MAARIT PAKARINEN

This thesis aims to clarify the relationship between life satisfaction, depressive symptoms and sense of coherence and outcomes of lumbar spinal stenosis surgery in a long-term follow-up. The results show that even slightly more psychological distress is associated with less benefit from surgery. This study demonstrated that psychological factors are closely connected to the surgical outcome, even ten years postoperatively, indicating a long and prevailing relationship that cannot be overlooked.
Psychological factors in postoperative recovery from lumbar spinal stenosis surgery
MAARIT PAKARINEN

Psychological factors in postoperative recovery from lumbar spinal stenosis surgery

A long-term follow-up

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ABSTRACT

Ways to improve the results of surgery for lumbar spinal stenosis (LSS) have been sought, and they include the development of surgical techniques and more accurate selection of surgery candidates. The results of surgery have been found to be related to factors such as age, comorbidity and the body mass index. According to the modern biopsychosocial model of health, psychological, physical and social aspects are all involved in health and sickness. Thus, it is important to also examine the psychososocial factors that might influence the outcomes of LSS surgery.

Few studies have focused on the psychosocial factors. In addition to preoperative predictors, the postsurgical recovery period is also important, especially in relation to the long-term outcome. There have been very few studies on the predictive value of postoperative psychological factors, and none have examined psychological factors with an extensive follow-up time.

The purpose of this study was to determine whether life satisfaction, depressive symptoms and sense of coherence are related to the outcomes of LSS surgery. Both preoperative and postoperative psychological factors were examined in relation to the long-term outcomes. The study also investigated the role of cumulative long-term symptoms.

The study population consisted of 102 patients with LSS who underwent decompression surgery. The follow-up times were 5 and 10 years postoperatively. The patients completed questionnaires preoperatively and at several follow-up points after the surgery. The studied psychological factors included life satisfaction, depressive symptoms and sense of coherence. Other study variables were disability, pain, walking distance and satisfaction with surgery.

Life satisfaction, depressive symptoms and sense of coherence were found to be related to the surgery outcome in the long-term follow-up. The same result was seen in cross-sectional and regression analyses. Long-term life dissatisfaction was related to more disability in the five-year follow-up and also to pain in the ten-year follow-up. Long-term depressive symptoms were related to more disability, and low sense of coherence to more disability and greater pain in the five-year follow-up.

According to this study, psychological factors evaluated pre- and postoperatively are associated with the outcomes of LSS surgery in the long term. Another especially
important finding is the association of milder, subclinical symptoms with poorer surgical outcomes.

National Library of Medicine Classification: WE 750, WE 727, WO 100, WM 101, WB 176, WA 900
Medical Subject Headings: Lumbar Vertebrae/surgery; Spinal Stenosis; Decompression, Surgical; Treatment Outcome; Postoperative Period; Personal Satisfaction; Sense of Coherence; Resilience, Psychological; Quality of Life/psychology; Depression; Pain; Surveys and Questionnaires; Follow-Up Studies
Lannerankakanavan ahtaumataudin (lumbar spinal stenosis = LSS) leikkaushoidon tuloksellisuuteen on pyritty parantamaan mm. leikkaustekniikoita ja potilasvalintaa kehittämällä. Tuloksellisuuteen ovat yhteydessä mm. potilaan ikä, oheissairastavuus ja painoindeksi. Biopsykososiaalisen terveyskäsityksen mukaan terveydessä ja sairastamisessa ovat mukana sekä fyysiset, että sosiaaliset tekijät. On siis tärkeää selvittää myös psykososialisten tekijöiden vaikutusta tuloksellisuuteen.

Psykososialisia tekijöitä on tutkittu vähän. Ennen leikkausta arvioitavien ennustekijöiden lisäksi myös leikkaukseen jälkeen kuntoutumisaikaa on tärkeä pitkän ajan ennusteen kannalta. Tutkimuksia leikkaukseen jälkeisen ajan psykologisten tekijöiden vaikutuksista on hyvin vähän, ja pitkä seuratutkimuksia niiden vaikutuksista ei ole toistaiseksi tehty.

Tämän tutkimuksen tarkoituksena oli selvittää elämäntyytyväisyyden, masennusoireiden ja koherenssin tunteen yhteyttä LSS:n leikkaushoidon tuloksellisuuteen. Tutkimuksessa arvioitiin sekä leikkausta edeltävien että sen jälkeen arvioitujen psykologisten tekijöiden vaikutuksia pitkän ajan ennusteeneseen. Tutkimuksessa selvitettiin myös kumulaatiivisen, pidempiäikaisen psykologisen oireilun merkitystä leikkaukseen tuloksellisuuteen.


Elämäntyytyväisyyys, masennusoireilu ja koherenssin tunne olivat yhteydessä leikkaukseen tuloksellisuuteen pitkäaikaisseurannassa. Sama tulos saatiin sekä poikkileikkausasetelmassa, että regressiomalleissa. Pitkäaikainen tyytymättömyys elämään oli viiden vuoden seurannassa yhteydessä huonompaan toimintakykyyn ja kymmenen vuoden seurannassa myös voimakkampaan kipuun. Pitkäaikainen masennusoireilu oli yhteydessä huonompaan toimintakykyyn ja matala koherenssin tunne huonompaan toimintakykyyn ja voimakkampaan kipuun viiden vuoden seurannassa.

Tämän tutkimuksen tulosten perusteella leikkausta edeltävällä ja sen jälkeisellä psykologisilla tekijöillä on merkitystä LSS:n leikkaushoidon tuloksellisuudessa pitkäaikaisseurannassa. Erityisen tärkeä uusi löydös oli myös lievempien, subkliinisten oireiden yhteys huonompaan leikkaustulokseen.
Luokitus: WE 750, WE 727, WO 100, WM 101, WB 176, WA 900
Yleinen suomalainen asiasanasto: lanneranka; ahtaumat; leikkaushoito; tuloksellisuus; kuntoutuminen; pitkäaikaisvaikutukset; psykologiset tekijät; resilienssi; elämänhallinta; elämänlaatu; masennus; kipu; seurantatutkimus; kyselytutkimus
This study was carried out at the Department of Psychiatry, University of Eastern Finland and Kuopio University Hospital. The study originally started as a part of the “ENNUSTENOOSI” project of the Department of Rehabilitation and Physical Medicine. The collaboration between the departments has been extensive throughout the project and I am grateful to all the participants.

I especially want to thank my supervisors. Professor Heimo Viinamäki, as the principal supervisor, has always given clear and speedy advice on any questions I might have had and truly introduced me to scientific research. With Docent Sanna Sinikallio, the discussions on questions relating to the concepts of health psychology have been especially inspirational. Docent Olavi Airaksinen has been most supportive in particular with respect to the more physical aspects of the study.

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I am also thankful to my colleagues and staff members at my current workplace, the Department of Psychiatry, University of Eastern Finland and Kuopio University Hospital. The combination of teaching, research and clinical work has been most inspiring, and having smart, empathetic and supportive coworkers has helped to make this combination even more enjoyable.

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Kuopio, November 2016
Maarit Pakarinen
List of the original publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:


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## Abbreviations

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<tr>
<td>ADHD</td>
<td>Attention Deficit Hyperactivity Disorder</td>
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<td>ANOVA</td>
<td>Analysis of Variance</td>
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<td>BDI</td>
<td>Beck Depression Inventory</td>
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<tr>
<td>BDNF</td>
<td>Brain-derived neurotrophic factor</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
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<tr>
<td>CNS</td>
<td>Central Nervous System</td>
</tr>
<tr>
<td>CRH</td>
<td>Corticotropin-releasing hormone</td>
</tr>
<tr>
<td>DEPS</td>
<td>Depressioeula (a Finnish depression test)</td>
</tr>
<tr>
<td>DSM</td>
<td>Diagnostic and Statistical Manual of Mental Disorders</td>
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<tr>
<td>ECT</td>
<td>Electroconvulsive Therapy</td>
</tr>
<tr>
<td>GABA</td>
<td>Gamma Amino Butyric Acid</td>
</tr>
<tr>
<td>HAM-D</td>
<td>Hamilton Depression Rating Scale</td>
</tr>
<tr>
<td>HPA</td>
<td>Hypothalamic-Pituitary-Adrenal</td>
</tr>
<tr>
<td>HPT</td>
<td>Hypothalamic-Pituitary-Thyroid</td>
</tr>
<tr>
<td>IQR</td>
<td>Interquartile Range</td>
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<tr>
<td>ICD</td>
<td>International Classification of Diseases</td>
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<tr>
<td>ICF</td>
<td>International Classification of Functioning, Disability and Health</td>
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<tr>
<td>LBP</td>
<td>Low Back Pain</td>
</tr>
<tr>
<td>LS</td>
<td>Life Satisfaction</td>
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<tr>
<td>LSS</td>
<td>Lumbar Spinal Stenosis</td>
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<tr>
<td>MADRS</td>
<td>Montgomery-Åsberg Depression Rating Scale</td>
</tr>
<tr>
<td>MAO</td>
<td>Monoamine oxidase</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetre</td>
</tr>
<tr>
<td>MMPI</td>
<td>Minnesota Multiphasic Personality Inventory</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<tr>
<td>n</td>
<td>Number</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>NA (or na)</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>NICE</td>
<td>National Institute for Clinical Excellence</td>
</tr>
<tr>
<td>ns</td>
<td>Nonsignificant</td>
</tr>
<tr>
<td>ODI</td>
<td>Oswestry Disability Index</td>
</tr>
<tr>
<td>PEI</td>
<td>Physical Exercise Intervention</td>
</tr>
<tr>
<td>RCT</td>
<td>Randomized Controlled Trial</td>
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<tr>
<td>RDoC</td>
<td>Research Domain Criteria</td>
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<tr>
<td>SE</td>
<td>Standard Error</td>
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<tr>
<td>SD</td>
<td>Standard Deviation</td>
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<tr>
<td>SNRI</td>
<td>Serotonin-norepinephrine Reuptake Inhibitor</td>
</tr>
<tr>
<td>SOC</td>
<td>Sense of Coherence</td>
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<tr>
<td>SSRI</td>
<td>Selective Serotonin Reuptake Inhibitor</td>
</tr>
<tr>
<td>TMS</td>
<td>Transcranial Magnetic Stimulation</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analogue Scale</td>
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<td>WHO</td>
<td>World Health Organization</td>
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1 Introduction

It is well known that good mental health is important for an individual’s somatic health (1). One of the main dimensions of good mental health is subjective well-being, i.e. experiences of life satisfaction and happiness. Good mental health can also be conceptualized as maturity, emotional or social intelligence and successful adaptation (2). Poor mental health is often described in terms of psychological symptoms, e.g. depression or anxiety. People with mental health problems have more somatic illnesses (3) than those with better mental health, and those with better mental health are healthier in general (1). In addition, somatic conditions can be risk factors for mental health problems (1). Thus, it is important to investigate the associations between mental health, different psychological factors and different somatic conditions in order to find new and more individual ways to improve overall health.

Low back pain is a common problem among the general population (4,5), and back pain is the leading cause of years lived with disability worldwide (6). Lumbar spinal stenosis (LSS) is one of the main underlying conditions of back pain, especially among the elderly population (7). Surgery is recommended for LSS if conservative treatment fails (8). However, the outcome of surgical treatment also varies considerably, although it might be improved by optimizing patient selection, surgical techniques and post-operative care (9). The clinical predictors for a poorer surgical outcome have been sought, but mainly with somatic indicators, while mental health has received less attention (10,11). However, the role of mental health in rehabilitation and the surgical outcome might be crucial.

Previously, indicators of decreased mental health, such as depression, anxiety and poor coping (12), have been reported to modulate the outcome of surgery among patients with lumbar problems. In LSS, this especially appears to be the case with depressive symptoms (13-15), which according to a recent review are thought to be a prognostic factor for disability and LSS-related symptoms, while the prognostic value for pain and walking
ability is less clear (13). In addition, dissatisfaction with life (16) and a low sense of coherence (17) are associated with poorer results, although the number of studies is limited. The follow-up times of all these studies have been short.

Studies on the effectiveness of postoperative rehabilitation of LSS are still scarce. Physiotherapy is often recommended as a treatment option for LSS (18), although its efficacy has been questioned. In studies by Mannion et al. (11) and Aalto et al. (19) no significant differences in pain or disability were found between groups receiving different types of postoperative treatment. Nevertheless, postoperative rehabilitation in LSS has proven to be effective according to a recent meta-analysis (20) including three previous studies. This rehabilitation was found to be effective in relation to low back and leg pain, as well as functional status, but not general health in a recent Cochrane review (21).

Taking psychosocial aspects in consideration in postoperative rehabilitation may improve the outcome of spinal surgery, as has already been seen in some studies (22,23). The evaluation of psychological factors preoperatively has already been recommended (12,13). In addition, rehabilitation always requires the active participation of an individual, which requires good psychological resources. Thus, information on the different psychological factors that predict surgical outcomes is needed in order to identify the patient groups that might need psychosocial support pre- and/or postoperatively in order to improve their outcomes.

The present study provides new information on the associations between several psychological factors and the outcome of LSS surgery. Psychological factors and their effects are evaluated preoperatively and postoperatively with a long follow-up time. The specific emphasis is on the postoperative period, positive modulators and the effects of various cumulative symptoms.
2 Psychological factors in health and sickness

The following sections discuss the concepts of well-being and health, and more specifically the psychological factors that are covered in the articles this study is based on, i.e. depressive symptoms, life satisfaction and sense of coherence. In addition, the dynamic biopsychosocial model of health, as well as the possible mechanisms explaining the continuous and complex interaction between psychological and biological health are discussed.

2.1 Psychological well-being and health

2.1.1 Well-being and mental health

Several descriptions and theories on good mental health and psychological well-being exist, but there is no one clear definition of either. Psychological well-being has been described as having dimensions of evaluative well-being (i.e. life satisfaction), hedonic well-being (i.e. feelings of happiness, sadness, stress etc.) and eudemonic well-being (sense of purpose and well-being) (24). Most often, studies have only focused on one of these aspects of well-being, but well-being in general has been found to be related, for example, to lower mortality, even when adjusting for mental and physical illnesses (24).

WHO has defined mental health as “a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community” (25), with a clear focus on the positive dimension of mental health. Another description of
mental health includes emotional, social and psychological well-being, and the idea of mental health being on a continuum rather than having clear limits (26).

