, we chose to present our interpretation of the categories and themes using the salutogenic model as a sensitizing concept.

Ethics

Ethical approval was obtained for all parts of this thesis. In study IV patients gave informed consent and were granted confidentiality. The interviewer (BK) was also the forthcoming surgeon. Serving in both roles could be considered an ethical problem, but all patients were on the waiting list for surgery and therefore the interview could not affect the planned surgery or follow-up. Finally, patients were informed that they
could terminate their participation in the study at any time without consequences. None of the other authors participated in the care of the patients.

To be included in a register or an interview study could arouse dormant negative experiences. In addition, patients might agree to participate because of perceptions that their choice may affect their treatment.

Furthermore, the results from study I, II and III could also be stigmatizing for patients with excess weight.
Summary of findings in comparison with other studies

Study I

Of the 2633 patients included in the analysis 819 (31%) had normal weight, 1208 (46%) were overweight and 606 (23%) were obese. The adjusted means with 95% CIs are reported in Table 6. For obese patients, the ODI and the EQ-5D indicated a lower HRQoL at baseline and at the 2-year follow-up. When differences in baseline were adjusted, the obese patients still showed inferior results after surgery compared with the normal weight patients. Differences between the normal weight and overweight groups were modest. Moreover, the obese patients reported more back and leg pain compared to the normal weight group.

We found that 39% of the obese (p<0.0001), 31% of the overweight (p=0.002), and 26% of the normal weight patients (reference group) were still using analgesics 2 years after surgery. No correlation was found between BMI and improvement in walking ability: 50% of the normal weight, 53% of the overweight and 48% of the obese patients had improved walking ability 2 years after surgery.

On average, 67% of the normal weight, 64% of the overweight, and 57% of the obese patients were satisfied with the surgical results. Furthermore, in the obese patients, we observed higher odds of dissatisfaction with higher BMI (Figure 4). In comparison with the normal weight patients, the average adjusted OR for dissatisfaction in the obese group was 1.73 (95% CI, 1.36–2.19).

Table 6. Adjusted means with 95% confidence intervals at the 2-year follow up. Models adjusted for age, smoking, earlier back surgery, duration of back pain, use of analgesics and baseline differences for the variable studied.

<table>
<thead>
<tr>
<th>Variable</th>
<th>BMI&lt;25 kg/m²</th>
<th>BMI 25-29.9 kg/m²</th>
<th>BMI≥30 kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ-5D</td>
<td>0.64 (0.62-0.66)</td>
<td>0.63 (0.61-0.65)</td>
<td>0.56 (0.54-0.59)</td>
</tr>
<tr>
<td>ODI</td>
<td>25 (23-26)</td>
<td>27 (26-28)</td>
<td>33 (31-34)</td>
</tr>
<tr>
<td>Back pain (VAS)</td>
<td>31 (29-33)</td>
<td>33 (31-34)</td>
<td>39 (37-42)</td>
</tr>
<tr>
<td>Leg pain (VAS)</td>
<td>31 (29-33)</td>
<td>32 (30-34)</td>
<td>40 (37-43)</td>
</tr>
</tbody>
</table>
Figure 4. The association between body mass index (BMI) and adjusted odds ratio for dissatisfaction displayed as a restricted cubic-spline curve based on multivariable logistic regression analysis. A BMI of 25 kg/m² was used as the reference. The dashed lines represent a 95% confidence interval.

Most of the patients regardless of the BMI group were satisfied with the treatment though obesity was a negative predictor of patient satisfaction. Differences between normal and overweight individuals were small and could not be regarded as clinically important.

Our results contrast with those reported in a systematic review on preoperative and postoperative outcomes in LSS. From this material, 21 studies were included in the analysis. Only one examined the relation between outcomes after surgical treatment: no differences in outcome were found between obese and non-obese patients. The number of patients (n=170), the definition of obesity, and the outcome measures differ from our study, making that study and our difficult to compare.

Antiviraham et al. found an association between BMI and worse outcome after surgery. The analysis included 89 patients and analyzed 16 covariates including BMI. The outcome measure differed from our study and details about the BMI data were not given.

The findings from a recent Norwegian register study are similar to our results. Giannadakis et al. evaluated the association between obesity (BMI≥30) and outcomes 1 year after surgery for LSS. The patients with a BMI≥30 (n=353) reported poorer outcomes (ODI, back pain, leg pain) compared with patients with a BMI<30 (n=1120).

In contrast, two recent analyses based on the Spine Patient Outcomes Research Trial (SPORT) reported similar results for obese (BMI≥30) and non-obese (BMI<30) patients, with equal or even greater treatment effects among
patients with a BMI $\geq 30$, which was largely due to poor outcome in the conservative treatment arm.$^{133, 134}$ Patients with degenerative spondylolisthesis were analyzed separately. Only 19% (118/634) reported a BMI $<$ 25, and the study was not powered for subgroup analysis according to BMI. The "as-treated" analysis was due to a great crossover between the treatment arms, which also introduces a risk for selection bias.

Several studies have used a small number of patients with LSS, making it difficult to draw any conclusions or to make comparisons with our study.$^{77-79}$ We believe our study is the first to use BMI as a continuous variable and demonstrates an increasingly higher odds of dissatisfaction with higher BMI values.

