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Pelvic Girdle Pain and Lumbar Pain in Relation to Pregnancy

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To Janne,
Julia and Janelle

"Nothing in science has any value to society if it is not communicated."
Anne Roe

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ABSTRACT

The prevalence of low back pain (LBP) is higher in pregnant women compared to women of the same age in a general population. Pregnancy-related LBP persists 6 years after pregnancy in 16% of women. Consequently, pregnancy represents a specific risk for LBP and persistent LBP. Pregnancy-related LBP is usually studied as a single entity, however, only one subgroup of LBP, i.e. pelvic girdle pain (PGP), seems to be associated with pregnancy. Accordingly, possible differences in subgroups of patients with LBP are unknown.

The aims of this thesis were the following: 1) to describe the prevalence of clinically classified subgroups of women with LBP in a cohort (no LBP, lumbar pain, PGP, and combined pain (PGP and lumbar pain)) during pregnancy and postpartum, and 2) to determine if there was a disparity in the course, health-related quality of life (HRQL), pain intensity, disability, depressive symptoms, or muscle function in subgroups of the cohort, and 3) to identify predictors for having persistent pregnancy-related PGP postpartum.

Consecutively-enrolled pregnant women were classified into LBP subgroups by mechanical assessment of the lumbar spine, pelvic pain provocation tests, standard history, and pain drawings. All women answered questionnaires (background data, EQ-5D). Women with LBP completed the Oswestry Disability Index and pain measures. The Edinburgh Postnatal Depression Scale was used to evaluate depressive symptoms at 3 months postpartum (cut-off ≥10). Trunk muscle endurance, hip muscle strength, and gait speed were investigated. Multiple logistic regression was used to identify predictors from self-reports and clinical examination.

At the 12-18 gestational week evaluation, 118/308 (38%) women had no LBP, 33 (11%) had lumbar pain, 101 (33%) had PGP, and 56 (18%) had combined pain. Three months postpartum, 183/272 (67%) women had no LBP, 29 (11%) had lumbar pain, 46 (17%) had PGP, and 14 (5%) had combined pain. Pregnant women with combined pain were most affected in terms of HRQL, pain intensity, and disability. Depressive symptoms were three times more prevalent in women with LBP (27/87, 31%) than in women without LBP (17/180, 9%). Women with PGP and/or combined pain had lower values for trunk muscle endurance, hip extensor strength and gait speed compared to women without LBP. Postpartum, 16-20% of the women had persistent combined pain or PGP, whereas 1/29 had lumbar pain. Predictors for

persistent PGP or combined pain were work dissatisfaction, older age, combined pain in early pregnancy, and low endurance of the back flexors.

In conclusion, women with combined pain were identified to be a target group since they had the lowest recovery rate and since the classification of combined pain was found to be a predictor for persistent PGP or combined pain postpartum. The hypothesis of an association between muscle dysfunction and PGP was strengthened. Based on the finding of high comorbidity of postpartum depressive symptoms and LBP, it seems important to screen for and consider treatment strategies for both symptoms.

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LIST OF PAPERS

I. Annelie Gutke, Hans Christian Östgaard, Birgitta Öberg. *Pelvic Girdle Pain and Lumbar Pain in Pregnancy: A cohort study of the consequences in terms of health and functioning*. Spine 2006; 31(5): E149-155

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III. Annelie Gutke, Hans Christian Östgaard, Birgitta Öberg. *Muscle function in pregnancy-related low back pain. A prospective cohort study in early pregnancy and postpartum.* Submitted

IV. Annelie Gutke, Hans Christian Östgaard, Birgitta Öberg. *Predicting persistent pregnancy-related low back pain.* Submitted

ABBREVIATIONS

ASLR	Active Straight Leg Raising Test
BMI	Body-Mass-Index
EPDS	Edinburgh Postnatal Depression Scale
EQ-5D	European Quality of Life 5 Dimensions Questionnaire
HRQL	Health-Related Quality of Life
ICC	Intraclass Correlation Coefficient
LBP	Low Back Pain
LP	Lumbar Pain (Paper I)
MDT	Mechanical Diagnosis and Therapy
MIC	Minimal Important Change
MID	Minimal Important Difference
ODI	Oswestry Disability Index
OR	Odds Ratio
PGP	Pelvic Girdle Pain
PPGP	Pregnancy-related Pelvic Girdle Pain (Paper I); the same classification as PGP in Papers II-IV
RCT	Randomised Controlled Trial
RDQ	The Roland-Morris Disability Questionnaire
SF-36	The Short Form 36 Health Survey
SIJ	Sacroiliac Joint
VAS	Visual Analogue Scale