Good mental health has also been conceptualized as maturity, emotional or social intelligence and successful adaptation, i.e. a mental state that is desirable and above the average (2). It is well known that good mental health is important for an individual’s somatic health, as the lack of it increases disability and mortality worldwide (1). Nevertheless, mental health research has mainly focused on mental illnesses and their negatives effects, instead of investigating how to promote good mental health and how it might affect health (27,28).

2.1.2 Poor mental health

Poor mental health is often described in terms of psychological symptoms, e.g. depression or anxiety, although the boundary between mental health and mental illness is not clear (29). In the current medical field, poor mental health is linked to the diagnosis of mental health problems with the ICD and DSM, both of which are examples of categorical systems (30,31) with an emphasis on symptoms and their level of intensity and duration. Dimensional evaluations (e.g. Research Domain Criteria, RDoC), which in addition to symptoms also take into account, for example, genetics, brain circuits and biological markers, are also being developed as another means to perform diagnostic evaluations (32,33).

According to the recent WHO Global Burden of Diseases study, mental health problems account for over 20% for years lived with disability globally, and the level of mental health problems has increased by 45% since 1990 (34).

People diagnosed with mental health problems have more somatic illnesses than those with better mental health (1,3). Mental health problems are associated with excess all-
cause mortality risk (35-38) and disability (39,40). Several somatic diseases are associated with mental health problems, including coronary heart diseases (41,42), hypertension (43,44), diabetes (45,46) and even some communicable diseases (47). On the other hand, somatic diseases can also be risk factors for mental health problems (1). Conditions that are known to directly affect the brain (e.g. cortical stroke, certain infections and neurodelepmental disorders) can cause different symptoms varying from behavioural disturbances and mood disorders to hallucinations and delusions. In addition, chronic conditions particularly increase the psychological burden which may lead to mental health problems. (1) All in all, the relationship between physical and mental health is not only bidirectional, but more complex and interactive.

2.1.3 Salutogenesis

The concept of salutogenesis (salus = health; genesis = birth/creation) is the opposite of pathogenesis (pathos = illness/sickness), and was first introduced and later developed and studied by Antonovsky (48-51). It enables health and sickness to be considered from another perspective: in addition to how to prevent diseases and how to better cope with illnesses when they have developed, it focuses on how to generate health. Antonovsky noticed that those who were optimistic, who thought that life was meaningful and who were able to use their resources survived better after concentration camp experiences (52). Sense of coherence is directly related to the concept of salutogenesis, and is discussed more in detail later. Other concepts that are directly related to salutogenesis have also been developed in order to find out more about the possible health-promoting factors of individuals and communities (53). These salutogenic factors include resilience (54), self-efficacy (55,56), learned optimism (57) and connectedness (58).

As the medical field mainly focuses on the detection and treatment of diseases, there is little information on factors that enhance and promote health, although research on this
topic is attracting increasing interest (59). With respect to mental health, the concept of positive psychiatry was introduced over a century ago (60), but research on this topic has only been a recent phenomenon. Nevertheless, several positive characteristics, such as resilience, optimism and social engagement, have been associated with positive outcomes, e.g. recovery from illnesses, posttraumatic growth and successful psychosocial aging. The assessment of positive characteristics and use of interventions to enhance them has been recommended. (60)

Promoting health, instead of only focusing on treating or preventing illness, means improving the possibilities for anyone to take care of their own well-being (61). According to an extensive review of studies, salutogenesis was found to be important for the well-being of an individual (62).

**2.2 DEPRESSION AND SUBCLINICAL DEPRESSIVE SYMPTOMS**

**2.2.1 Definition and clinical picture of depression**

Depression in the medical context is defined as a mental health problem that presents with different symptoms. According to ICD-10, at least two of the following have to be present: depressed mood, loss of interest and feelings of pleasure. In addition to these, at least four other symptoms have to be present, e.g. difficulties in concentrating, changes in eating and/or sleeping patterns, decreased self-esteem and suicidal thoughts (30). To be diagnosed with depression, the symptoms have to last for at least two weeks and be unexplained by other conditions. The DSM-5 criteria for depression differ only slightly from those of the ICD-10 (30,31).

Depression is a heterogenic condition with varying symptoms, severity, aetiology and outcomes. The severity can vary from mild to severe depression. With increasing severity, the number of symptoms increases and functional abilities decrease; in addition, some
patients may suffer from psychotic symptoms. Depression is sometimes also categorized into different types. For example, in the ICD-10, a single episode and recurrent depression have their own codes. One commonly used distinction is based on different symptoms: depression can be seen as typical/melancholic or atypical depression. Typical/melancholic depression is associated, for example, with more anhedonia, fatigue, loss of appetite and insomnia, whereas atypical depression is associated with symptoms such as more hypersomnia, increased appetite and a more reactive mood. (63) The symptoms can also be categorised as affective, cognitive and vegetative/somatic, which might be helpful when diagnosing depression amongst the somatically ill, in particular (64).

Other possible symptoms of depression include somatic symptoms, such as gastrointestinal complaints, psychomotor slowing or pain. The prevalence of pain amongst the depressed is higher than among the general population, and it is associated with a lower level of education, other somatic symptoms and anxious features of depression (65). The heterogeneity of depression is also related to high comorbidity rates with other health conditions, some with overlapping clinical pictures (e.g. anxiety and personality disorders) (63). In addition, depression may differ in men and women, so that atypical and anxious features are more common in women (66) and alcohol and drug abuse (67) and decreased libido in men (68).

2.2.2 Epidemiology of depression

Depression is one of the most common mental health problems (40,69), and the prevalence in women is roughly twice as high as in men. In addition to actual differences in prevalence, this may also be due, for instance, to differences in reporting and treatment-seeking, as well as differences in symptomology (66). The 12-month prevalence of depression in the World Health Surveys was 3.2% without a comorbid physical condition, and ranged from 9.3% to 23.0% with different somatic conditions (70). In the more recent
World Mental Health Survey Initiative Study, the 12-month prevalence of depression was even higher, being 5.5% in high-income and 5.9% in low-income countries (71). In a recent Global Burden of Disease study, the 12-month prevalence was 3.7% (69). In the Finnish population, the 12-month prevalence of depression in the Health 2000 study was 6.5% (72). In a new 11-year follow-up, the 12-month prevalence of depression was 7.4% (73).

Lifetime prevalence has been reported to be 16.6% in retrospective studies (74). More recently, lifetime prevalence was reported to be 14.6% (71). However, the figures could in reality be even twice as high, if studies are prospectively designed (75). In the 1990s, WHO ranked depression as the fourth leading cause of disability in the world (76,77) and suggested that it would become the second leading cause by 2020 (78). This prediction was more optimistic than the reality: in the most recent WHO statistics, depression is either the leading or the second leading cause for years with disability in most countries, and the second leading cause globally (6).

### 2.2.3 Diagnosis and screening of depression

The diagnosis of depression is always based on a thorough clinical evaluation of the patient. Nevertheless, some of the symptoms can in addition be evaluated using different scales that are most often based on the patient’s self-evaluation. These scales are also helpful when monitoring possible changes in mood. The Beck Depression Inventory (BDI) is one of the most often used scales, and is used for both the screening of depression and evaluation of symptom severity (79). Other possible screening tools include Depressioseula (DEPS) (80,81), the Montgomery-Åsberg Depression Rating Scale (MADRS) (82) and the Hamilton Depression Rating Scale (HAM-D) (83). Of these, DEPS has especially been developed for the general practitioner for screening. The latter two are based on a clinician’s interview and require more time and effort to use. Of these, HAM-D
gives more weight to somatic symptoms, while MADRS focuses more on the cognitive features of depression (64).

The BDI has high internal consistency and validity in differentiating between depressed and non-depressed individuals (84), and it is useful in detecting depression among the general population (85) and in psychiatric and non-psychiatric subjects (86). The reliability is good and it can be used to interpret the severity of depression as well as monitor the change in mood during treatment (87). All the screening tools for depression, including the BDI, may be influenced by physical conditions, as the symptoms may be overlapping (88,89). This may be especially true for patients with chronic pain (90-92), amongst whom the BDI may give information on cognitive, affective or behavioural distress, rather than clinical depression (92). Nevertheless, the BDI has been used in several studies that have investigated depression or depressive symptoms in patients with LSS (13). The BDI is now one of the recommended tools for screening depression in spinal pain patients due to its high sensitivity and specificity and easy administration in clinical practice (93). The BDI is also acceptable and easy to use for both patients and clinicians, and is in wide clinical use, which allows for direct clinical comparisons.

Screening for depression in the somatically ill is emphasized in the British guidelines (94,95), and recommended for all adults in the guidelines in the United States (96). The effectiveness of screening is nevertheless still under debate (97-100), and the recommendations in different countries vary. In the Finnish Current Care Guidelines screening is recommended when treatment and consultation with a psychiatrist is possible, especially if, for example, the patient has previously been depressed, is pregnant or has long-term somatic illnesses (101). The screening scales do not necessarily increase the rate of recognition of depression (97), and the diagnosis of depression should never only be based on use of scales.

The recognition of depression in primary health care is poor, and only about half of those
with depression are recognized worldwide, although in some countries the rate of recognition is even lower (102,103). Patients often present with somatic symptoms and do not recognize the symptoms of depression or consider them to be part of their present (somatic) illness, which may make the recognition of mental disorders even more difficult (104,105).

2.2.4 Depression and comorbidity

Depression is linked to several psychiatric comorbidities, most often anxiety, personality disorder or substance abuse disorder. Roughly 50% of depressed patients have an anxiety disorder and almost 50% also have a personality disorder. Substance abuse disorders are a more common comorbidity among men, while anxiety disorders are more common among women. Other psychiatric disorders are also common, some with symptoms close to those of depression. (63,101) As the focus of this study was on psychosomatic issues, the comorbidity between depression and somatic illnesses is discussed more in detail in the following.

Depression is also common among the somatically ill (70). Within the somatically ill patient group, depression appears to reduce the quality of life (106), increase morbidity and mortality (107) and amplify physical symptoms (108).

Some studies have shown that depression can also be seen as a risk factor for several somatic illnesses, including cardiovascular diseases (109), stroke (110), Alzheimer’s disease (111), coronary heart disease and myocardial infarction (41,42,112) and diabetes (113-115).

Depression and depressive symptoms are also associated with poorer adherence to treatment (116,117), which might lead to devastating results in some conditions (118). In addition, depression is associated with excess mortality (35,119-121), and this excess mortality has been seen, for example, in coronary heart disease (112,122), cancer (123,124) and diabetes (125-127).
Pain and depression also often co-exist and are important comorbidities in the clinical context. Studies have shown that each of them can be precursors of the other: pain can predict the onset of depression and depression can increase pain (128-130). The relationship between pain and mood is nevertheless thought to be more than bidirectional, and several models describing their interaction have been proposed (131).

2.2.5 Aetiology of depression

The aetiology of depression is multifactorial: psychological, social and biological factors play a role (132-136). There is genetic predisposition (137), which supposedly leads to depression in interaction with environmental factors (138-140). Psychosocial factors (which can also include gene–environment interactions) that increase the risk of depression mostly comprise adverse childhood events (e.g. physical or sexual abuse), other lifetime trauma, low social support, marital problems and divorce (133,138).

Studies among the general population have shown rates of heritability to be roughly 30 - 40% (137). There are no known specific genes for depression; rather, it is thought that several genes are involved, and some of them are also associated with other internalizing problems (e.g. anxiety, neuroticism) (63). The genes studied have been linked, for example, to the serotonergic system, HPA axis and BDNF (135).

The monoamines are thought to be involved in depression, especially serotonin (63), but also dopamine and noradrenaline. Pharmacological treatments have mainly been developed to act on the monoaminergic systems. Other neurotransmitters have also been studied, including glutamate and GABA. (133)

In animal models, BDNF also seems to be involved in stress-induced states. An increase in BDNF induced by antidepressants is proposed to increase neurogenesis and neuroplasticity. (133,135,141)
Hormonal changes in depression involve CRH and the HPA axis, and the HPT axis might also be involved. The CRH level is increased by stress in animal models, and most depressive patients have higher levels of CRH than healthy subjects. Serum cortisol is also increased in depression, especially in psychotic depression, although not in atypical depression. (141,142)

Inflammatory markers are thought to be another possible mechanism in the pathophysiology of depression. Stress increases cytokine levels, and these could also affect the CNS. (141,143-146)

Some anatomical changes in the CNS of depressed patients have been reported. The lateral ventricles might be larger, the gyrus cingulum smaller and white matter integrity decreased. The hippocampus can atrophy. In older patient groups, vascular changes are common amongst depressed patients. Functional changes include diminished metabolism of the frontal cortex and increased metabolism in the limbic system. The gyrus cingulum is overactive in depression, and pharmacological treatments normalize this. (135)

2.2.6 Treatment of depression

The treatment of depression is multimodal. The present Finnish guideline for treatment recommends psychotherapy, medication or a combination of these. In some cases, ECT, TMS, light therapy or exercise can be used, while some might benefit from omega-3 substitution. The importance of monitoring and follow-up are emphasized. Treatment choices are always chosen individually. The choices are based on factors such as the severity of depression, possible comorbidities (both psychiatric and somatic), effects of possible earlier treatments, presence of suicidality and patient preferences. (63,101)

The recommended first line medications are SSRIs (selective serotonin reuptake inhibitors). Other possible medications include SNRIs, TCAs and MAO inhibitors, and some medications that cannot be categorized into the aforementioned groups (e.g.
bupropion, agomelatine, vortioxetine and mirtazapine). Monotherapy is recommended, but another drug might be added in case of treatment resistance or psychotic symptoms, among other reasons. (101)

The mechanisms of action of different antidepressant are often associated with neurotransmitters and their receptors, but other mechanisms have also been proposed (63). For example TCAs and SSRIs have anti-inflammatory properties (147,148), and SSRI’s have been associated with changes in neuronal plasticity (149). With respect to the inflammatory hypothesis of depression, it is noteworthy that anti-inflammatory medications might be effective in treating depression (150). SNRIs and TCAs are also recommended treatment options in painful conditions (151), and this might be explained by common neurobiological or other common factors in pain and depression.

Different forms of psychotherapy are effective in the treatment of depression, and the combination of psychotherapy and medication is probably more effective than either of these alone (101). As the aetiology of depression is multifactorial and depression is a heterogenic condition, new treatment options with different mechanisms of action are constantly being developed. Newer treatments for depression include TMS (152), which might also be effective in the treatment of pain (153,154).