**Obesity as a plausible cause of unsatisfactory results after LSS surgery**

Mechanical, structural, metabolic and behavioral changes have previously been discussed.$^{87}$ Obesity, especially central obesity, contributes to several metabolic disorders. For instance, obesity is correlated to neuropathic disorders in both diabetic and nondiabetic individuals.$^{87, 135}$ Miscio et al demonstrated that even nondiabetic obese individuals could develop impairment in the function of sensory fibers. This impairment is linked to hyperinsulinemia and insulin sensitivity.$^{135}$ Central obesity is associated with diabetes and atherosclerosis. Increased blood cholesterol is associated with the development of atherosclerosis, where atherosclerosis of the abdominal aorta and lumbar arteries can lead to disc degeneration and LBP.$^{136}$ Leino-Arjas et al found baseline serum lipids to be associated with LBP and sciatica,$^{137, 138}$ and Hangai et al described an association between increased low-density lipoprotein (LDL) and disc degeneration.$^{139}$

Toda et al observed a correlation between body composition and LBP in women aged 45 to 69 years. In their study, 203 patients had LBP and the control group consisted of 127 participants. The two groups were matched for age, height, and weight. An increased percentage of body fat and increased waist to hip ratio were correlated with LBP.$^{140}$ Vismara et al noted differences in thoracic spinal mobility and anterior pelvic tilt between obese and normal weight individuals. These mechanical and structural differences in obese individuals could contribute to the development of LBP and disc degeneration.$^{141}$ Obesity can also be associated with socioeconomic factors and lifestyle choices that may affect surgical results.$^{87}$
Study II

Of the 538 patients included in the analysis in study II, the mean weight at baseline was 94.6 kg (SD, 11.9) and the average weight loss was 1.9 kg (95% CI, 1.5-2.3) 1 year after surgery and 2.0 kg (95% CI, 1.5-2.4) 2-years after surgery. Eight percent of the patients who completed the follow-up reported a CIWL (n=45). Table 7 presents the mean improvement in PROMs at the 2-year follow-up. We found no significant differences in EQ-5D, ODI, back pain (VAS) or leg pain (VAS) between weight-stable and weight-loss patients. Ten patients reported a weight gain after surgery. These patients reported lower numerical improvements in EQ-5D, ODI, back pain and leg pain compared to weight-stable patients. However, except for leg pain the differences between the weight-loss and weight-stable patients were not statistically significant.

Table 7. Mean improvement (standard deviation, SD) in patient-reported outcome measures (PROMs) between inclusion and the 2-year follow up. The Mann-Whitney U test was used with the weight-stable group as reference (ref). A Bonferroni-adjusted significance level of 0.017 was calculated ($\alpha$ level, 0.05).

<table>
<thead>
<tr>
<th>Means (SD)</th>
<th>Weight stable N=483</th>
<th>Weight loss N=45</th>
<th>Weight gain N=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ-5D</td>
<td>0.23 (0.35)</td>
<td>0.22 (0.36)</td>
<td>0.08 (0.36)</td>
</tr>
<tr>
<td>p=0.802</td>
<td>p=0.217</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ODI</td>
<td>15 (19)</td>
<td>14 (18)</td>
<td>8 (15)</td>
</tr>
<tr>
<td>p=0.644</td>
<td>p=0.248</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back pain (VAS)</td>
<td>27 (29)</td>
<td>18 (33)</td>
<td>-6 (40)</td>
</tr>
<tr>
<td>p=0.095</td>
<td>p=0.113</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg pain (VAS)</td>
<td>31 (36)</td>
<td>23 (26)</td>
<td>-14 (34)</td>
</tr>
<tr>
<td>p=0.147</td>
<td>p=0.011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To our knowledge, this is the largest patient group used to study weight and weight changes after surgery for LSS. It is also the first large prospective study to analyze associations between improvement in PROMs and weight loss after surgery for LSS.

Our results are in contrast to those of Garcia et al. who found a 2.48 kg mean weight gain after surgery for LSS in overweight and obese patients. That study included 63 patients with a mean age of 53 years (range 35 to 65). In another study Vaidya et al found a minor weight gain among 58 obese and morbidly obese patients after spine surgery (mean age 53 years). Both of these retrospective studies included younger patients than ours, which might affect the generalizability to older patients. The follow-up period was 14-37 months in Vaidya et al. and 24-51 months in Garcia et al.

The majority of patients in our study reported no change in weight, even in those with improved functional outcome after surgery. Weight loss after surgery was not associated with a significant greater improvement in EQ-5D, ODI, back pain or leg pain. We consider our results consistent with those of
Garcia et al who found no correlation between weight loss and the outcome results, even though we used different outcome measures than Garcia et al.91

**Sensitivity analysis**

Using the same cut-off level for obesity and correcting for age, sex and self-reported BMI, the number of obese patients increased (n=726), but the proportion of patients with reported CIWL did not change (8%). Further, the reported weight changes 1 and 2 years after surgery were not significantly different from the weight changes reported based on unadjusted data (data not shown). Using corrected BMI data, the weight-loss group reported a mean improvement in leg pain of 36 (SD, 37), which can be compared with a mean of 22 (SD, 36) in the weight-stable group (p=0.008). Weight loss was not associated with better improvement in EQ-5D, ODI or back pain when compared with weight-stable patients.