DEFINITIONS

Back pain	A general term used when the study referred to do not specify localisation.
Centralisation	If, as a result of repeated movements or positions, the radiating symptoms originating from the spine and referred distally, regress proximally towards the lumbar midline of the spine (57). Opposite of peripheralisation.
Clinical natural course	Defined as without directed intervention from the study except for evaluation of low back pain (269).
Combined pain	Affected by the two syndromes pelvic girdle pain and lumbar pain.
Delivery	Giving birth.
Disability	A general term for impairment, activity limitations, and participation restrictions from the problematic aspect, according to ICF 2001 (255).
Functioning	A general term for all body functions, activities, and participation from a healthy perspective, according to the ICF 2001 (255).
Low back pain	Pain and discomfort localised below the costal margin and above the inferior gluteal folds, with or without leg pain (242).
Lumbar pain	Pain perceived as arising from anywhere within a region bounded superiorly by an imaginary transverse line through the tip of the last thoracic spinous process, inferiorly by an imaginary transverse line through the tip of the first sacral spinous process, and laterally by vertical lines tangential to the lateral borders of the lumbar erector spinae (151).
Lumbopelvic pain	Including the syndromes pelvic girdle pain and/or lumbar pain (267).
Nonpregnancy-related low back pain	Low back pain present outside pregnancy with no known association to a pregnancy like time of debut.
Pelvic girdle pain	Pain experienced between the posterior iliac crest and the gluteal fold, particularly in the vicinity of the

	sacroiliac joints. The pain may radiate in the posterior thigh and can also occur in conjunction with/or separately in the symphysis (258).
Peripheralisation	If, as a result of repeated movements or positions, the radiating symptoms originating from the spine and referred distally, progress farther distally (57). Opposite of centralisation.
Persistent pain	Pain present most of the time or recurrent episodes ≥12 weeks.
Postpartum	After delivery (American English), similar to postnatal (British English).
Predictor variable	Explanatory variable or covariate (6).
Pregnancy-related low back pain	Low back pain present in pregnancy.
Red flag	A symptom described by the patient that may indicate serious pathology (242).
Risk factor	A determinant that influences the incidence (relative risk) (193).
Sensitivity	The ability of a test to identify the patients with the condition (224).
Specificity	The ability of a test to identify the absence of a condition (224).

INTRODUCTION

The starting point of this thesis was based on the histories of many women who suffered from low back pain (LBP) in relation to their pregnancy. Women who previously had experienced of LBP recurrently stated that they experienced a "new" form of LBP while pregnant. The "new" LBP was different in terms of location and character as well as included new symptoms. It could occur instead of or in addition to the previously experienced intermittent LBP. Descriptions such as "a very strong training ache that spread", "I feel like my body is falling apart", and "my hip is locking" were descriptions not typically heard in relation to nonpregnancy-related LBP.

LBP in pregnancy is sometimes looked upon as a normal consequence of pregnancy that the woman must endure. The question has arisen as to what impact pregnancy-related LBP has on daily life. Previous descriptions of the impact of pregnancy-related LBP on functioning have mostly been obtained from self-reported pain increasing activities or sick leave reports. Therefore it is difficult to compare results between studies and to compare with studies on nonpregnancy-related LBP.

Throughout the years, one clinical opinion has been that women with pregnancy-related LBP are women who are less tolerant to pregnancy, either physically or mentally. The question has arisen as to whether there is a difference in muscle function in women who have pregnancy-related LBP compared to pregnant women without LBP. Additionally, is there an association between persistent LBP and mental health, which should be considered by the caregiver when planning the treatment strategies?

After delivery, the majority of women report that the "new" type of LBP disappears whereas the "old" bad back remains. However what happens when the "new" LBP persists beyond delivery? Furthermore, is it possible to predict early on who is at risk for persistent LBP postpartum?

BACKGROUND

TERMINOLOGY

Pain localisation is one way of classifying low back pain (LBP). LBP has been defined as pain located between the twelfth rib and the gluteal folds (89, 242). In this thesis the terms low back pain, pelvic girdle pain and lumbar pain are used.