Medication (155) and psychotherapy (156,157) are also effective in treating depression amongst the somatically ill. The patient preference is psychological treatment amongst the somatically ill, and most patients hope that their doctors will also discuss emotional issues in their care (158).

2.2.7 Subclinical depression and depressive symptoms

In addition to clinical depression, subclinical depression or depressive symptoms can also have health effects. The definition of subclinical depression varies, demonstrated in the review by Rodriguez et al (159). Some definitions require the presence of depressed mood and a lack of interest but no significant impairment. The terms subthreshold depression,
minor depression and subsyndromal depression have also been used in some studies. Nevertheless, most studies have applied a definition by Judd (160), in which for subclinical depression, two or more symptoms of depression need to be present for most of the time, with the duration of at least two weeks. The prevalence rates have also been variable, ranging from 1.3% to 17.2% in community settings and 2.9% to 9.9% in primary care (159).

Subclinical depression or depressive symptoms without a depression diagnosis can predict a later onset of depression (161-163). These milder symptoms of depression also have independent associations with other health conditions and disability (164,165), and as such represent an independent risk factor for other health problems. Roughly 40% of those with subclinical depression had at least one other comorbid disorder in a study by Rucci et al. (165). Subclinical depression is also associated with more health care use (166) and mortality (119).

The aetiology of subthreshold depression is assumed to be similar to that of depression, and evidence of similar changes in brain structures has been found (167). There is some evidence that the treatment of subclinical depression with antidepressant does not give an advantage over placebo (168). According to meta-analyses, psychological interventions (169) as well as psychotherapy (170) might help.

2.2.8 Mechanisms connecting depression and somatic comorbidities

As depression is linked to several illnesses, research has aimed to determine the mechanisms connecting these different phenomena. Depression and pain circuits converge in the brain (171,172), and both have also been associated with inflammation (173,174). Chronic stress is associated with depression and systemic illnesses, and these have further been related to inflammation and changes in the brain. Thus, stress is suggested to be the driving force for the comorbidity of mental and physical illnesses, as also shown in Figure 1 (173).
Figure 1. The relationship between systemic illness and psychiatric disorders. Figure from (173). Reprinted with permission.
2.3 LIFE SATISFACTION AND DISSATISFACTION

2.3.1 Definition, properties and evaluation of life satisfaction

Life satisfaction can be seen as an indicator of good mental health, which includes good coping mechanisms, better than average functioning and resilience (2,175), and life satisfaction is one way to evaluate subjective well-being. Life satisfaction also has a correlation with sense of coherence, another determinant of good mental health (176,177).

Life satisfaction is related to the concepts of well-being and quality of life, all of which aim to describe what constitutes a good life. Quality of life and life satisfaction are often equated, and they do have some overlapping qualities. Both are broad concepts, and the definitions have not been clear. The main difference between the two is, that life satisfaction, and its evaluations, are subjective evaluations of personal satisfaction with life, i.e. how a person feels about his or her life (178), whereas evaluation of the quality of life also includes more objective evaluations (e.g. perceived problems in daily functioning, living conditions or the presence of social contacts) (179,180).

The evaluation of life satisfaction has nevertheless been attempted with methods based on both objective and subjective measures (181). The different commonly used methods for evaluating life satisfaction are nevertheless subjective, including the four-item Life Satisfaction Scale (178), 1-item scales asking: “How do you feel about your life as a whole?” (181) and Overall Life Satisfaction (182).

Of these, the scale introduced by Allardt et al. (178) has gained most popularity in Northern Europe, and has been used in clinical and research contexts. The questions of the LS scale include subjective evaluation of life as interesting, happy, easy and lonely. This short self-administered scale has been well accepted by both the general population (183,184) and patient samples (185-187). All the items are positively correlated with the other items and the LS score (188).
Life satisfaction as evaluated by the LS scale appears relatively stable (189), although it can be sensitive to treatment intervention (184). The results from studies evaluating the association of subjective well-being with age, have given differing results (190-192), although positive affect and life satisfaction generally appear to increase with age. It has also been proposed that a higher level of life satisfaction amongst the elderly might be explained by differential mortality, i.e. those who are dissatisfied die younger (193).

2.3.2 Life satisfaction and mental health

The association between poor mental health and life dissatisfaction is clear: psychiatric in-patients have lower life satisfaction than other patient groups (188). The duration of a disorder, as well as the presence of psychiatric comorbidities, is related to lower life satisfaction (194).

In particular, depression and life dissatisfaction are strongly associated in both the general population (195,196) and psychiatric patients (184). Depressive symptoms, low self-evaluated health and dissatisfaction with life have been strongly associated in the general population (195,197). The same correlation has been found among psychiatric patients (185). Amongst patients recovering from depression, life dissatisfaction was associated with depressive symptoms and hopelessness (187). In addition, in a general population sample, the long-term life dissatisfaction burden was related to subsequent major depressive disorder (198).

Evaluation of life satisfaction can also be used in the assessment of recovery from depression (184) and the level of life satisfaction of originally depressed patients can eventually reach the life satisfaction level of the general population (184,188).
2.3.3 Life satisfaction and somatic health

Life dissatisfaction is related to the health status and disability (197, 199, 200). It has also predicted several adverse long-term health outcomes in a healthy general population, including disability (195, 201) and mortality (202), while the subjective experience of life satisfaction has been found beneficial for these outcomes.

In addition, life dissatisfaction has been associated with coronary heart disease (203), high BMI (204) and chronic pain (205). In a recent study, low life satisfaction was found to be related to osteoporosis and bone loss (206). In Parkinson’s disease, life satisfaction decreases as the symptoms progress, and life satisfaction is also related to sense of coherence (207).

Health behaviour is also associated with life satisfaction. This can be seen, for example, in higher levels of alcohol consumption, more smoking and physical inactivity among those with lower levels of life satisfaction. (185, 208, 209)

Thus, life satisfaction can be seen as a mediator of different factors affecting the health of an individual, whether measured subjectively or by more objective evaluations, and as such could be used as a tool to monitor the overall well-being of both the general population and different patient groups.

2.3.4 Possible mechanisms of associations between life satisfaction and health

The mechanisms underlying associations between life satisfaction and somatic health are still unclear. Hormonal and other biological processes were already suggested as possible mediators in the 1980s (199). Depression and life satisfaction are closely related, and possible mechanisms linking them and different somatic disorders can be similar. The links between depression and life satisfaction might also be explained by genetics (210).
There is some evidence of associations between well-being and changes in inflammatory markers (211,212). Changes in health behaviour could also be an important factor, as well as other psychosocial factors, as described above.

2.4 SENSE OF COHERENCE

2.4.1 Definition and measurement of sense of coherence

Sense of coherence (SOC) is a concept that is directly related to the salutogenic model of health, where orientation towards life is intricately connected with health (48,52). These concepts were introduced and developed by Antonovsky, who described SOC as a way of seeing life as comprehensible, manageable and meaningful.

SOC has been suggested to develop until the age of 30 and to be relatively stable (48-52). Nevertheless, SOC can be affected by various life-changing events, such as experiencing multiple severe traumas (213,214) or becoming a victim of physical, psychological or sexual violence (214). SOC can also improve with age (215,216), with the highest values observed amongst the eldest. Some studies have shown that it is also possible to improve SOC with psychosocial interventions (217-219).

Antonovsky initially studied salutogenesis and sense of coherence qualitatively, but later developed the SOC scale, which measures the three above-mentioned components separately. This scale has received criticism, and according to two large reviews, it seems to associate especially with psychological well-being, while the associations with physical well-being appear to vary more (62,220,221).
2.4.2  Sense of coherence and health

SOC is associated with good coping abilities and good mental health (222) and a better quality of life (62). Those with a greater sense of coherence generally appear to do better when facing different somatic diseases (223-225), although opposite findings have also been reported (220).

Low SOC is associated with several mental health problems, e.g. depression, anxiety, substance abuse disorders and psychotic disorders (226,227), as well as the symptom severity of ADHD (228). SOC has been associated with depressive symptoms in several studies (222,224,229,230). A low sense of coherence may predict the onset of later depression (231,232), and a high level of SOC may protect against it (233). Improvement in SOC has coincided with recovery from depression (234).

In the Helsinki Heart Study, a high sense of coherence protected against cardiovascular diseases (235), and those with high sense of coherence had a lower prevalence of cancer (236) and were less prone to be involved in accidents (237). In addition, SOC has been associated with depression in somatically ill patients, for instance in patients suffering from cardiovascular diseases (238), musculoskeletal problems and spinal problems (17,233,239).

The mechanisms connecting sense of coherence to health are unclear, although, as with depression and life satisfaction, they are most likely to be complex and involve biological and psychosocial pathways. A high sense of coherence has been linked to changes in health behaviour, e.g. exercise, nutritional choices and alcohol consumption (237,240,241), which might be one possible explanation for how it is related to overall health and different illnesses. To my knowledge, there have been no studies on biological markers as related to sense of coherence.
2.5 DYNAMIC BIOPSYCHOSOCIAL MODEL OF HEALTH

2.5.1 History of theories on interactions between the body and the mind

The interactions between the mind and the body have been understood in different ways throughout the ages. One of the main questions has been the so called mind-body problem: some philosophies and traditions answer it with a clearer distinction of mind and body as separate, while others consider the body and the mind to be inseparable. In Western culture, Descartes (242) is most often associated with dualism, i.e. suggesting that the mind and the body are separate. The opposing view has been associated with Kant (243). The question has been discussed in religious and philosophical contexts and later also addressed in sociological, psychological, medical and neurobiological research.

In relation to medicine, as Descartes’s view became more popular, it was thought that it gave more freedom to study the biology and physiology of the human being, enabling the development of a more biomedical view of health and sickness. Nevertheless, the importance of patient–doctor interactions and the effects of different aspects of everyday life have been seen as important throughout history by clinicians, as well as the relationships between the mind and the body.

The study of psychosomatic issues began more actively in the early 19th century, with several study questions: is the mind more powerful than the body, or the other way around, or might their connection be more complicated? (244) At the beginning of the 20th century, psychoanalytic theory with its interpretation of psychosomatic issues became more popular, and the diagnosis of “conversion hysteria” included the idea, that certain physical symptoms have psychogenic origins (245). Later, this type of psychosomatic explanation was suggested to be involved in all phenomena, i.e. everything has a psychological background (244,246).
In the research field, biomedical research and new psychological theories developed further in the 20th century, with changing and evolving terminologies and concepts. Later, interest in research into more integrative models of health also became more popular, and these have formed the main background theory of modern research in the field. (244)

2.5.2 Development of the modern biopsychosocial model of health

Engel (247-249) proposed a biopsychodynamic model of health, in order to improve the simpler biomedical model of disease and to provide the clinician with a wider perspective. This conceptual model adds psychological and social aspects, thus enabling health and sickness to be more broadly examined and providing clinicians with more tools to understand individual patients’ experiences of their illness. The model also encourages the treatment of all aspects of illness simultaneously, not separately. Engel criticized the biomedical model as follows (250):

1. Biochemical alterations do not directly translate into an illness and, conversely, psychological alterations may have biochemical correlates;
2. Biological findings do not tell about the meaning of the symptoms to the patient;
3. Psychosocial variables are more important than the biomedical model proposes;
4. Adopting a sick role does not always associate with biological changes;
5. Biological treatments are also influenced by psychosocial factors;
6. The patient–clinician relationship influences the outcomes;
7. Patients are influenced by the way they are studied, and scientists are influenced by their subjects/patients.

Engel thus criticised the popular dualistic view at the time of the body and the mind, the reductionist and materialistic orientation of medicine and the omission of the effects of
interaction between the observer and the observed. Later, the biopsychosocial model received both appraisal and criticism (250-253). Nevertheless, newer developments that are based on this model include concepts such as “patient-centred care”, “biopsychosocially-oriented clinical care” and “relationship-centred care”, which take into account both the biological and the psychosocial aspects of health, as well as the interactions between the patient and the doctor/other caretaker (252,254-256). Possibly the best known adaptation of the model is by WHO, which introduced the ICF (International Classification of Functioning, Disability and Health). The ICF can be used as a framework for measuring health and disability at both individual and population levels and it is endorsed by all WHO member states. (257)

2.5.3 Mechanisms explaining health as a biopsychosocial phenomenon

The mechanism explaining the dynamic interaction of the different factors in the biopsychosocial model is most likely multifactorial. For example, the relationship between mental and somatic illnesses could be explained by the stress model involving the HPA axis (142,144,258). The inflammation hypothesis is another possible mechanism (174), as well as alterations in the functioning of different neuromodulators, e.g. TNF and neurotransmitters (133). Furthermore, neuroanatomical common pathways between different biopsychosocial phenomena (e.g. for pain, anxiety and depression) have been found (171,172). All in all, the psychological and the biological phenomena appear to be connected via complex pathways, as also shown in Figure 2 (258).
2.5.4 Biopsychosocial model of health in relation to spinal problems

Earlier, the aetiology of low back pain was thought to be either psychogenic or organic, but the modern view considers the aetiology to be multifactorial (259). The biopsychosocial model of health has been a useful tool in assessing and treating some spinal problems, especially in relation to low back pain (LBP) (260). Some have criticised the modern care of LBP and CBP as “too psychological” (261), and uniform guidelines have been called for in order to optimize patient-centred care (262). In LBP, psychosocial factors play an important role (130,263,264), and taking them into account in the treatment
has been found useful (265). These previous studies have, however, investigated patients with non-specific low back pain, with none particularly focusing on LSS patients.

Nevertheless, in LSS different psychosocial (e.g. mood, satisfaction with life) and biological factors (e.g. nerve compression, neurotransmitters) are all involved. Surgery changes the biological factors, and at the same time it can affect the psychological and the social factors. It has previously been found that as well as functional abilities (266), mood (267) can also improve after surgery. Moreover, psychological factors can predict the outcome of surgery, at least in a short follow-up (12,13). This circular nature of these interactions is in line with the biopsychosocial model of health. However, only some aspects of the psychosocial factors have been studied, and more information is needed in order to establish a clearer view of which factors affect this particular illness and the recovery from its surgery.

All in all, approaching patient care with the help of the biopsychosocial model could improve the outcomes and increase patient satisfaction. Figure 3 summarizes some aspects of the model in relation to LSS and its treatment, also showing the factors evaluated in this study. Although the factors are organized into separate categories such as biological, psychological and sociocultural factors, some of them could be placed in other factor categories as well, which further demonstrates the dynamic and interactive nature of this model of health.
Figure 3. Biopsychosocial model of health in relation to LSS, showing examples of several possible factors involved.