**Study III**

Two-thirds (65%, n=235 247) of the participants had normal weight, 29% (n=106 730) were overweight, 5% (n=16 695) were obese and 2% (n=5795) were underweight. A vast majority of the construction workers were men (95%, n=345 921). The average age at baseline was 34 years (SD, 13). As expected, there was a positive association between age and BMI.

During an average follow-up of 30.7 years (11 190 944 person-years), 2381 participants were diagnosed with LSS. More than half of these cases were overweight or obese at baseline. We observed an almost linear positive association between BMI and LSS (Figure 5). Assuming a linear relation, the incidence of LSS showed an increase of 10% (95% CI, 9%-11%) per BMI unit, i.e. the lowest rates of LSS were found in lean workers and the highest rates in obese workers.

Accordingly, the IRRs of LSS varied across BMI categories, with the highest values seen in obese individuals (Table 8). Compared with normal weight, obesity was associated with a multivariable-adjusted IRR of 2.18 (95% CI, 1.87-2.53) for LSS and overweight with an IRR of 1.68 (95% CI, 1.54-1.83). Underweight workers halved their future risk of LSS (IRR 0.52, 95% CI 0.30-0.90).

As expected, the number of outcomes were lower (n=1816) in patients diagnosed with LSS and who underwent surgery. Nevertheless, when we used surgically treated LSS as an outcome the results remained comparable with the original analysis (Table 9). Restricted cubic spline curves stratified by sex indicated a higher IRR with increasing BMI, irrespective of sex (Figure 6).

The findings are consistent with those from a cross-sectional subgroup analysis of the Framingham cohort in which an association between osteoar-
rthritis of the lumbar spine and a tendency for radiological LSS associated with increased BMI were shown. The analysis included 187 participants, of whom 13 had radiological findings of LSS.

Another recent cross-sectional study (n=938), in which 78% of the participants were considered to have more than moderate radiographic central spinal stenosis found a positive association between radiological LSS and BMI in men.17

Obesity as a plausible cause for LSS
An increase in body mass leads to an abnormal and altered load on the spine. Particularly noteworthy is that obese individuals have, in addition, a lower relative muscle mass than normal weight individuals, which further imposes strain on the lumbar spine.89, 143, 144 Furthermore, besides a direct biomechanical effect on cartilage and skeleton, indirect effects by changes in body mass can be mediated by mechanoreceptors, cytokines and growth factors. These factors have the potential to alter the properties of bone matrix, ligamentum flavum, synovium and cartilage, all of which could promote the development of osteoarthritis, hypertrophy of the ligamentum flavum and disc degeneration.23, 25, 26, 86, 145-147

Decreased muscle mass is also associated with insulin resistance, which further weakens the skeletal muscles and promotes systemic inflammation.143, 148 Adiponectin and leptin, hormones secreted by adipocytes, regulate low-grade inflammation caused by obesity and an increase in the levels of CRP, interleukins and tumor necrosis factors is related to the progression of spondylosis.89, 147, 149, 150 In addition, a high serum concentration of free fatty acids is known to increase systemic inflammation and the development of osteoarthritis.148, 151, 152 Moreover, hyperlipidemia-induced atherosclerosis is proposed as a cause of disc degeneration and ischemic pain.137, 138 Finally, obesity is related to reduced walking capacity and fear of movement (kinesiophobia), events known to also increase muscle loss and pain.153, 154
Figure 5. The association between body mass index (BMI) and Incidence rate ratios (IRRs) of lumbar spinal stenosis displayed as a restricted cubic-spline curve based on multivariable Poisson regression analysis. A BMI of 20 kg/m² was used as the reference. The dashed lines represent a 95% confidence interval. The model was adjusted for age (continuous), sex, occupation (22 categories) and smoking status (5 categories).

Figure 6. Restricted cubic spline curves stratified by sex indicated a higher incidence rate ratio (IRR) with increasing body mass index (BMI), irrespective of sex displayed as a restricted cubic-spline curve based on multivariable Poisson regression analysis. A BMI of 20 kg/m² was used as the reference. The dashed lines represent a 95% confidence interval. The model was adjusted for age (continuous), occupation (22 categories) and smoking status (5 categories).
Table 8. Incidence rate ratios (IRRs) with 95% confidence intervals (CIs) for lumbar spinal stenosis from Poisson regression models by categories of body mass index (BMI).

<table>
<thead>
<tr>
<th>BMI category</th>
<th>Underweight &lt;18.5</th>
<th>Normal weight 18.5-24.9</th>
<th>Overweight 25-29.9</th>
<th>Obese ≥30</th>
<th>Per one BMI unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%) total 364,467</td>
<td>5,795 (1.6)</td>
<td>235,247 (64.6)</td>
<td>106,730 (29.3)</td>
<td>16,695 (4.6)</td>
<td></td>
</tr>
<tr>
<td>N cases total 2381</td>
<td>13</td>
<td>1144</td>
<td>1019</td>
<td>205</td>
<td></td>
</tr>
<tr>
<td>Person-years total 11,190,944</td>
<td>184,530</td>
<td>7,363,115</td>
<td>3,181,583</td>
<td>461,716</td>
<td></td>
</tr>
<tr>
<td>Crude rate (n/10 000 person-years; 95% CI)</td>
<td>0.7 (0.4-1.2)</td>
<td>1.6 (1.5-1.7)</td>
<td>3.2 (3.0-3.4)</td>
<td>4.4 (3.9-5.1)</td>
<td></td>
</tr>
<tr>
<td>IRR, age-adjusted model (95% CI)</td>
<td>0.55 (0.32-0.94)</td>
<td>1.00 (reference)</td>
<td>1.67 (1.53-1.82)</td>
<td>2.18 (1.87-2.54)</td>
<td>1.10 (1.09-1.11)</td>
</tr>
<tr>
<td>IRR, multivariable model* (95% CI)</td>
<td>0.52 (0.30-0.90)</td>
<td>1.00 (reference)</td>
<td>1.68 (1.54-1.83)</td>
<td>2.18 (1.87-2.53)</td>
<td>1.10 (1.09-1.11)</td>
</tr>
</tbody>
</table>