Low Back Pain is considered as an umbrella term for pain localised in the pelvic and lumbar regions. The numerous terms for pregnancy-related LBP in the pelvis (267) reflect the uncertainty of the etiology and to date, it is considered a syndrome, i.e. a group of signs or symptoms whose appearance together usually indicates the presence of a particular disease or disorder (Chambers Reference Online). There existed a need for a term that described the pregnancy-related LBP syndrome and included the ligaments, joint capsules and muscles in the pelvis, as well as the sacroiliac joint (SIJ) and that excluded gynecological and/or urological disorders. The term *Pelvic Girdle Pain* (PGP) was proposed, with the following definition: "*Pelvic girdle pain (PGP) generally arises in relation to pregnancy, trauma or reactive arthritis. Pain is experienced between the posterior iliac crest and the gluteal fold, particular in the vicinity of the sacroiliac joints (SIJ). The pain may radiate in the posterior thigh and can also occur in conjunction with/or separately in the symphysis. The endurance capacity for standing, walking and sitting is diminished. The diagnosis of PGP can be reached after exclusion of lumbar causes. The pain or functional disturbances in relation to PGP must be reproducible by specific clinical tests.*"(258).
In this thesis, the PGP that arises in relation to pregnancy is studied.

The term *Lumbar Pain* is used for pain that is of lumbar origin (151), with or without radiation in the leg, and without a specifically defined pain structure.

EPIDEMIOLOGY

Prevalence of low back pain in women

In general, women report more musculoskeletal pain than men (15, 114, 257). Among all musculoskeletal disorders, LBP is the largest entity (195). In a general population, it has been found that 10-28% of women relate their debut of LBP to a pregnancy (20, 229).

Pregnancy-related back pain has been reported from all over the world (2, 24, 55, 61, 72, 128, 137, 138, 150, 157, 169, 174, 185, 235, 236, 241, 245, 263). The incidence of back pain in pregnancy is rarely reported, and the 2 studies identified showed a large variation (27-61%) (116, 177). In a recent review, the period prevalence of any type of LBP was estimated to 45% (range 3.9-89.9%) in pregnancy and 25% (range 0.3-67%) postpartum (267). Although not directly in association with the pregnancy term, a self-reported 1-year period prevalence of LBP of 45-54% was found in general Nordic populations of 30 to 50 year old females (126). The point prevalence of LBP in the female reproductive years has been self-reported as 26% in the 25-44 year age band (195), and 20% in the 16-44 year age band (237). The point prevalence of LBP in pregnant women is increased (range 22-63.4%) compared to women of the same mean age (6.3%) in a general population (19, 116, 177). Sixteen percent of women with pregnancy-related LBP reported persistent pain 6 years after childbirth (182). Pregnancy is thereby a specific situation that increases the risk of LBP, as well as the risk of persistent LBP.

The prevalence of LBP in pregnancy and postpartum is mostly based upon self-reports through questionnaires or interviews (24, 61, 66, 128, 138, 154, 169, 176, 177, 185, 211, 235, 236) and rarely confirmed and classified with clinical evaluation (3, 14, 116, 121, 183). Differences in terminology, methodology, including different classification criteria for the studied syndrome, and the samples under study, e.g. only those with pain warranting medical help, are plausible causes for the wide range in reported prevalence.

In a few studies, PGP was clinically differentiated from pain of lumbar origin. The reported prevalence of PGP during pregnancy was found to be 14-28% (2, 121, 157) and 4-5% 2-3 months postpartum. The prevalence of lower lumbar pain in pregnancy was reported as 6.5% by Albert et al. (2000) (2) and as 13.2%

by Mousavi et al. (2007) (157), however the postpartum prevalence of lumbar pain is unknown.

It is complicated to compare the prevalence of pregnancy-related LBP with the epidemiology of LBP in general populations. Besides methodological differences, general populations usually have broader age ranges, older age bands, LBP of longer duration, and are not gender differentiated. However, it does appear that the 9-month prevalence, as well as the point prevalence of LBP in a pregnancy is higher compared to women of the same age in a general population.

Course and predictors of low back pain

More than 70% of the industrialized population has LBP sometime during their lifetime. Among patients with acute LBP, 76-90% improved within 1 month (8, 44, 79), regardless of the type of treatment received (99). However these numbers do not refer to complete recovery. The majority continue to be symptomatic after 1 year, with only 21% having recovered with regard to pain and 25% with regard to disability (48). Within a year, relapses are seen in 60% (range 44-78%) of the patients (89). Nonspecific LBP is increasingly regarded as having a persistent, fluctuating symptom course with intermittent flares (48, 262).