2.5.1 Future directions of mind–body (psychosomatic) research

As the research methods improve, it will be possible to investigate the mind–body problem from new perspectives. Often, the body–mind problem is divided into so-called easy and hard problems (246). Studies on the hard problems try to explain consciousness or how, and especially why, physiological processes might create the mind, sense of self or
sense of consciousness/being conscious (268,269). The easy problems include studies investigating the different ways in which the body and the mind interact in different everyday situations, i.e. focusing more on the question of “how”. The present study might be categorized as one solving this type of easy problem (246).

As the field of medicine has developed, with advances in research methodology, these ancient philosophical questions have become more concrete. Although the questions may remain unanswered, research into them will help us understand these issues better, and assist in developing better ways to improve the overall health and well-being of each individual.
3 Lumbar spine and lumbar spinal stenosis

3.1 ANATOMY AND FUNCTION OF THE LUMBAR SPINE

The spine consists of 33 vertebrae, of which 5 are located in the lumbar spine. Below the lumbar spine is the sacrum, the lumbosacral angle occurring between these two. Above the lumbar spine is the thoracic spine.

The vertebrae of the spinal column are separated and bound together by intervertebral discs, and the vertebrae also articulate via synovial joints (zygagophyseal joints/facet joints), which enable the movement of the spinal column. The intervertebral discs consist of an outer fibrous part (annulus fibrosus) and a gelatinous inner part (nucleus pulposus). Furthermore, the vertebrae are connected by several ligaments, e.g. the ligamentum flavum and the thick anterior and posterior longitudinal ligaments.

The lumbar vertebrae have massive bodies and lack costal facets. They have long, thick transverse processes, but their spinous processes are short. The articular processes have superior facets directed posterolaterally and inferior facets directed anterolaterally. This enables the greatest extension of the spine in the lumbar region, whereas rotation is limited. The large intervertebral discs make lateral flexion quite free in the lumbar spine.

The spinal cord is located in the spinal canal within the vertebrae, between the body and the posterior arch. The spinal nerves of the lumbar region exit through the foramen between two vertebrae. The spinal cord is supplied by paired posterior spinal arteries and one anterior spinal artery.
The whole spine is protected and its movement further enabled by musculature, which consists of several layers. The deepest layers of muscles are closest to the spinal column and they act specifically on the spinal column, moving it and maintaining posture. The more superficial muscle layers are more involved in the movement of the limbs and respiratory movements. (270,271)

### 3.2 PATHOPHYSIOLOGY AND CLASSIFICATION OF LSS

In degenerative lumbar spinal stenosis, the most common type of LSS (272), the vertebral or lateral canals gradually narrow, leaving less space for the neurovascular tissue and causing compression of the nerves (272,273). The intervertebral discs can be compressed and the nucleus pulposus herniated, the ligamentum flavum can develop hypertrophy and several bony parts of the column have hypertrophy and osteophytosis (273).

LSS can be further classified as central or lateral stenosis. Central stenosis includes narrowing of the antero-posterior diameter of the spinal canal, the transverse diameter or both. In lateral stenosis the spinal nerve is compressed within the root canal or the vertebral foramina. (273) Figure 4 shows stenosis in the lumbar spine, and normal spine in the lower thoracic spine.
Figure 4. A normal part of the spinal canal and a stenotic part of spinal canal in the same spine, as shown by MRI.
In addition to the above-described anatomical classification, aetiological classification can also be used, the classes being aetiological/congenital and acquired stenosis. Degenerative stenosis is classified as acquired stenosis, as are, for example, spondylolytic and spondylolisthetic stenosis. (272,273)

Usually, the degenerative process is slow and benign, rarely leading to acute cauda equine syndrome. Furthermore, in most patients the stenotic process occurs at several levels, especially in patients in need of surgery and having more symptoms (274).

### 3.3 DIAGNOSIS AND EPIDEMIOLOGY OF LSS

Low back pain is a common problem among the general population (4-6). According to the 2013 Global Burden of Disease Study, back pain is the leading cause for years lived with disability globally, in both developed and developing countries (6). Lumbar spinal stenosis (LSS) is one of the main underlying conditions of low back pain, with the highest prevalence in the elderly population (7). As diagnostic accuracy has improved and the population has aged, the prevalence of LSS has increased (275). The rate of surgery for LSS is also increasing (276).

Neurogenic claudification is considered to be the classical symptom of LSS, meaning that patients often especially suffer from radicular symptoms in the lower extremities when walking (277). Other symptoms of LSS often include pain in the back and/or lower extremities, and in addition, patients can experience numbness, fatigue, heaviness and weakness in the lower extremities. Symptoms are exacerbated with lumbar extension (e.g. when standing for prolonged periods or while walking), and this can be used as a test to help the diagnosis (278). A greater age, severe lower extremity pain and the absence of pain when seated were most strongly associated with a diagnosis of LSS (279), and in a
recent review, in addition to these, a wide-based gait and improvement in the symptoms when bending forward were suggested to be useful in the diagnosis of LSS (280).

When making the diagnosis, the radiographic findings should include evidence of nerve root compression. (279) Up to 21% of people over 60 years of age have radiological findings of LSS in MRI (281). Several radiological criteria for LSS diagnosis have been suggested, and studies most often report measures of the antero-posterior diameter (<10 mm) and cross-sectional area (<70 mm²) of spinal canal in central stenosis and the height (<2 mm) and depth of the lateral recess (<3 mm) in lateral stenosis (282). In central stenosis, classification is often done so that a dural sac area of <75 mm² indicates severe, 75–100 mm² is moderate and >100 mm² is mild (283). However, the correlation between radiological findings and symptoms is poor (284-286). The most promising imaging technique, nevertheless, is MRI (280).

Efforts have been made to establish a consensus on the criteria to define and classify LSS, but there is still a need for more research (280). At the moment, the diagnosis is made by evaluating the symptoms and radiographic evidence combined (280,287,288).

Thus, a diagnosis of (degenerative) LSS can be made if:

1. There are symptoms related to nerve root compression: back, buttock and/or lower extremity pain and/or neurogenic claudication. (Other symptoms might include fatigue, heaviness and paraesthesia during walking.)
2. There is radiographic evidence of stenosis: CT, MRI or myelography showing compression of exiting nerve roots and/or cauda equine due to degenerative changes.
Differential diagnosis includes the exclusion of tumours, cysts, inflammatory diseases, osteoarthritis, vascular claudication and disc herniation. The most common of these is vascular claudication. (273)

3.4 CONSERVATIVE TREATMENT

Mild symptoms in LSS can be treated conservatively after basic clinical examination, for instance, with analgesics, physiotherapy and massage (18,289,290). Many patients receive conservative treatment for non-specific low-back pain before the diagnosis of LSS has been made. In the treatment of pain, non-pharmacological treatment is recommended (151). In addition, with regard to pain, antidepressants might be useful (151).

The conservative treatment methods might, in addition to those mentioned above, include back exercises or epidural steroids (18,289,291). There is evidence that exercise therapy, spinal manipulation, multimodal rehabilitation and cognitive behavioural therapy are effective in treating low back pain (265,292,293). There is little evidence of optimal conservative treatment focusing especially on LSS patients. However, physiotherapy can be beneficial (294,295).

3.5 SURGICAL AND POSTOPERATIVE TREATMENT

3.5.1 Effectiveness and predictors of surgical treatment

Surgery is recommended for LSS if conservative treatment fails, based on a review by Kovacs et al. (8). In other systematic reviews, it has been concluded that decompressive
surgery is also better than nonsurgical therapy in the long term (296,297). The most recent Cochrane review analysed studies comparing different surgical methods and conservative approaches, but found the evidence to be of low quality and made no conclusions on which treatment option is better (298).

The outcome of surgical treatment also varies considerably, but it might be improved by optimizing patient selection, surgical techniques and post-operative care (9). The effects of surgery appear to decline with time, but surgery is nevertheless considered to be more beneficial than conservative treatment for up to 3–4 years and possibly even 10 years (299-302). In a recent RCT, decompressive surgery provided slightly better improvement in functional ability than conservative treatment in a six-year follow-up among patients with moderate lumbar spinal stenosis (303).

The most common surgical technique is decompression laminectomy. Sometimes spinal fusion is added, with several possible techniques. (273,304)

Different predictors of the surgical outcome have been identified. They include comorbidities, BMI, age, severe stenosis and depressive symptoms. Psychological predictors have only been examined in a few studies (10,15,305-307)

3.5.2 Postoperative treatment

Postoperative rehabilitation methods differ and there is no clear consensus on which methods are the most effective, mainly due to the lack of research in this area. Rehabilitation may include exercise, physical therapy and/or patient education. (20,21)

There have been very few randomized controlled trials (RCTs) investigating the effects of postoperative rehabilitation of LSS, and the effectiveness of different interventions has
been found to vary (9,11,19). Earlier research on the postoperative rehabilitation of LSS was evaluated in a recent Cochrane review (21). The review included data from three RCTs with a follow-up time of up to one year after surgery. The results indicate that active rehabilitation is more effective than the usual care in relation to the functional status and low back pain. As these results are based only on few studies and on short follow-up times, further information is needed on the effectiveness of postoperative rehabilitation.

3.5.3 **Outcome measures of LSS treatment**

Assessment of the outcome of surgery can include observation of the symptoms, degree of stenosis, functional status, well-being, work disability and satisfaction with surgery, and is mainly based on subjective evaluation by the patients (274).

The Oswestry Disability Index is considered to be a reliable outcome measure for spinal conditions (287,308-310), and is probably the best choice in populations with high disability rates (311). Validation studies for both the first and second Finnish versions of the ODI have also been performed, and the scale has been found reliable and valid (312,313). The ODI has been used in several LSS studies and has become one of the most commonly used tools to evaluate outcomes (314).

The visual analogue scale (VAS) is a valid measure of experimental, clinical and chronic pain (315,316), and is one of the recommended tools to evaluate pain intensity in both acute (316) and chronic pain (317). Walking distance as a subjective measure is thought to be a valid method of evaluation (318), and treadmill tests are not commonly in use (319). Satisfaction with surgery is also often used as an outcome measure (274,279,320).
3.6 PSYCHOLOGICAL FACTORS IN LSS

Psychosocial factors have been found to affect the outcome of spinal surgery (305,321,322). A review by Celestin et al. (12) suggested that depression, anxiety and poor coping predict a poorer outcome following spinal surgery. Below are presented the main results from previous studies, focusing on the factors investigated in this study, i.e. life satisfaction, depression and sense of coherence. Since studies particularly focusing on psychological factors as predictors of LSS surgical outcomes are scarce, some results from studies on other spinal conditions are also presented.

3.6.1 Life satisfaction

The only studies on life satisfaction and LSS have been conducted on the same patient cohort as this study. In recent clinical studies by Sinikallio et al. (16,323), life satisfaction improved after surgery in LSS patients in a 2-year follow-up. Moreover, baseline life dissatisfaction was associated with comorbidity (324) and a poor surgery outcome in a 2-year follow-up (16), which indicates a possibility for early intervention when those at risk are recognised. However, although these studies suggest that prevailing life dissatisfaction may essentially worsen the surgery outcomes in the short term, there have been no previous studies with follow-up times exceeding two years.

3.6.2 Depression

A recent systematic review summarised the earlier research on the predictive value of depression concerning the outcome of LSS surgery, including 13 articles using 5 separate cohorts (10,306,325-328). The studies used several methods of evaluation of depression (BDI, MMPI and the Zung self-rating depression scale). The review states that preoperative depression is likely to be a prognostic factor for disability and LSS-related
symptoms. The prognostic value of the walking capacity and pain is less clear. (13)

Earlier studies by Sinikallio and coworkers also examined factors related to the rehabilitation period after surgery, and demonstrated that depressive symptoms in the early recovery phase, in addition to preoperative symptoms, were strong predictors of the outcome of surgery at 1- and 2-year follow-ups (328,329). In previous research on the association between depression and surgery, the mean follow-up times have only been up to two years (13).

### 3.6.3 Sense of coherence

In spinal patients, psychological distress is associated with a lower SOC (239). In patients with low back fusion for LBP, SOC correlated significantly with the disability score, and had a good predictive value postoperatively, as it associated with better functional ability in a long-term follow up of up to 13 years (330,331). In surgically treated LSS patients, SOC has strongly associated with depressive symptoms in earlier studies on this same cohort (17,332). Among LSS patients, preoperative SOC interfered with postoperative recovery in a one-year follow-up according to an earlier study by Sinikallio et al (17). To my best knowledge, there have been no follow-up studies concerning SOC in this patient group that exceed the duration of one year.

### 3.6.4 Psychosocial support as a part of LSS treatment

There have been two studies evaluating the effects of psychosocial support as a part of the conservative treatment or rehabilitation of lumbar surgery, and no intervention studies focusing only on patients with LSS.

In an intervention study by Abbott et al. (2010), the group receiving psychomotor therapy had better lumbar fusion surgery outcomes than the group receiving exercise therapy as
measured, for example, by the ODI and VAS (22). In a study by Christensen et al. employing a “Back Café” concept, where patients had group support meetings after lumbar spinal fusion combined with exercise therapy or exercise therapy only, the combination of psychosocial support proved to be more effective than exercise therapy alone (23).
4 Conclusions from the previous literature

The biopsychosocial model of health considers health and sickness as multifactorial, dynamic processes that differ for each individual. It suggests that the management of illnesses should simultaneously address all the different factors affecting health. In lumbar spinal stenosis, the biological changes (e.g. stenotic process, neural compression) can be corrected in surgery. Postoperatively, changes can also take place in, for example, functional capabilities, pain levels and even mood.

Most operated LSS patients have good surgical outcomes, but for some the result remains poor. Predictors of a good surgical outcome have been sought, and there is some evidence that they are both biological and psychosocial, which is in line with the biopsychosocial model of health. Nevertheless, studies on psychosocial factors are still scarce, and the follow-up times have been short. In addition, only some possible psychosocial factors have been investigated. It is also known that even slight changes in mental well-being can influence other areas of health, which is why, for instance, subclinical symptoms require further investigation.