*Adjusted for age (continuous), sex, occupation (22 categories) and smoking status (5 categories)
Table 9. **Incidence rate ratios (IRRs) with 95% confidence intervals (CIs) for surgically treated lumbar spinal stenosis from Poisson regression models by categories of body mass index (BMI).**

<table>
<thead>
<tr>
<th>BMI category</th>
<th>Underweight &lt;18.5</th>
<th>Normal weight 18.5-24.9</th>
<th>Overweight 25-29.9</th>
<th>Obese ≥30</th>
<th>Per one BMI unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>N cases, total 1816</td>
<td>10</td>
<td>855</td>
<td>793</td>
<td>158</td>
<td></td>
</tr>
<tr>
<td>Crude rate (n/10 000 person-years; 95% CI)</td>
<td>0.8 (0.4-1.4)</td>
<td>1.7 (1.6-1.8)</td>
<td>3.8 (3.6-4.1)</td>
<td>5.2 (4.5-6.1)</td>
<td></td>
</tr>
<tr>
<td>IRR, age-adjusted model (95% CI)</td>
<td>0.59 (0.31-1.10)</td>
<td>1.00 (reference)</td>
<td>1.69 (1.53-1.87)</td>
<td>2.23 (1.88-2.65)</td>
<td>1.10 (1.09-1.12)</td>
</tr>
<tr>
<td>IRR, multivariable model* (95% CI)</td>
<td>0.56 (0.30-1.04)</td>
<td>1.00 (reference)</td>
<td>1.71 (1.55-1.89)</td>
<td>2.23 (1.87-2.65)</td>
<td>1.10 (1.09-1.12)</td>
</tr>
</tbody>
</table>

*Adjusted for age (continuous), sex, occupation (22 categories) and smoking status (5 categories)
Study IV

The themes identified in the content analysis are summarized in Table 10. A content validation with an external experienced qualitative researcher was performed to support the inductive category and theme application.131

Table 10. Themes identified in the content analysis

<table>
<thead>
<tr>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiencing an impaired physical, social and emotional life</td>
</tr>
<tr>
<td>A good physician-patient relationship can alleviate the burden of long</td>
</tr>
<tr>
<td>waiting times</td>
</tr>
<tr>
<td>Struggling for being believed and taken seriously</td>
</tr>
<tr>
<td>Ways to manage pain and disability</td>
</tr>
<tr>
<td>Ambiguous expectations and hope for recovery</td>
</tr>
<tr>
<td>Ways to handle concerns before surgery</td>
</tr>
</tbody>
</table>

The six themes are summarized below. Full text and quotes are presented in paper IV.

**Experiencing an impaired physical, social and emotional life**

The pre-symptomatic experience of patients provided a context for their current suffering. Patients described having had an active physical life before the LSS became severe. The pain and limited function were also associated with sleeping disturbances. In the interviews the participants expressed profound feelings of shame in situations when they had problems with body functioning. The undesired sedentary lifestyle could also be perceived as a factor for weight gain and the inability to lose weight because of impaired function and walking ability.

The interviewees described isolation and how it affected relationships with family and friends. Because of LSS symptoms partnerships were described as being altered (e.g., using separate bedrooms and restrictive sexual activity).

**A good physician-patient relationship can alleviate the burden of long waiting times**

The patients' situation of dependence and vulnerability in the relationship with the physician and long waiting times was a concern in many interviews. A good physician-patient relationship was perceived as a resource that could alleviate the negative experience of being on a waiting list. In contrast, misinformation and appointments with different unknown physicians increased unpleasant effects of long waiting periods.

**Struggling for being believed and taken seriously**

Some patients described struggling with the healthcare system and feelings of not being believed. Moreover some patients even felt discriminated
against because of their age, weight or former alcohol abuse. Continuity in
care and personal information and dialogue with the surgeon were depicted
as particularly important. The patients felt that the MRI was very important
for confirmation that their suffering and pain were real as a means to being
properly diagnosed. A diagnosis also excluded other more serious conditions
such as cancer.

**Ways to manage pain and disability**
The patients described several ways to manage the disease. One strategy was
to make comparisons between themselves and someone else they knew who
had worse problems. Another way of handling the situation was to focus on
things that were experienced as positive. Several patients described their
ability to use their own resources in the sense of a “fighting spirit”. Further-
more, physical activities, performing duties for other people or animals, stay-
ing at work and visiting church were expressed as important events that
helped them manage to carry on with life.

**Ambiguous expectations and hope for recovery**
Concrete and common expectation were improved leg function and reduced
leg pain. However, expectations could also be more generic, i.e. some pa-
tients described a combination of modest expectations and expectations of
full recovery after surgery.