In this study, all the aspects of well-being described in the previous sections will be addressed to some extent: life satisfaction giving information on evaluative, depressive symptoms on hedonic and sense of coherence on eudemonic well-being. Life satisfaction is a possible positive modulator of the surgical outcome, although in this study the results have been reported in the traditional way, i.e. how the lack of satisfaction might influence the outcomes. Investigation of depression and depressive symptoms reveals how negative affect might be associated with surgical outcomes. Sense of coherence is directly related to the concept of salutogenesis, and as such is a possible positive modulator of the outcome of surgery.
This study provides new information on long-term recovery following LSS surgery, with extensive follow-up times of up to ten years postoperatively, focusing on several psychological modulators of surgical outcomes. The factors studied include sense of coherence, depressive symptoms and life satisfaction, enabling the evaluation of both positive and negative factors. Due to the long follow-up time, it is also possible to analyse the cumulative effects of these factors and to analyse the effects of postoperative factors on the long-term outcome, both of which provide a new aspect in addition to evaluating preoperative predictors.
5 Aims of the study

The general aim of this study was to investigate the associations of different psychological factors with the postoperative outcome of lumbar spinal stenosis surgery in a long-term follow-up, with a specific focus on the postoperative rehabilitation period.

The specific aims were to:

1. Examine whether life satisfaction is associated with the surgical outcome in a 5-year follow-up (Study I);

2. Investigate the associations between depressive symptoms and the surgical outcome in a 5-year follow-up (Study II);

3. Analyse the associations between postoperative sense of coherence and the outcome of surgery in a 5-year follow-up (Study III);

4. Investigate the associations between life satisfaction and the surgical outcome in a 10-year follow-up (Study IV).
6 Materials and methods

6.1 STUDY SETTING AND PARTICIPANTS

6.1.1 Study subjects and design

The study population of the present prospective clinical study consisted of 102 patients with radiologically and clinically defined LSS who underwent decompressive surgery. Selection for surgery was carried out by an orthopaedist or a neurosurgeon at Kuopio University Hospital, Finland, between October 2001 and October 2004. (314,333)

After five years of follow-up there were 6 deaths, 11 patients were not reached and 11 did not complete the questionnaires. Thus, at the 5-year follow-up, 74 of the original subjects responded to the questionnaires. Of these, 7 did not complete the LS questionnaires, and thus the final study population was thus 67 in Study I. Similarly, in Study II, 12 subjects had not filled in the BDI questionnaire, the final study population being 62, while in Study III, all the subjects completed the SOC questionnaire and study population was 74. After ten years of follow-up, 72 responded to the questionnaires. At this point, 17 of the original subjects had died, one could not be contacted, 10 refused to participate and two were unable to complete the 10-year questionnaire. The final study population of Study IV was 54, including only those subjects who had completed all LS questionnaires throughout the follow-up. The mean age of the study group at the 10-year follow-up point was 69 years, 38% were male and 58% were married or living with a partner. The baseline general characteristics (e.g. age, gender, marital status, VAS, ODI, BDI) did not differ between drop-outs and the study subjects after 5 years of follow-up. At the 10-year follow-up point, the baseline age was higher amongst the drop-outs, but other characteristics did not differ significantly.
The patients received an account of the study during their outpatient visit to the Department of Physical and Rehabilitation Medicine and provided informed consent. The study design was naturalistic, so participating in the study did not change the treatment. Half of the patients were randomized for postoperative intervention. The aim was to recruit all criteria-fulfilling patients with LSS. The study design was approved by the Ethics Committee of the University of Kuopio and Kuopio University Hospital.

6.1.2 The inclusion criteria of the study population

The inclusion criteria of the study population were the presence of:

1) severe pain in the back, buttocks and/or lower extremities;

2) radiographic evidence of compression of the cauda equine or degenerative changes in the nerve roots; and

3) the surgeon’s clinical evaluation of degenerative lumbar spinal stenosis requiring operative treatment.

All patients also had a history of ineffective responses to conservative treatment. The exclusion criteria were: emergency or urgent spinal surgery precluding recruitment and protocol investigations; cognitive impairment prohibiting completion of the questionnaires or other failures in co-operation; and the presence of metallic particles in the body preventing the MRI investigation.

6.1.3 Surgical treatment

As published earlier (19), 82% (84/102) of the original study population had central and lateral stenosis, and 18% (18/102) had lateral stenosis only. The mean dural sac area at the
most stenotic level was 68.6mm\(^2\). Sixteen patients had previously undergone lumbar operation. The surgery was performed either at the Department of Orthopaedics or Neurosurgery.

All the patients had open or microscopic decompressive surgery of the affected level(s), i.e. laminotomy, hemilaminectomy or laminectomy, with undercutting facetectomy. As published by Aalto et al. (266), at the present operation, in addition to laminar decompression, disc excision was also performed in seven cases. LSS due to other degenerative stenotic changes was also the main diagnosis in these patients. Nineteen patients had additional fusion (two with instrumentation). The indication for additional lumbar fusion was concomitant spondylolisthesis.

All the patients received routine preoperative information at the hospital about immediate postoperative mobilisation. They were advised to remain active with no restrictions in normal daily living.

### 6.1.4 Postoperative treatment

Patients had routine control visits to the orthopaedic or neurosurgical clinic 2 to 3 months postoperatively. Here, the surgeon also confirmed that there were no restrictions to rehabilitation.

Physical exercise intervention (PEI) started 3 months postoperatively for some of the patients. A two-block randomization was performed (adjusted for age and gender), and in the final group receiving PEI there were 50 members, while the control group comprised 52 members. Other postoperative treatments (e.g. analgesics, other types of physiotherapy) prescribed by a surgeon/GP were not prohibited.

The rehabilitation intervention included a supervised training session once a week (including strengthening and stretching exercises) lasting for 12 weeks and was repeated
12 months postoperatively. However, this intervention did not influence the surgical outcome in a 2-year follow-up when evaluated according to the functional outcome, pain, satisfaction with surgery and walking distance (19).

6.2 DATA COLLECTION AND QUESTIONNAIRES

6.2.1 Data collection

Data collection took place before surgery and 3 months, 6 months, 1 year, 2 years, 5 years and 10 years postoperatively with the same questionnaires. Questions concerning the sociodemographic background, lifestyle and health were included in the preoperative questionnaire, which was mailed to the patients by the secretary of the Department of Physical and Rehabilitation Medicine. The questionnaires for each original study were chosen as appropriate.

6.2.2 Evaluation of the main psychological factors

Life satisfaction (Studies I and IV)

Life satisfaction was assessed with a four-item self-evaluation scale (LS, range 4–20, higher scores indicating lower satisfaction, the cut-off for dissatisfaction in this being 12) (178).

The LS scale includes four items on interest and happiness in life, the ease of living, and loneliness. All the patients are asked: Do you feel that your life at present is (all questions presented on the next page with the scoring, different questions separated by /):
very interesting/happy/easy/not at all lonely = 1;
fairly interesting/happy/easy = 2;
cannot say/missing data = 3;
fairly boring/unhappy/hard/lonely = 4;
very boring/unhappy/hard/lonely = 5. (178)

**Depressive symptoms (Study II)**
Assessment of depressive symptoms was performed with the Finnish version of the 21-item Beck Depression Inventory (BDI) (range 0–63) (79). The items include questions on mood, concentration, feelings of pleasure, suicidal thoughts and changes in weight, and are rated on a 4-point Likert scale. A higher score indicates more depressive symptoms, and the cut-off point for clinically significant depressive symptoms in this study was 15 (93,334).

**Sense of coherence (Study III)**
SOC was evaluated with the validated 13-item SOC scale (range 13-91). The items include questions evaluating whether life feels meaningful, manageable and comprehensible. Each item has response options on a seven-point Likert scale. There are no specific cut-off values for high/normal/low SOC scores. Thus, we used the mean score as the cut-off in our analyses, with higher scores indicating better coping resources (51,52).
6.2.3 Evaluation of other variables

The sociodemographic factors used in the analysis included age, gender and marital status. Other measured variables were mostly used as continuous variables, and they included the following:

1) Self-reported walking capacity in metres (continuous scale). (15)

2) An estimation of overall back and leg pain intensity with the visual analogue scale (VAS: 0–100 mm), with 0 mm indicating “no pain” and 100 mm “the worst possible pain”. The cut-off point of 50 (used in Study IV) is in the middle of the scale, indicating moderate pain. (315).

3) Subjective disability measured with the validated Finnish version of the Oswestry Disability Index. The range of the scale is 0–100%, where 0% equals no disability and 100% equals extreme disability. The cut-off value (used in Study IV) was 21, and values higher than this indicated at least moderate disability. (308,309,312,313,335)

4) Subjective satisfaction with surgery estimated with a scale ranging from -3 to 3, negative values indicating worsening after surgery, positive values improvement after surgery and 0 points indicating no change in either direction. (314,333)
6.3 STATISTICAL ANALYSIS

The statistical analyses were performed using SPSS/PC (versions 19 and 22, SPSS/Chicago IL, USA).

Study I

The life dissatisfaction burden was calculated by summing all the individual LS scores from all follow-up points (preoperatively, 3 and 6 months and 1, 2, and 5 years postoperatively) in order to gain a thorough longitudinal evaluation of the participants’ life satisfaction level (198). Three equal-sized life dissatisfaction burden groups were used in the basic statistical analysis. In linear regression analysis, the life dissatisfaction burden was used as a continuous variable.

The means were compared using the Student’s t-test, one-way ANOVA and the Kruskal-Wallis test where appropriate. The correlations between continuous variables were tested with Spearman’s correlation coefficient due to the non-normal distribution of some of the variables. All correlations between the variables used in the regression analysis were less than 0.7, and no multicollinearity was observable. Two linear regression models (method: enter) were used separately for the 5-year ODI and VAS. Both models were adjusted for age, gender and marital status. In the model for the 5-year ODI, other variables included the preoperative ODI and 5-year VAS. In the model for the 5-year VAS, the preoperative VAS and 5-year ODI were included.

Study II

The participants were first divided into two groups according to their BDI score preoperatively, the cut-off point for significant depressive symptoms being 15 (334). The depressive burden was then calculated by summing the individual BDI scores from all observation points (preoperatively, 3 and 6 months and 1, 2, and 5 years postoperatively). The study patients were divided into two groups based on the median sum score, those with a high depressive burden (sum of all BDI scores > 40, n = 28) and those with a low
depressive burden (sum ≤ 39, n = 30).

We used the independent samples t-test, one-way ANOVA and Mann-Whitney U-test where appropriate to compare the means, first between groups in a cross-sectional analysis, and then within groups to evaluate the longitudinal change. To evaluate the correlation between the variables, Pearson’s correlation was used.

Several linear regression models (method: enter) were performed separately for ODI and VAS scores at the 5-year follow-up point. In linear regression models, three different variables of depressive symptoms were used: BDI, the depressive burden as a continuous variable and the depressive burden as a dichotomized variable. The models were adjusted for age, gender, marital status, walking distance on 5-year follow-up and preoperative and 5-year ODI and VAS scores.

Study III

The means were compared using the Student’s t-test and the Kruskal-Wallis test where appropriate. Cross-sectional analysis was performed by comparing the groups with a higher and lower 3-month SOC (mean value as cut-off = 73) at the three-month and five-year follow-up points. Longitudinal analyses were also performed to compare the change within the groups between the three-month and five-year follow-up points.

Several linear regression models (method: enter) were tested: four models for the five-year ODI and the five-year VAS and two models for the five-year SOC. SOC was used as a continuous variable. All the models were adjusted for age and gender.

In the first model for the five-year ODI, the predictive values of the three-month SOC, walking capacity and VAS were assessed. An additional three-month variable, BDI, was included in the second model, satisfaction with surgery in the third model and receiving/not receiving PEI in the fourth model. The models for the five-year VAS were similar, except that the three-month VAS was replaced with the three-month ODI.
In the model for predicting the five-year SOC, the first model included walking capacity, ODI, BDI and VAS, and the second model receiving/not receiving PEI as an additional three-month variable.

**Study IV**

The means were compared using one-way ANOVA and the Kruskal-Wallis test where appropriate. Cross-sectional analyses were performed for three equally sized life dissatisfaction burden groups, as in Study I.

Six logistic regression models (method: enter) were used to evaluate the associations between life satisfaction, pain (as measured with VAS) and disability (as measured with ODI). Two different logistic models were used for each: the 10-year VAS, ODI and LS. The following basic variables were used in all the models: age, gender, marital status and preoperative walking distance.

The two models for the 10-year ODI included the preoperative VAS. In addition, the preoperative LS was included in Model 1, and the LS burden in Model 2.

In the models for the 10-year VAS, other variables included the preoperative ODI in both models, and preoperative LS in Model 1 and LS burden in Model 2.

In the two models for the 10-year LS, both the preoperative ODI and preoperative VAS were included, while the preoperative BDI was also added to Model 1 and the depression burden to Model 2.
7 Results

7.1 LIFE SATISFACTION AND LIFE DISSATISFACTION BURDEN IN A 5-YEAR FOLLOW-UP (STUDY I)

The three-category life dissatisfaction burden was associated in the cross-sectional analysis with higher scores for the ODI and VAS at the 5-year follow-up, both indicating a poorer surgical outcome (Table 1). The life dissatisfaction burden was also associated with satisfaction with surgery at the end of the follow-up (p < 0.05), the means being 2.23 (SD 0.69) for a low, 1.35 (1.56) for an intermediate and 1.24 (1.34) for a high burden. Furthermore, a significant correlation between the continuous life dissatisfaction burden score and satisfaction with surgery was seen (rho = 0.391, p < 0.001), with better life satisfaction also indicating greater satisfaction with the surgery.

Table 1. Relationship of study variables with the dissatisfaction burden on 5-year follow-up.

<table>
<thead>
<tr>
<th></th>
<th>Low burden (n = 22, range = 30–41)</th>
<th>Intermediate burden (n = 23, range = 42–51)</th>
<th>High burden (n = 22, range = 52–90)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [mean (SD)]</td>
<td>64.84 (9.80)</td>
<td>68.84 (12.22)</td>
<td>67.82 (12.32)</td>
<td>ns</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>31.8</td>
<td>39.1</td>
<td>36.4</td>
<td>ns</td>
</tr>
<tr>
<td>Marital Status (% married/living with a partner)</td>
<td>81.8</td>
<td>56.5</td>
<td>40.9</td>
<td>ns</td>
</tr>
<tr>
<td>LS [median (IQR)]</td>
<td>7.00 (6.00–7.00)</td>
<td>7.00 (7.00–10.00)</td>
<td>11.00 (10.00–13.00)</td>
<td>***</td>
</tr>
<tr>
<td>ODI [mean (SD)]</td>
<td>17.00 (15.56)</td>
<td>25.89 (15.15)</td>
<td>34.00 (15.02)</td>
<td>*</td>
</tr>
<tr>
<td>VAS [mean (SD)]</td>
<td>23.68 (27.20)</td>
<td>33.75 (26.16)</td>
<td>48.05 (27.95)</td>
<td>*</td>
</tr>
<tr>
<td>Walking distance [median (IQR)]</td>
<td>2500.00 (1000.00–8000.00)</td>
<td>2000.00 (750.00–3000.00)</td>
<td>1000.00 (500.00–3000.00)</td>
<td>ns</td>
</tr>
</tbody>
</table>

Statistical significance: *p < 0.05; ** p < 0.01; *** p < 0.001, ns = nonsignificant (p > 0.05)

LS = Life Satisfaction scale, ODI = Oswestry Disability Index, VAS = Visual Analogue Scale (estimation of overall back and leg pain), IQR = Interquartile range
In linear regression analysis, the life dissatisfaction burden independently associated with the 5-year ODI (adjusted $R^2 = 0.61$, $B = 0.41$, SE of $B = 0.15$, $t = 2.82$, $p = 0.008$) after multiple adjustments, but no independent association was found between the life dissatisfaction burden and the 5-year VAS score. (Table 2)

**Table 2.** Linear regression models showing associations with respect to the surgical outcome on 5-year follow-up (B-values shown with their standard errors).

<table>
<thead>
<tr>
<th></th>
<th>Oswestry Disability Index $^1$</th>
<th>VAS $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age $^1$</td>
<td>0.21 (0.16)</td>
<td>-0.15 (0.36)</td>
</tr>
<tr>
<td>Gender</td>
<td>3.58 (3.3)</td>
<td>1.64 (7.20)</td>
</tr>
<tr>
<td>Marital status</td>
<td>-0.08 (4.05)</td>
<td>1.29 (8.64)</td>
</tr>
<tr>
<td>Preoperative ODI $^1$</td>
<td>0.30 (0.12) *</td>
<td>NA</td>
</tr>
<tr>
<td>Preoperative VAS $^1$</td>
<td>NA</td>
<td>0.20 (0.16)</td>
</tr>
<tr>
<td>VAS on 5-year follow-up $^1$</td>
<td>0.27 (0.06)***</td>
<td>NA</td>
</tr>
<tr>
<td>ODI on 5-year follow-up $^1$</td>
<td>NA</td>
<td>1.04 (0.29)**</td>
</tr>
<tr>
<td>Life dissatisfaction burden $^1$</td>
<td>0.41 (0.15)**</td>
<td>-0.007 (0.35)</td>
</tr>
</tbody>
</table>

Statistical significance: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

LS = Life Satisfaction scale, ODI = Oswestry Disability Index, VAS = Visual Analogue Scale (estimation of overall back and leg pain); NA = not applicable

$^1$ = Continuous variable
7.2 DEPRESSIVE SYMPTOMS IN A 5-YEAR FOLLOW-UP (STUDY II)

A total of 17.7% (n = 11) of the patients had clinically significant, elevated depressive symptoms (BDI ≥ 15) at the 5-year follow-up point. According to self-reports, seven of the patients were using antidepressive medication at the 5-year follow-up point and three (43%) of these had BDI scores ≥ 15.

In cross-sectional analysis, the group with higher BDI scores preoperatively also had a slightly higher ODI at that point. The patients with a high depressive burden had higher ODI scores than those with a low depressive burden at all follow-up points. In addition, their walking distance was shorter on 1-, 2- and 5-year follow-up. There were no significant differences in VAS scores according to the depressive burden.

Within the low depressive burden group, the ODI and walking distance at the preoperative stage differed significantly from those at the 5-year follow-up (p < 0.001), indicating improvement after surgery. A similar difference was seen in the high depressive burden group (p < 0.05 and p < 0.05 respectively). No statistically significant differences were observed between preoperative and 5-year follow-up BDI or VAS values in either of the groups. (Table 3)
Table 3. Comparison of clinical characteristics at different follow-up points according to the depressive burden status on 5-year follow-up.

<table>
<thead>
<tr>
<th></th>
<th>Low depressive burden</th>
<th>High depressive burden</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BDI score [mean(SD)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preoperatively</td>
<td>5.80 (2.4)</td>
<td>13.11 (5.3)</td>
<td>***</td>
</tr>
<tr>
<td>on 1-year follow-up</td>
<td>3.10 (2.4)</td>
<td>12.61 (6.6)</td>
<td>***</td>
</tr>
<tr>
<td>on 2-year follow-up</td>
<td>3.47 (2.3)</td>
<td>10.89 (6.1)</td>
<td>***</td>
</tr>
<tr>
<td>on 5-year follow-up</td>
<td>5.33 (3.5)</td>
<td>12.46 (7.9)</td>
<td>***</td>
</tr>
<tr>
<td><strong>ODI [mean(SD)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preoperatively</td>
<td>37.02 (14.3)</td>
<td>48.11 (13.0)</td>
<td>**</td>
</tr>
<tr>
<td>on 1-year follow-up</td>
<td>16.09 (14.6)</td>
<td>31.81 (17.7)</td>
<td>**</td>
</tr>
<tr>
<td>on 2-year follow-up</td>
<td>15.50 (14.4)</td>
<td>30.50 (17.3)</td>
<td>**</td>
</tr>
<tr>
<td>on 5-year follow-up</td>
<td>18.90 (14.8)</td>
<td>32.00 (16.2)</td>
<td>**</td>
</tr>
<tr>
<td><strong>VAS [mean(SD)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preoperatively</td>
<td>30.30 (25.5)</td>
<td>31.50 (24.1)</td>
<td>ns</td>
</tr>
<tr>
<td>on 1-year follow-up</td>
<td>11.50 (19.2)</td>
<td>17.61 (20.0)</td>
<td>ns</td>
</tr>
<tr>
<td>on 2-year follow-up</td>
<td>8.40 (13.9)</td>
<td>11.81 (15.0)</td>
<td>ns</td>
</tr>
<tr>
<td>on 5-year follow-up</td>
<td>29.52 (26.3)</td>
<td>36.50 (28.6)</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Walking distance [mean(SD)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preoperatively</td>
<td>2121.63 (2545.0)</td>
<td>1225.54 (1410.8)</td>
<td>ns</td>
</tr>
<tr>
<td>on 1-year follow-up</td>
<td>5210.60 (4925.4)</td>
<td>2412.50 (3076.4)</td>
<td>**</td>
</tr>
<tr>
<td>on 2-year follow-up</td>
<td>4562.27 (3900.3)</td>
<td>2121.43 (2287.7)</td>
<td>**</td>
</tr>
<tr>
<td>on 5-year follow-up</td>
<td>4294.57 (4279.5)</td>
<td>2313.46 (3167.3)</td>
<td>**</td>
</tr>
</tbody>
</table>

Statistical significance: * p < 0.05; ** p < 0.01; *** p < 0.001
BDI = Beck Depression Inventory, ODI = Oswestry Disability Index, VAS = Visual Analogue Scale

The preoperative BDI had a significant correlation with the preoperative walking distance ($r = -0.253$, $p = 0.032$) and ODI ($r = 0.471$, $p = 0.001$). No significant correlation was seen between the preoperative BDI and preoperative VAS ($r = 0.225$, $p = 0.112$) or the area of tightest stenosis ($r = -0.159$, $p = 0.200$). The preoperative BDI showed no significant
correlation with the change in the ODI (r = 0.017, p = 0.904), VAS (r = 0.065, p = 0.609) or walking distance (r = 0.149, p = 0.234).

In linear regression model 1, an independent association was found between a high depressive burden and the 5-year ODI score (B = 9.37, SE of B = 3.92, t = 2.39, p < 0.05). In model 2, the same independent association of the depressive burden variable was seen when it was included as a continuous variable (B = 0.14, SE of B = 0.07, t = 2.18, p < 0.05). In model 3, a high BDI score at the 5-year follow-up was independently associated with a high ODI score (B = 0.57, SE of B = 0.26, t = 2.21, p < 0.05). The adjusted R² values varied between 64.4–65.5%. No associations were observed between depressive symptoms and VAS scores. (Table 4)
Table 4. Linear regression models showing associations with respect to the 5-year outcome of surgery (B-values with standard errors).

<table>
<thead>
<tr>
<th>MODEL 1</th>
<th>Oswestry Disability Index</th>
<th>VAS score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.30 (0.19)</td>
<td>-0.11 (0.51)</td>
</tr>
<tr>
<td>Gender</td>
<td>-4.53 (3.86)</td>
<td>-1.53 (-19.6–16.6)</td>
</tr>
<tr>
<td>Marital status</td>
<td>- 1.0 (4.05)</td>
<td>-1.36 (9.61)</td>
</tr>
<tr>
<td>Preoperative ODI</td>
<td>0.27 (0.13)</td>
<td>NA</td>
</tr>
<tr>
<td>Preoperative VAS</td>
<td>NA</td>
<td>0.36 (0.19)</td>
</tr>
<tr>
<td>VAS on 5-year follow-up</td>
<td>0.18 (0.07) *</td>
<td>NA</td>
</tr>
<tr>
<td>ODI on 5-year follow-up</td>
<td>NA</td>
<td>0.83 (0.38) *</td>
</tr>
<tr>
<td>Depressive burden (Low/high)</td>
<td>9.37 (3.92) *</td>
<td>-3.53 (9.95)</td>
</tr>
<tr>
<td>Walking distance on 5-year follow-up</td>
<td>-0.002 (0.000) **</td>
<td>0.000 (0.001)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MODEL 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative ODI</td>
<td>0.29 (0.13) *</td>
<td>NA</td>
</tr>
<tr>
<td>Preoperative VAS</td>
<td>NA</td>
<td>0.38 (0.20)</td>
</tr>
<tr>
<td>VAS on 5-year follow-up</td>
<td>0.19 (0.07) *</td>
<td>NA</td>
</tr>
<tr>
<td>ODI on 5-year follow-up</td>
<td>NA</td>
<td>0.85 (0.37) *</td>
</tr>
<tr>
<td>Depressive burden</td>
<td>0.14 (0.07) *</td>
<td>-0.9 (0.16)</td>
</tr>
<tr>
<td>Walking distance on 5-year follow-up</td>
<td>-0.001 (0.000) **</td>
<td>0.000 (0.001)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MODEL 3</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative ODI</td>
<td>0.34 (0.12) **</td>
<td>NA</td>
</tr>
<tr>
<td>Preoperative VAS</td>
<td>NA</td>
<td>0.20 (0.18)</td>
</tr>
<tr>
<td>VAS on 5-year follow-up</td>
<td>0.18 (0.07) **</td>
<td>NA</td>
</tr>
<tr>
<td>ODI on 5-year follow-up</td>
<td>NA</td>
<td>0.81 (0.47) *</td>
</tr>
<tr>
<td>BDI on 5-year follow-up</td>
<td>0.57 (0.26) *</td>
<td>0.24 (0.67)</td>
</tr>
<tr>
<td>Walking distance on 5-year follow-up</td>
<td>-0.001 (0.000) **</td>
<td>0.000 (0.001)</td>
</tr>
</tbody>
</table>

Statistical significance: *p < 0.05; **p < 0.01; ***p < 0.001
BDI = Beck Depression Inventory, ODI = Oswestry Disability Index, VAS = Visual Analogue Scale
NA = not applicable
¹ = Continuous variable
7.3 SENSE OF COHERENCE IN A 5-YEAR FOLLOW-UP (STUDY III)

The group with a lower SOC at the three-month follow-up point also concurrently had higher pain ratings, more depressive symptoms and less satisfaction with life than the group with a higher three-month SOC. At the five-year follow-up point, a low three-month sense of coherence was associated with more depressive symptoms, lower life satisfaction, higher pain ratings, lesser satisfaction with surgery and a poorer functional ability (ODI). (Table 5.)

In the follow-up, we compared the change within the groups with a lower and higher three-month sense of coherence. In the group with a lower sense of coherence, the changes between three-month and five-year follow-ups were significant in the ODI, the latter being worse. (Table 5.)

In the group with a higher three-month sense of coherence, the VAS and BDI were higher and SOC was lower at the five-year than at the three-month follow-up point. However, satisfaction with surgery was higher at the five-year follow-up point. (Table 5.)
Table 5. Three-month and five-year characteristics in relation to the three-month sense of coherence. Statistical differences are indicated between the SOC groups (p-value column), and between three-month and five-year characteristics (after the latter).