**Ways to handle concerns before surgery**
Some patients expressed fear of complications such as infection, anesthesia
awareness or to be confined to a wheelchair after surgery. In contrast, sever-
al patients describe no worries at all related to their approaching surgery.
Because of severe suffering, some patients surgery was described as the
only viable option. Furthermore, earlier positive experiences from the
healthcare and reports from friends successfully operated on for LSS served
as important resources to reduce the stress and worry before surgery.

The results from study IV are interpreted from the salutogenic framework,
with focus on resources and strengths on different levels: on a legislative
level the Swedish healthcare system is equitable and patient-centered care is
statutory. According to Antonovsky these are important community re-
sources to achieve a high SOC.103 Furthermore, on a community level, mu-
nicipalities can provide an individual who suffers from a disability, with
community companions, walking aids, home adaptations and other disability
tools to make life more convenient and efficient. On the personal level, so-
cial support from family and friends is important and although Sweden is a
secular society, church was seen as important for social interaction. In addi-
tion, other people's experiences of surgery and health care could ease patient
concerns before the surgical procedure. Although only a few of the inter-
viewees were still working, staying employed has been seen as a way to cope with chronic LBP and sciatica.\textsuperscript{155}

Similar to earlier studies, our results stress a good physician-patient relationship based on patient-centered care, including continuity, proper treatment, investigations, examination and information/dialogue, all of which produce more satisfied patients.\textsuperscript{156-160} In agreement with previous studies, an established diagnosis and a known cause for the pain are important for the patient to understand and accept the symptoms. In contrast, delegitimization (feelings of not being believed or denied) is associated with dissatisfaction and thereby caring-suffering.\textsuperscript{100, 101, 160-162} A diagnosis is also important to exclude severe spine pathology especially in the elderly who have a high frequency of comorbidities. Furthermore, information is an important and complex issue. Timely and knowledge-based information should be provided from the treating physician and operating surgeon to enhance comprehensibility and trust.\textsuperscript{103, 160}

Expectations of recovery from surgery may be seen as the strongest source for the interviewees' to experience life-satisfaction and meaningfulness in everyday life. Even if improved leg function and decreased leg pain were common goals, some of the expectations were similar to how life used to be perhaps 5-10 years earlier, or how life is for healthy individuals of a comparable age. Living with LSS is a physical, mental and social challenge where resources to cope with the condition may be more important than a full recovery.\textsuperscript{160, 163}
General Discussion

Treatment and prevention of LSS are a major challenge on a personal level, for healthcare system and society. On average, two thirds of the patients are satisfied with the outcome after surgery for LSS, with lower rates of satisfaction in obese compared with normal weight patients. To my knowledge, study I was the first to use BMI as a continuous variable. The study demonstrates increasingly higher odds of dissatisfaction with higher BMI values. Furthermore, a trend towards greater surgery increases both costs and surgically related complications without achieving better results, especially in obese patients.

The indication for LSS surgery is seldom immediate and the LSS symptoms are often unchanged or improved over time and severe deterioration is rare. Consequently, we could consider other treatment options than surgery, especially in patients with unsatisfactory results after surgical treatment. However, patients with obesity should not be denied surgery for LSS. In study I, obese patients achieved significant pain reduction, better walking ability and improved HRQoL after surgery. For a person with severe symptoms from spinal stenosis, surgery is perhaps the best option because of the limited effect of conservative treatment.

In study II, we found that even after successful surgery patients with excess weight did not achieve a clinically important weight reduction on their own accord. If weight loss is considered important, it should be carefully monitored by health professionals with focus on physical activity and diet to help prevent muscle catabolism and impaired health. Furthermore, weight loss after surgery was not associated with significant greater improvement in EQ-5D, ODI, back pain or leg pain.

Similar to obesity, prevention is perhaps the best treatment for LSS. Consequently identification of risk factors associated with the disease is important. Study III was the first cohort study on the relation between BMI and clinical LSS. Our major finding was that higher BMI increased the risk of clinical LSS.

We suggest that future studies attempt to identify causality for this association, which has the potential to enhance the prevention for LSS.

Finally, many studies have relied on the pathogenetic paradigm, i.e. medical-disease model. At the center of the disease model is a dichotomous classification of individuals as diseased or healthy. The salutogenic patient-centered approach described briefly in study IV, is a model that guides
health promotion by shifting attention towards the individual's resources and strengths.168

Choice of study design

Although estimates from RCT’s are often considered as evidence of the highest grade, the results from many observational and RCT studies are similar.169, 170 Two recent studies on LSS and surgical treatment reported comparable findings between a RCT and a cohort study on Swespine data.35, 51 We consider a cohort observational study as the most appropriate design to answer our research questions in study I, II and III. Nevertheless, the cohort study design has limitations and there is the risk of systematic error.

The choice of a qualitative content analysis in study IV aimed to capture the experience of being a person with LSS and how life, pain and suffering are managed with respect to the disease. The collection of experiences may create a deeper understanding for patients with LSS. Furthermore, the presentation of the context and findings enables alternative interpretations. However, whether the findings can be applied to other settings is ultimately the reader's decision.