<table>
<thead>
<tr>
<th></th>
<th>Low three-month (SOC&lt;73, n=32)</th>
<th>SOC High three-month (SOC&gt;=73, n=42)</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age [mean (SD)]</strong></td>
<td>69.5 (12.8)</td>
<td>65.8 (9.6)</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Gender [% male]</strong></td>
<td>34.4</td>
<td>35.7</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Marital status [% married/living with a partner]</strong></td>
<td>89.5</td>
<td>77.8</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Number of comorbidities [mean (SD)]</strong></td>
<td>5.7 (3.8)</td>
<td>5.3 (3.5)</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Three-month walking distance [mean (SD)]</strong></td>
<td>2506.2 (2125.8)</td>
<td>3235.7 (3770.6)</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Five-year walking distance [mean (SD)]</strong></td>
<td>2474.3 (2539.3) ns</td>
<td>3212.6 (4295.8) ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Three-month ODI [mean (SD)]</strong></td>
<td>27.1 (16.0)</td>
<td>21.8 (17.1)</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Five-year ODI [mean (SD)]</strong></td>
<td>32.1 (16.2) *</td>
<td>20.4 (15.0) ns</td>
<td>**</td>
</tr>
<tr>
<td><strong>Three-month VAS [mean (SD)]</strong></td>
<td>32.2 (24.3)</td>
<td>14.2 (17.9)</td>
<td>***</td>
</tr>
<tr>
<td><strong>Five-year VAS [mean (SD)]</strong></td>
<td>44.4 (26.7) ns</td>
<td>27.9 (27.1) *</td>
<td>*</td>
</tr>
<tr>
<td><strong>Three-month satisfaction with surgery [mean (SD)]</strong></td>
<td>1.55 (0.9)</td>
<td>1.64 (1.0)</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Five-year satisfaction with surgery [mean (SD)]</strong></td>
<td>1.10 (1.5) ns</td>
<td>1.98 (0.9) *</td>
<td>**</td>
</tr>
<tr>
<td><strong>Three-month BDI [mean (SD)]</strong></td>
<td>9.3 (5.5)</td>
<td>5.5 (3.9)</td>
<td>***</td>
</tr>
<tr>
<td><strong>Five-year BDI [mean (SD)]</strong></td>
<td>11.8 (7.4) ns</td>
<td>7.2 (6.0) *</td>
<td>**</td>
</tr>
<tr>
<td><strong>Three-month LS [mean (SD)]</strong></td>
<td>9.2 (3.1)</td>
<td>7.1 (2.0)</td>
<td>***</td>
</tr>
<tr>
<td><strong>Five-year LS [mean (SD)]</strong></td>
<td>9.8 (3.4) ns</td>
<td>7.8 (2.6) ns</td>
<td>**</td>
</tr>
<tr>
<td><strong>Three-month SOC [mean (SD)]</strong></td>
<td>61.9 (8.0)</td>
<td>81.6 (4.6)</td>
<td>***</td>
</tr>
<tr>
<td><strong>Five-year SOC [mean (SD)]</strong></td>
<td>63.3 (11.9) ns</td>
<td>76.3 (9.9) **</td>
<td>***</td>
</tr>
</tbody>
</table>

Statistical significance: *p < 0.05; ** p < 0.01; *** p < 0.001, ns = nonsignificant (p > 0.05)
BDI = Beck Depression Inventory, LS = life satisfaction, ODI = Oswestry Disability Index, SD = standard deviation, SOC = sense of coherence, VAS = visual analogue scale (for pain)
In linear regression analysis, the three-month SOC and walking distance were independently associated with the five-year ODI. These associations remained the same after adjustments for three-month satisfaction with surgery, which also had an independent association with the five-year ODI (B = -4.06, SE = 2.02, p < 0.05). When the three-month BDI was adjusted for, the only significant association was between the three-month walking distance and five-year ODI (B = -0.00, SE = 0.00, p < 0.05). After adjustments for receiving/not-receiving PEI, the associations were similar to the first model, but PEI was not associated with the five-year ODI (B = -3.14, SE = 4.10, p = ns). (Table 6)

Table 6. Linear regression analysis in relation to the ODI and VAS at the five-year follow-up point (B-values shown with standard error).

<table>
<thead>
<tr>
<th></th>
<th>Five-year ODI</th>
<th>Five-year VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>0.27 (0.20) ns</td>
<td>0.20 (0.3) ns</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>2.82 (4.2) ns</td>
<td>11.60 (6.6) ns</td>
</tr>
<tr>
<td><strong>Three-month SOC</strong></td>
<td>-0.37 (0.18) *</td>
<td>-0.61 (0.28) *</td>
</tr>
<tr>
<td><strong>Three-month walking capacity</strong></td>
<td>-0.00 (0.00) **</td>
<td>-9.09e-5 (0.0) ns</td>
</tr>
<tr>
<td><strong>Three-month VAS</strong></td>
<td>-0.00 (0.9) ns</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Three-month ODI</strong></td>
<td>NA</td>
<td>0.56 (0.2) **</td>
</tr>
</tbody>
</table>

Statistical significance: *p < 0.05; **p < 0.01; ***p < 0.001, ns = nonsignificant (p > 0.05)  
NA = not applicable, ODI = Oswestry Disability Index, SOC = sense of coherence, VAS = visual analogue scale (for pain)

In the first linear regression model for the five-year VAS, the three-month ODI and SOC had an independent association with the five-year VAS. This association was also seen when BDI was adjusted for (B = -0.79, SE = 0.31, p < 0.01). In the model in which satisfaction with surgery was adjusted for, an association between the three-month SOC and five-year VAS was also seen (B = -0.62, SE = 0.28, p < 0.05). After adjusting for receiving/not receiving PEI, the associations were similar to the first model, and PEI had no association with the five-year VAS (B = -11.04, SE = 0.638, p = ns). (Table 6)
In linear regression analysis for the 5-year SOC, we used a model for the three-month variables. A significant association was detected between a low sense of coherence and a high BDI. When including receiving/not receiving PEI in the analysis, the same association between the three-month BDI and 5-year SOC was observed ($B = -1.33$, $SE = 0.34$, $p < 0.001$), and PEI was not associated with SOC.
7.4 LIFE SATISFACTION AND LIFE DISSATISFACTION BURDEN IN A 10-YEAR FOLLOW-UP (STUDY IV)

The mean life satisfaction score was 9.4 (SD 3.4) preoperatively and 8.4 (SD 3.3) at the 10-year follow-up (p < 0.01). The mean age of the study group at the 10-year follow-up point was 69 years, 37.5% were male and 58% were married or living with a partner.

In cross tabulations, the three-category long-term life dissatisfaction burden was positively associated with the ODI, VAS, BDI and LS, indicating poorer outcomes (Table 7).

Table 7. Clinical characteristics at the 10-year follow-up in relation the life dissatisfaction burden.

<table>
<thead>
<tr>
<th>Clinical characteristics</th>
<th>Low burden (n=17; range: 35–47)</th>
<th>Intermediate burden (n=19; range: 48–57)</th>
<th>High burden (n=18; range: 60–104)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [mean (SD)]</td>
<td>67.7 (7.2)</td>
<td>68.9 (11.6)</td>
<td>69.5 (10.9)</td>
<td>ns</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>35.3</td>
<td>36.8</td>
<td>22.2</td>
<td>ns</td>
</tr>
<tr>
<td>Marital status (% married/living with a partner)</td>
<td>76.5</td>
<td>52.6</td>
<td>38.9</td>
<td>ns</td>
</tr>
<tr>
<td>LS [median (IQR)]</td>
<td>6.0 (5.5-7.0)</td>
<td>7.0 (7.0-8.0)</td>
<td>11.0 (7.8-14.5)</td>
<td>***</td>
</tr>
<tr>
<td>Satisfaction with surgery [median (IQR)]</td>
<td>2.0 (2.0-3.0)</td>
<td>2.0 (1.0-2.5)</td>
<td>2.0 (1.0-2.0)</td>
<td>ns</td>
</tr>
<tr>
<td>ODI [median (IQR)]</td>
<td>10.0 (5.0-28.0)</td>
<td>24.0 (10.0-42.0)</td>
<td>42.0 (21.0-51.8)</td>
<td>**</td>
</tr>
<tr>
<td>VAS [median (IQR)]</td>
<td>10.0 (2.0-26.0)</td>
<td>18.5 (4.5-36.3)</td>
<td>58.0 (24.0-70.5)</td>
<td>**</td>
</tr>
<tr>
<td>Walking distance [median (IQR)]</td>
<td>3000.0 (1250.0 - 8999.5)</td>
<td>2000.0 (500.0 - 3500.0)</td>
<td>1000.0 (200.0-2500.0)</td>
<td>ns</td>
</tr>
<tr>
<td>BDI [median (IQR)]</td>
<td>3.0 (1.3-5)</td>
<td>6.0 (3.3-9.8)</td>
<td>13.5 (5.5-18.8)</td>
<td>**</td>
</tr>
</tbody>
</table>

Statistical significance: *p < 0.05; ** p < 0.01; *** p < 0.001, ns = nonsignificant (p > 0.05)

LS = Life Satisfaction Scale, ODI = Oswestry Disability Index, VAS = Visual Analogue Scale (estimation of overall back and leg pain), IQR = Interquartile range
In logistic regression analyses, the preoperative LS score and the life dissatisfaction burden were independently and positively associated with the 10-year ODI and VAS (Table 8), but no other significant associations emerged.

Table 8. The risk (OR 95% CI) of a poor surgical outcome defined by disability (ODI) and pain intensity (VAS) at the 10-year follow-up according to the logistic regression models.

<table>
<thead>
<tr>
<th>Variables in the model</th>
<th>ODI (&gt; 21%)</th>
<th>VAS (&gt; 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1†</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.06 (0.98–1.14)ns</td>
<td>1.01 (0.98–1.10)ns</td>
</tr>
<tr>
<td>Gender</td>
<td>2.06 (0.45–9.50)ns</td>
<td>1.97 (0.37–10.37)ns</td>
</tr>
<tr>
<td>Marital status</td>
<td>0.27 (0.05–1.56)ns</td>
<td>0.98 (0.21–4.49)ns</td>
</tr>
<tr>
<td>Preoperative ODI</td>
<td>NA</td>
<td>1.04 (0.98–1.10)ns</td>
</tr>
<tr>
<td>Preoperative VAS</td>
<td>0.98 (0.95–1.01)ns</td>
<td>NA</td>
</tr>
<tr>
<td>Preoperative walking distance</td>
<td>1.00 (1.00–1.00)ns</td>
<td>1.00 (1.0–1.0)ns</td>
</tr>
<tr>
<td><strong>Model 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative LS (continuous)</td>
<td>1.45 (1.14–1.84)**</td>
<td>1.31 (1.03–1.67)*</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS burden (continuous)</td>
<td>1.14 (1.04–1.25)**</td>
<td>1.05 (1.00–1.10)*</td>
</tr>
</tbody>
</table>

LS = Life Satisfaction Scale, ODI = Oswestry Disability Index, VAS = Visual Analogue Scale (estimation of overall back and leg pain), NA = not applicable.
† Model 2 had the same significances as Model 1 in relation to these variables.
Statistical significance: *p < 0.05, ** p < 0.01, ns = nonsignificant (p > 0.05)

Finally, in the model for 10-year life satisfaction, both preoperative BDI and the 10-year depression burden were associated with life dissatisfaction (LS > 12) at the 10-year follow-up. This was also the case for being unmarried/not living with a partner.
7.5 SUMMARY OF THE RESULTS

I  The life dissatisfaction burden, indicating long-term low life satisfaction, was negatively associated with the VAS and ODI in cross-sectional analysis at the 5-year follow-up point. In linear regression analysis, the life dissatisfaction burden was negatively associated with the 5-year ODI.

II  The depressive burden, indicating long-term depressive symptoms, was conversely associated with the ODI and walking distance cross-sectionally at the 5-year follow-up point. In linear regression analysis, the depressive burden was associated with the 5-year ODI.

III  The 3-month sense of coherence was associated with the 5-year ODI, VAS, LS, BDI and satisfaction with surgery at the 5-year follow-up point. In logistic regression analysis, it was associated with the ODI and VAS.

IV  At the 10-year follow-up point in cross-sectional analysis, the life dissatisfaction burden was associated with the ODI, VAS and BDI. In logistic regression analyses, preoperative LS and the LS burden were in separate models associated with the 10-year VAS and ODI.
8 Discussion

8.1 LIFE SATISFACTION IN A 5-YEAR FOLLOW-UP (STUDY I)

The long-term life dissatisfaction burden was associated with subjective 5-year disability, but not with pain intensity when age, marital status, preoperative disability and preoperative pain were adjusted for in LSS patients who underwent decompressive surgery.

Previously, the life satisfaction score in the Finnish general population aged 18 to 64 years has been reported to be 8.8, being 8.4 for the healthy and 9.4 for the ill (188). The latter was the same as the preoperative score of this study population, but after the surgery, life satisfaction improved during the five-year follow-up and reached the level of the general population. Although this improvement was not statistically significant, its magnitude indicates a good recovery or at least very successful coping with this surgically treated severe condition, its symptoms and aging. This is especially true considering that the mean age of the LSS patients was much higher than that of the general population, with the highest LS scores (i.e. highest dissatisfaction) being found amongst the 55- to 64-year-olds (183). The life satisfaction score has demonstrated considerable stability among healthy adults over a 15-year follow-up (189). The improvement in LSS patients after surgery should be viewed against this natural stability of the LS score, and the non-detected significance of the improvement against the quite small sample size. However, life satisfaction is also sensitive to intervention. This was apparent in the present study, and has also been seen among depressive outpatients, whose level of life satisfaction was lower than among LSS patients before, during and after the treatment interventions (184,336).

This study demonstrated that the long-term life dissatisfaction burden was linearly associated with the ODI, a measure of subjective disability. This was true even when
preoperative disability and 5-year pain assessment (VAS) were included in the same model. The long-term life dissatisfaction burden among LSS patients after surgical intervention reflects not only their well-being, but also the process of regaining security in their functional abilities. In addition, it associated with their overall satisfaction with surgery. Importantly, those with long-term life satisfaction reported better functional ability and lower pain ratings five years after surgery. Thus, evaluating the psychological well-being of patients throughout the recovery process might be important. In this study, the use of the life dissatisfaction burden variable was a new approach. This enabled us to evaluate the effects of long-term psychological distress and to take into account the effects of even lower dissatisfaction.

Both life satisfaction and pain are related in a complex way to regulation of the central nervous system. According to Sprangers et al. (210), the prefrontal cortex is a candidate brain area for positive emotional states. Both positive (increasing) and negative (decreasing) affect have an impact on pain tolerance (337). Among older adults, the processing of positive affect changes, resulting in the remembering of more positive than negative loaded information (338). The common explanation is, however, that the affect acts as a distractor (337,339). In the cross-sectional association found between LS and VAS, these phenomena may play a role. On the other hand, the strongest correlates of life satisfaction are closely related to environmental and psychosocial factors such as social support (187), and it is possible that after surgery, patients with LSS will regain at least some of their previous social functioning.

Monitoring life satisfaction pre- and postoperatively might enable the recognition of patients in need of additional psychosocial support as part of their treatment.
8.2 DEPRESSIVE SYMPTOMS IN A 5-YEAR FOLLOW-UP (STUDY II)

The most important finding in this study was that there was a clear difference in postoperative recovery measures between the depressive burden groups. A high depressive burden, a long-term indicator of clinical and subthreshold depression symptomatology, was associated with greater disability at the 5-year follow-up point in regression analysis with \( R^2 \) values between 64.4–65.5%.

Furthermore, the patients who had higher depressive burden showed poorer recovery from surgery throughout the follow-up when assessed with the Oswestry index. Previous studies have suggested a need for preoperative screening for depression in spinal conditions (12,13), and our results also demonstrate this need during the long rehabilitation period following LSS surgery. Similarly to our study, earlier observations have also shown that subclinical depressive symptoms are connected to poorer recovery from surgery and impairment in physical functioning and overall self-evaluated health (267,340,341).

It is important to note, that these results demonstrate improvement in the walking distance and ODI within both depressive burden groups, indicating overall positive effects of the surgery, i.e. depressive symptoms did not inhibit the gaining of benefit from surgery, even though the results were poorer. No longitudinal association was found between the depressive burden and VAS score, which could be explained by the low level of depressive symptoms in this sample or by adjustment to chronic pain.

When considering the possible mechanisms underlying these findings, there are several potential explanations. The association between immune function, pain and depression may play a role in the process of recovery from surgery (144,174,342,343).

With regard to the treatment of depression during the rehabilitation period, our study setting was naturalistic, i.e. no treatment protocols were specifically planned as a part of this observational study. Only 43% the depressed patients, according to the BDI score,
received antidepressive medication on 5-year follow-up; thus, the treatment of depression appears to have been inadequate. Moreover, antidepressants can also be used to treat chronic pain, and antidepressant use with a pain indication may have occurred in this sample as well. It is also possible that in some cases, depression was poorly recognised in this patient group.

As low back pain is the leading cause for years lived with disability globally, and depression the second leading cause, the interactions between the two deserve attention in both future research and clinical practice. The outcomes of this study emphasize the importance of subthreshold depressive symptoms in the long-term follow-up of LSS surgery. Psychosocial support for the patients with subthreshold depressive symptoms should be taken into consideration, as well as support for those with clinical depression. It would be important to assess whether the management of depression or depressive symptoms can improve the outcome of surgery.

### 8.3 SENSE OF COHERENCE IN A 5-YEAR FOLLOW-UP (STUDY III)

This was the first study to examine the associations between postoperative SOC and the long-term outcomes of LSS surgery. The analyses were performed according to the three-month sense of coherence, since this follow-up point after surgery was the time at which any possible activity restrictions were lifted on the instruction of the surgeon, and because of this, it can be a definitive changing point in the recovery process.

The main finding was the association between a low sense of coherence and a poorer surgical outcome. After multiple adjustments, the three-month sense of coherence had predictive value for both higher pain ratings and poorer functional capability at the five-year follow-up. The latter association has also been observed in a one-year follow-up (17). Low SOC has been linked with disability among surgically treated chronic LBP patients
Some studies considering other medical conditions have not detected such an association between SOC and disability (344). This could be explained by differences in the pathophysiological processes, symptoms and rehabilitation of medical problems.

When comparing participants with a higher and lower three-month SOC, life dissatisfaction, BDI and pain ratings were higher among those having a low sense of coherence at the three-month follow-up point. Interestingly, at the five-year follow-up, in addition to BDI, VAS and LS, the three-month sense of coherence was also associated with satisfaction with surgery and functional capability. Thus, the participants with a higher sense of coherence also had a better outcome at this later follow-up point.

Other studies have demonstrated that the surgical outcome in LSS often declines with time, but surgery is nevertheless considered to be more beneficial than conservative treatment for up to 3 to 4 years, and possibly even 10 years (299,301,302). In this study, the functional capability actually slightly weakened during the follow-up in the group with a lower three-month sense of coherence. Furthermore, in the group with a higher SOC, pain ratings, SOC and BDI were worse at the 5-year follow-up when compared with the three-month follow-up point. Interestingly, the group with a higher SOC was more satisfied with surgery five years than three months after the surgery, even though the pain ratings and BDI were slightly higher. This could be explained by their better adjustment to their illness and better coping mechanisms than participants in the group with a lower sense of coherence.

Interestingly, the mean SOC in this participant group (mean = 73) was higher than among the Finnish general population (mean = 64) (214) or among Finnish surgical low-back patients (mean = 65) (330). Our study population was older than in these earlier studies, and SOC has previously been shown to improve with age (215), which might explain the differences in the mean SOC. In studies on older patient groups (345), the mean SOC has been closer to the level of SOC in this study. Nevertheless, those with a lower SOC, which
was still relatively high, had a poorer outcome. The associations between aging, health and SOC require further investigation.

In linear regression analysis, a strong association was observed between BDI and SOC. This is in line with earlier findings and underlines the significance of depressive symptoms in connection with a low SOC. These results also suggest that those with a high postoperative SOC might benefit more from surgery in the long term and for a longer time than those with a low postoperative SOC. Thus, monitoring postoperative psychological distress would enable the identification of those at risk of poorer recovery.

Altogether, these associations between SOC and different psychological and physical variables support the salutogenic model of health in the LSS participant group. Those with a higher sense of coherence appeared to have a better outcome after surgery. The LSS participants with a lower postoperative SOC (i.e. more psychological distress) did not appear to gain as much benefit from the surgery as those with better psychological well-being, and depressive symptoms were also more common among them. In the future, psychological well-being should be taken into account when evaluating surgical patients preoperatively and during postoperative rehabilitation. Further research is needed to investigate the effects of interventions aimed at increasing postoperative SOC in patients with LSS.

**8.4 LIFE SATISFACTION IN A 10-YEAR FOLLOW-UP (STUDY IV)**

The main finding in this study was that life dissatisfaction was associated with poorer outcomes of LSS surgery during a long-term follow-up measured with several indicators. After multiple adjustments, both the preoperative dissatisfaction with life and 10-year life dissatisfaction burden associated with greater disability and more pain ten years after the
surgery. It is also noteworthy that preoperative disability, the pain level and walking distance were not predictive for the 10-year overall outcomes.

In a previous study, preoperative life dissatisfaction predicted disability after a two-year period (16). In Study I, the life dissatisfaction burden predicted disability five years after surgery. The present study demonstrated that both preoperative life satisfaction and the life dissatisfaction burden have the same significant association up to 10 years after surgery, indicating an even more persistent relationship.

The mean life satisfaction score among healthy individuals in the Finnish general population has been reported as 8.4 (188), which is the same as in this patient group 10 years after surgery, and the level that was already reached at the 5-year follow-up point. As mentioned before, LS was significantly higher preoperatively, indicating more dissatisfaction with life. Surgery, as well as subsequent rehabilitation, can be seen as a life-changing event, which might explain the change in the life satisfaction of the study subjects during the follow-up. The change in life satisfaction can be considered as a global sign of good recovery from surgery, including both somatic and mental well-being.

When comparing patients according to their levels of life satisfaction, those reporting more satisfaction with life had lower levels of disability, less pain and fewer depressive symptoms than those with less satisfaction with life. Thus, life satisfaction is closely associated not only with several psychological factors, but according to the present study, with the long-term surgical outcome. Another important aspect of this study is that it demonstrated the close and persistent long-term association between depressive symptoms and life dissatisfaction. In this patient group, life satisfaction and depressive symptoms can modulate the outcomes several years postoperatively. Thus, the associations between life satisfaction and surgical outcomes appear multidimensional.

The life dissatisfaction burden enables an evaluation of the effects of the long-term
cumulative mental burden or distress, as well as good subjective well-being. Compared with utilizing single measurement scores, this cumulative life dissatisfaction measure enables more sensitive evaluation of the potential effects of dissatisfaction with life on well-being.

Monitoring of subjective well-being of LSS patients before and after surgery may help in detecting those at risk of a poorer surgical outcome in the long-term. Well-being can be monitored by evaluating, for instance, life satisfaction and mood. Studies focusing on multimodal approaches in the post-operative rehabilitation of LSS are needed to determine whether the addition of psychosocial support would be beneficial in the treatment of LSS patients after surgery.

8.5 METHODOLOGICAL CONSIDERATIONS

The conclusions are based on a relatively small sample size, which is a limitation of this study. Some of the patients could not be reached at all follow-up points and some did not complete all the questionnaires. However, when the drop-outs at the 5-year follow-up point were compared with the study-subjects with respect to baseline characteristics, no significant differences were found between them, while after 10 years of follow-up, the drop-outs were slightly older. Some selection bias may have occurred, as reported earlier by Aalto (314) at the beginning of the study: some of the patients refused to participate in the postoperative rehabilitation intervention and were included in the control group. However, in two-block randomization, this can be considered as a random event. Nevertheless, the rehabilitation did not influence the outcome (19). The attrition rate was 27.5%, similarly to earlier follow-up studies focused on LSS surgery (274,346). We could have also used a control group for comparison of functional ability and pain, for example, but since the study group consisted of patients who were evaluated to be in need of
surgery, this type of study setting would have caused ethical concern. In addition, our study design was observational, which does not allow for the establishment of causality, unlike RCTs.

The analyses were based on self-reported questionnaires, which are subjective in nature. Evaluation of the mental status with a diagnostic interview by a doctor, psychiatrist or a psychologist would have provided more objective evaluation. The main outcome measures were also based on self-evaluation, and some more objective measures could have been used (e.g. treadmill tests, inflammatory markers). Subjective evaluations are affected by factors such as personality and circumstances, and the answers are often presented so as to be socially acceptable (347). Nevertheless, subjective measures are often used and self-evaluation has been found to predict long-term outcomes, and the importance of, for example, patient satisfaction after treatments has been recognized, as described earlier. In addition, the studied factors are subjective in nature. Experience of pain is an intimate internal experience and self-report is the golden standard in its evaluation. Although mental health problems are diagnosed by clinicians, mental well-being is an especially subjective experience and subjective evaluation is a necessity in gaining information on it.

Psychiatric evaluation of the study subjects with a clinical interview by a physician or a psychiatrist would have given us better information on the overall psychological health of the study subjects, and would have provided us with diagnostic evaluation. Another possibility could have been the use of structured interviews, e.g. SCID. With respect to depression, we have chosen to use the expression “depressive symptoms”, since the BDI is not a direct diagnostic tool. Nevertheless, with our cut-off, the sensitivity and specificity are good, and the value is clinically important (93,334). There is also current debate on the diagnostic systems, and whether the categorical systems ICD and DSM should be replaced by dimensional systems (32). Nevertheless, the specific focus of this study was on
subclinical symptoms and more positive indicators of mental health, not on diagnosed mental health problems.

We only investigated some possible psychological factors and some outcome measures, and certain other factors (e.g. social support, amount of physical activity, anxiety, possible psychiatric diagnoses) might therefore have given more information and understanding on the matter. The factors studied were nevertheless chosen based on earlier findings, and the coefficients of determination of the statistical models that were used were high. Some unrecorded psychosocial factors (e.g. self-esteem, social isolation and self-worth) might potentially be confounders. In addition, sedentary lifestyle patterns could explain the results, regardless of the variables we investigated.

The questionnaires were chosen based on the earlier research literature. Furthermore, the easy usability in clinical practice supported their usage. The Oswestry Disability Index has been recommended as an outcome measure for spinal conditions (308,348), while the VAS is valid and reliable, as well as in wide clinical use and fast and easy for both patients and doctors (315,316). The BDI may be influenced by physical conditions. Nevertheless, it is one of the recommended tools for screening depression in spinal pain patients (93). The BDI is also acceptable and easy to use for both patients and clinicians, and is in wide clinical use, which allows for direct clinical comparisons. The four-item self-administered LS scale has been well accepted by both the general population (183) and by psychiatric patients (198), being a useful tool for monitoring life satisfaction.

The study also had several strengths. The long follow-up time is a definitive strength, since earlier research has had significantly shorter follow-up times. The extensive follow-up time enabled us to examine the long-term outcomes, and take into account several observation points and cumulative evaluations, all of which strengthen the importance of these findings. The study design was naturalistic, i.e. the study group consisted of ordinary LSS patients operatively treated at the secondary level (despite the university
setting), and participation in the study did not influence their treatment, which makes the results applicable to regular clinical practice.

8.6 SUMMARY OF THE DISCUSSION

All of the studied psychological factors were associated with the results of LSS surgery in a long-term follow-up. According to this study, psychological factors are especially associated with the ODI, as both the 5-year and 10-year follow-ups showed the association with respect to all of the measured psychological factors in regression analyses. In addition, sense of coherence and LS were associated with the VAS in regression analyses.

In cross-sectional analyses the associations between the measured variables were even more extensive. Life satisfaction associated with the ODI and VAS at both follow-up points, the BDI with the ODI and walking distance, and SOC with the ODI, VAS and satisfaction with surgery. The psychological factors were also associated with each other.

The mechanisms explaining these complex associations between pain, psychological factors and disability are still unclear. Different biological (e.g. inflammation, different neurotransmitter levels), psychological (e.g. coping skills, resilience) and social (e.g. support, treatment options) factors are likely to be intricately connected, and their associations need to be studied further.

The main limitations of this study were the small sample size, use of only subjective measures, and studying only some possible factors and using only certain outcome measures. The main strengths are the long follow-up time and the applicability of the results to regular clinical practice.
These results indicate the need to evaluate the psychological well-being of LSS patients. In addition to recognizing psychiatric disorders (such as depression), subclinical symptoms also need attention, as well as positive psychological modulators of health. Studies that include psychological evaluation and psychosocial support as part of treatment are needed. The psychological well-being of LSS patients is intricately connected with the outcome of surgery in the long-term and deserves attention in clinical practice.
9 Conclusions and recommendations

This study demonstrated that psychological factors play an important part in the recovery from lumbar spinal stenosis surgery. Depressive symptoms, life satisfaction and sense of coherence all modulate the outcomes. This follow-up revealed the association of psychological and physical factors up to 10-years after surgery.

Intervention studies are needed in order to examine whether by improving life satisfaction, sense of coherence or relieving the symptoms of depression, the surgical outcome of LSS could be improved.

These observations also deserve attention in clinical practice. When planning multimodal approaches to rehabilitation, psychosocial support for patients with depressive symptoms, low life satisfaction or low sense of coherence should be taken into consideration, in addition to support for those with clinical depression. Intensified monitoring of different psychological properties would enable us to identify those at risk of a poorer surgical outcome.

This study demonstrated that psychological factors are closely connected to the surgical outcome, even ten years after surgery, indicating a long and prevailing relationship that cannot be overlooked. Thus, the use of several supportive measures before and after the surgical procedure could allow more patients to enjoy the full benefits of surgery in the long term. Psychological well-being should be taken into account when evaluating surgical patients preoperatively and also during the postoperative rehabilitation period.
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This thesis aims to clarify the relationship between life satisfaction, depressive symptoms and sense of coherence and outcomes of lumbar spinal stenosis surgery in a long-term follow-up. The results show that even slightly more psychological distress is associated with less benefit from surgery. This study demonstrated that psychological factors are closely connected to the surgical outcome, even ten years postoperatively, indicating a long and prevailing relationship that cannot be overlooked.