Limitations and strengths of the studies

Study I and II

The major strengths of study I and II are the prospective design and large sample size. The data were collected by patient self-reports from postal questionnaires unrelated to hospital visits or contact with a surgeon. Further, the registration rate in Swespine is high.114 A possible limitation is patient self-reported weight and height.118, 171

Another limitation is the response rate, i.e. only 57% and 67% of the patients in study I and II, respectively, fulfilled the 2-year follow-up. However, in study I the response rate was similar for the three BMI groups and in study II no differences occurred in baseline characteristics between the responders and non-responders. Furthermore, the response rate does not necessarily affect the generalization of the results.172 A study on a Scandinavian register for lumbar surgery found no significant differences, including functional outcomes, between responders and non-responders at a 2-year follow-up.173

In study II, we lack information on the cause of weight loss, which can bias the results between weight change and outcomes. Weight change in an older population is associated with severe comorbidities and mortality that could affect the estimates.174
Study III

The main strengths of study III are the prospective design, the large sample size and the high validity of both exposure and outcome. Weight and height were measured at inclusion in the study. Date of diagnosis, date of surgery, occurrence of death and emigration data were collected through national registers known to have high accuracy. Complete linkage between the registers is rendered by the individual personal identification number provided to all Swedish residents. Furthermore, the sensitivity analysis, using only cases with codes for diagnosis connected to a surgical procedure, revealed similar results as the original analysis. The population included both blue- and white-collar workers and the models were adjusted for type of occupation.

Several potential limitations of the study need to be discussed. Although BMI is an established measure of overweight and obesity in both a clinical and research setting, the measure has admittedly a major limitation in its inability to differentiate lean mass from fat mass.

A further conceivable limitation is that weight and height were assessed only once and we had, on average, a rather long follow-up. Further research may elucidate whether time-varying BMI predicts LSS differently from fixed measures. However, obesity as estimated by BMI in mid-life is a predictor for health in later life.

Another possible limitation is the predominance of male participants, but the increased risk of LSS with higher BMI levels was observed in both males and females.

Study IV

The primary strength of study IV are the defined context and method of sampling. All eligible patients, representing various life experiences, accepted the offer to participate. BK served not only as the interviewer but also as the forthcoming surgeon. This dual role could have resulted in observer bias and is therefore a limitation of the study. Still, to minimize this potential bias, the interviews were analyzed by all authors and the results from the content analysis were validated by an external observer. Furthermore, the quotations translated by an external assistant who had Bachelor of education degrees in both Swedish and English increase the credibility.

Although SOC is a validated quantitative measure and has been applied as a theoretical framework for qualitative research, the concept has some limitations: the direction of the causality between SOC and health is uncertain, and SOC could be a measure of physical and mental health instead of a predictor of health; and little is known about whether interventions to increase SOC on a personal and community level have any long-term effects.
A social, mental and physical stressor such as living with LSS may be handled differently by men and women. Because the majority of the patients in the present study were females, our results could have been affected by the skewed distribution of participants.

The precision of an estimate
Variance or standard deviation (SD) is often used to describe the variability of the observations used to calculate the arithmetic mean. 

Variance: \( s^2 = \frac{\sum (x_i - \bar{x})^2}{n-1} \)

Standard deviation: \( s = \sqrt{s^2} \)

Furthermore, the precision of an estimate can be described with a standard error, often incorporated into an interval estimate (CI).

Standard error of the mean, SEM = \( s/\sqrt{n} \)

Sample mean with 95% CI, mean ± \( t_{0.05} \times SEM \)

A narrow CI indicates a precise estimate, and as shown above the width of the CI is strongly dependent on the sample size. Consequently, a mean from a large population is in general a more precise estimate than an estimate from a small population.

Random and systematic errors
The opposite of precision is random error. Rothman defines random error as "variability in the data we cannot readily explain". A random error could also be defined as sampling variability. Random error can be minimized through increased sample size, improved sampling procedures, reduction of measurement variability and proper choice of statistical methods.

Although large populations can reduce random errors, systematic errors also known as bias, could remain. Systematic error/bias could be defined as the difference between the estimate and the true value. Bias can be classified into three main categories: selection bias, information bias and confounding.

Selection bias
The population included in a register is not randomized, and patients who select to participate in a register, can differ from non-participants. Selection bias occurs when the association between exposure and outcome differs be-
tween participants and non-participants. Selection bias could have been introduced into study I if the association between obesity and inferior outcomes was different between participants and non-participants. The association between obesity and outcomes after LSS in non-participants is unknown and must therefore be inferred.¹⁷⁸ p 96-98

Information bias
Information about the exposure and outcome collected in a register can be misclassified leading to information bias. For example, an obese person can be classified as overweight because of erroneous weight data, which could result in a misclassification in the exposure. Another example is the classification of LSS in Swespine and the NPR. As we know it the diagnosis LSS has not been validated either in Swespine or in NPR. However, the website for Swedish Society of Spine Surgeons recommends a radiological criterion of a $\text{CSA} \leq 75 \text{ mm}^2$ together with typical LSS symptoms for diagnosis.¹⁹ Furthermore, the diagnosis, indications for surgery and predictors for surgery are discussed on a regular basis at annual meetings. These regular discussions may serve to increase the validity of the diagnosis of LSS in the registers, but does not exclude erroneous registration.

Confounding
A confounder could be defined as a factor that is mixing the effects. A confounder must be a cause or proxy for the disease and associated with the exposure. Furthermore, a confounder must be imbalanced between the exposure groups.¹⁷⁸ p 108 An example is increased BMI as a risk factor for LSS. BMI is a proxy for biomechanical and metabolic causal mediators, and also associated with increased age. Age is a proxy for the disease and a cause for LSS regardless of BMI category. Finally, age is not a mediator between BMI and LSS. Therefore, age could be considered a confounder.¹²⁸ s¹²⁹-¹³⁴ Common methods to deal with confounding is to identify covariates and adjust for them by stratification or in a regression model. However, recent studies have shown that these criteria are insufficient and thus questioned the traditional approach to confounding. A process, referred to as directed acyclic graphs (DAGs), is a novel model to achieve unbiased estimates.¹⁷⁹, ¹⁸⁰

Differential and non-differential misclassification
Misclassification can be divided into differential and non-differential. Differential misclassification occurs if there were an association between the misclassification in the exposure and outcome. For example, an association between a misclassified BMI category and outcome after surgery. However, we consider this potential misclassification in our cohort studies as non-
differential, which in general makes the effect estimates converge towards one another.

Generalization

Generalization of our findings in study I and III, should be regarded as an elaboration of the theory that an increased BMI through causal pathways is a cause for LSS, as well as a cause for inferior results after surgery for LSS. The biologic theory is based on earlier animal experiments and research on humans.

Statistical representativeness is considered by many authors as a criterion for external validity and generalization of the findings from a study. However, generalization is a complex process. Thus it is important to bring knowledge from several branches of science, rather than consider generalization as a statistical process. Furthermore, opposite to survey sampling, statistical representativeness is not necessarily a major concern and should perhaps even be avoided.

Animal studies are often based on a strictly selected population of rats, rabbits or some other animal that rather increase the possibilities for biologic representativeness. Although these strictly selected populations are not statistically representative of a general population of humans, they help us to understand human diseases. Another parallel can be drawn to smoking as a cause of premature death, which was first established in male British physicians, which is a highly selected subgroup of the population.

Trustworthiness

Although there are similarities between qualitative and quantitative research, the concepts and methods used to achieve trustworthiness differ between qualitative and quantitative analysis. Preconception, reflexivity, credibility and transferability are important concepts to achieve trustworthiness in qualitative studies. Some examples from study IV are given in relation to each concept.

Preconceptions

Preconceptions could be summarized as the researcher's back pack. Previous personal and professional experiences and prestudy beliefs may affect how researchers judge and interpret information and the course of action they take. Several preconceptions in study IV need to be discussed. The interviews and surgery was performed by the same person (BK). Therefore, the patients are placed in a position of dependence that may affect how they
express themselves. This thesis focuses on obesity and overweight and the present author (BK) thought that weight loss should be a common expectation among patients with obesity. Furthermore, BK's preoperative belief about this patient group in general was positive and these patients are often perceived as modest and grateful. BK is a 44-year-old male Caucasian with a high level of education, which may affect the interview and how the information is interpreted.

Reflexivity
Reflexivity involves a process of deeper reflection that should be addressed to increase the trustworthiness. A researcher's interaction with participants is a subjective process. To accept the subjective nature of qualitative research is not enough, however. How the researcher, participants and findings are presented for the reader is important to avoid bias. Our main reflections were not to "force" the patients into the study, and we sought how to decrease dependency and create a more neutral environment.

BK as a single interviewer would be a conceivable limitation. Should we include several interviewers? One purpose of this study was to educate and develop BK as a qualitative researcher. In addition, the preoperative interview could also raise questions about the treatment. Therefore the research team agreed on using BK as the sole interviewer.

Our interpretation of the findings reflect our preconceptions which include models for suffering, coping and the salutogenic model. How should we make this transparent for the reader?

Credibility
Credibility summarizes the context, method of data collection and selection of patients. Credibility also includes the selection of the most meaningful units and whether the categories and themes actually cover the data. To increase credibility, representative quotations, were translated by an external assistant who had a Bachelor of education degrees in both Swedish and English. Furthermore, a specific research nurse gave information about the study once the patients were on the waiting list for surgery and therefore guaranteed that the interview could not affect the planned surgery or follow-up. The interviews were performed at the patient hostel as this provides a more neutral environment than the orthopedic reception or ward. The interviewer (BK) was dressed in casual clothing rather than the traditional white coat.

Credibility was further increased by seeking agreement on the categories and themes among co-researches and an external expert. We used the salutogenic model as a sensitizing concept, which creates a possibility for alternative interpretations.
Transferability

Although findings from a qualitative study cannot be generalized, the experiences and needs described in this study are not necessarily restricted to a specific context, hospital or country. Transferability reflects whether the findings can be applied to other settings. Even if the author gives suggestions about transferability, it is the reader's choice and interpretation whether the findings are transferable to another setting or population.
Conclusions

1. Obesity is associated with inferior PROMs (ODI, EQ-5D, back pain and leg pain) and a higher rate of dissatisfaction compared with normal weight patients 2 years after surgery for LSS.

2. Weight reduction 1 and 2 years after surgery is modest in obese patients, with only 8% reporting a CIWL. In comparison with weight-stable patients, weight loss in obese patients after surgery for LSS is not associated with greater improvement in PROMs: ODI, EQ-5D, back pain and leg pain.

3. Obesity and overweight are associated with an increased risk to develop LSS. Our findings indicate that obesity is one plausible explanation for the increased number of patients with clinical LSS.

4. Being a patient with LSS inevitably involves a certain amount of pain and suffering. Yet, the patient with LSS is also a person with his or her own resources who is able to find strategies to cope with the suffering, of the disease or who has support structures for doing so. Both physicians and patients need to work towards a salutogenic perspective, focusing on resources to improve care, making it more comprehensible, manageable and meaningful.

Clinical implications

Our studies expand the knowledge about excess weight and LSS. This increased knowledge is potentially important for patients, physicians and health care providers.

The results from this thesis:
- Provide patients, physicians and health care providers accurate information about different outcomes after surgery that are related to BMI.
- Show that the weight change in general is modest, even after successful surgery.
• Inform citizens, patients, physicians and health care providers that high BMI could be a risk factor for the development of clinical LSS, even if future studies are important to confirm our finding.
• Increase not only the knowledge and understanding about being a patient with LSS but also suggest a shift towards delineating what resources and strengths are needed to cope with the disease.

Future perspectives
A major limitation in studies on LSS is that the definition of LSS differ from one study to another. Thus a national and international agreement on a clear and unambiguous definition of LSS is warranted. A definition of LSS could also be implemented in registers on spine surgery to increase internal validity. An international consensus on outcomes for LBP has been attained through the International Consortium for Health Outcomes Measures, (ICHOM).\textsuperscript{184} With a similar national and international definition, covariates and outcome measures, results from different studies can be more readily compared.

This thesis has emphasized several aspects of obesity and LLS. Future studies could focus on the following questions.

  Can a weight loss program improve the symptoms and results after surgery for LSS in obese persons?
  Can a weight loss program reduce the progression of LSS?
  Can the causality between obesity and LSS be further described through studies on leptin concentration in humans and/or Mendelian randomization studies?\textsuperscript{185}
  Can a salutogenic in- and outpatient routine increase the patients' satisfaction with care, as well as improve the outcome after surgery?
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Svensk sammanfattning

Lumbal spinal stenos (LSS) är den vanligaste indikationen för ländryggskirurgi i Sverige, med en ökad förekomst både nationellt och internationellt. Denna ökning är multifaktoriell, om övervikt är en riskfaktor för att utveckla LSS är inte tidigare känt.

LSS är en förträngning av spinalkanalen i ländryggen orsakad av ben och mjukdelsförändringar. Symptomen debuterar ofta i 50-60 års ålder. Typiska symtom är förutom ryggsmärta en läges- och belastningskorrelerad bensmärta, s.k. pseudoclaudicatio.

Även om majoriteten av de patienter som opereras för spinal stenos blir nöjda, är en alltför stor del av patienterna missnöjda. Att identifiera faktorer som påverkar resultatet efter en operation är därför viktigt. Hos patienter med högt BMI, kan det finnas en förväntan att operationen ska bidra till en viktnedgång genom en förhöjd fysisk prestationsförmåga efter operationen.

Patienternas perspektiv är viktigt. Tidigare studier har beskrivit upplevelser och erfarenheter av rygg och bensmärta, men ett fåtal har inkluderat specifikt patienter med LSS.

**Studie I:** En kohortstudie där 2633 patienter från svenska ryggregistret inkluderades. Det patientrapporterade resultatet (livskvalitet, funktion, smärtar, patientnöjdhet) 2 år efter operation var sämre hos patienter med BMI ≥30 (fetma) jämfört med BMI <25 (normalvikt).

**Studie II:** Från samma kohort som studie I inkluderades 538 patienter med BMI ≥30. Under uppföljningstiden på två år reducerade patienterna sin medelvikt med 2 kg, och enbart åtta procent (45/538) rapporterade en kliniskt relevant viktreduktion. Vi fann ingen korrelation mellan viktreduktion och operationsresultat.

**Studie III:** Genom samkörning med det nationella Patientregistret och Bygghälsan som inkluderar 389 132 personer, fann vi att övervikt och fetma är en riskfaktor för att utveckla LSS.

**Studie IV:** Individuella intervjuer med 18 patienter. Analysen utmynnade i sex stycken teman, som beskrev patienternas lidande, men också resurser och styrkor för att klara av sina besvär.
Avhandlingens resultat kan bidra till:

- Utifrån resultaten i studie I, kan vi ge patienter och vårdgivare bättre information om det förväntade operationsresultatet korrelerat till BMI.
- Informera om att kroppsvikten vanligen förändras marginellt efter en operation. Om målet är en substantiell bestående viktreduction krävs troligen, vilket andra visat, ett aktivt deltagande i viktreduceringsprogram. Interventionsstudier med målet att reducera vikten efter kirurgi för LSS bör dock först göras för att påvisa effektiviteten av ett sådant viktreduktionsprogram för just denna patientgrupp.
- Informera patienter och vårdgivare att ett ökat BMI kan vara en riskfaktor för att utveckla en operationskrävande spinal stenos, även om våra resultat behöver bekräftas av ytterligare studier.
- Öka kunskapen om upplevelsen av att vara patient med spinal stenos, och hur man kan klara av sina besvär. Även om resultaten som redovisas i den kvalitativa studien inte är generaliserbara så tar den upp flera viktiga aspekter av att vara patient med spinal stenos och vikten av att fokusera på sjukvårdens värdegrund och patientens resurser/styrkor. Huruvida sådana interventioner kan förbättra patienternas upplevelse av vården och resultatet efter ryggkirurgi, får framtida studier visa.
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A doctoral dissertation from the Faculty of Medicine, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine. (Prior to January, 2005, the series was published under the title “Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine”.)