Most women recover from pregnancy-related LBP, although the risk of LBP in a subsequent pregnancy is high (36). Improvement is apparent until about 3-6 months postpartum (112, 176, 182). For those women with persistent pain at 3 months postpartum, the risk of long-term problems is great (176, 182), which is similar to nonpregnancy-related LBP of duration longer than 3 months (89). The time point may have an association with the early findings of the remission of joint relaxation, which terminates 6 months postpartum at the latest (90). In a 12-year follow-up study of women with LBP severe enough to require sick leave while pregnant, 92% reported LBP during a subsequent pregnancy and 86% had recurrent LBP while not pregnant (36).

One of the most frequently reported predictors for either developing LBP during pregnancy or having persistent LBP postpartum is the previous experience of LBP, either in an earlier pregnancy or outside the pregnancy (11). Reported premorbid risk factors are trauma of the back or pelvis, (5), previous lower abdominal pain (121), and multiparity (5, 177). A greater

number of years of previous regular leisure physical activity decreased the risk of developing pregnancy-related LBP (153). Reported episode-related factors for LBP in pregnancy are lack of exercise (121), younger age (177), higher levels of stress, work dissatisfaction (5), uncomfortable working conditions (121, 177), occupations described as mainly physically demanding (153), and higher BMI (116).

Episode-related factors associated with persistent LBP and PGP include features specific to the pain episode (severity of complaints, earlier onset of pain, high pain intensity, and walking deficiency), and maternal factors (higher BMI, age, and joint hypermobility)(11, 154, 211). Lumbar pain has shown a stronger association to pre-pregnancy LBP (14, 183), while PGP is more closely related to a pregnancy in occurrence and recurrence. The self-reported predictors and course of pregnancy-related LBP postpartum are partly known, but not for clinically classified subgroups of patients with pregnancy-related LBP. Thus it is not known whether or not a specific subgroup of patients with pregnancy-related LBP has an increased risk for persistency.

PREGNANCY-RELATED PELVIC GIRDLE PAIN AND LUMBAR PAIN

Several authors have identified PGP and lumbar pain as 2 major subtypes of pain in the lower part of the spine and in the pelvis during pregnancy (38, 40, 61, 116, 157, 183, 189, 228, 238). Women with PGP have a different clinical presentation than women with lumbar pain (Table 1)(183, 228). Clinical experience, as well as previous research, suggest different treatment strategies for PGP and lumbar pain in relation to pregnancy (183, 189). It has been stated that PGP can worsen if treated as general nonpregnancy-related LBP (183). It has further been reported that PGP and PGP combined with lumbar pain (combined pain) have a greater impact on daily activity such as walking and housework than lumbar pain alone 3 years after pregnancy (168).

Table 1. Characteristic features of pregnancy-related Pelvic Girdle Pain and Lumbar Pain from clinical experience.

Features	Pelvic Girdle Pain	Lumbar Pain
Pain Location	Deep uni/bilateral pain in buttocks between iliac crest and gluteal fold, distal to lumbar spine or in the symphysis. May radiate to posterolateral thigh, to knee, rarely to calf, never to foot.	Pain origin in and beside the lumbar spine, with or without radiation to leg or foot.
Functional Limitations	Prolonged positions or activities, above all sitting, standing, walking. Activities involving abduction-external rotation of hip or asymmetrical loading of the pelvis	Some positions or activities decrease pain; others increase.
Clinical Features	Catching of the leg*. Delay in pain response. Pain debut in relation to pregnancy. No positive nerve root test.	Restricted spinal range of motion. Recurrent pain episodes before pregnancy. May have positive nerve root test.

*Catching of the leg: difficulty in moving one or both legs forward when walking (228).

Most studies do not differentiate between PGP and lumbar pain, neither during pregnancy nor postpartum (12, 66, 128, 138, 154, 169, 174, 176, 182, 185, 235, 236, 263), or exclude women with lumbar pain (3, 121, 165). However, clinical classification is important in order to evaluate possible differences in subgroup prevalence, course, cause, consequences, and predictors of persistency, and thereby possible differences in management. Pregnancy itself may interfere with studied factors. Therefore it is important to follow all pregnant women of a cohort, including women with all types of nonspecific LBP, as well as women without LBP.

Classification of low back pain

Healthcare planning and clinical professionals need information sufficient enough to decide on the choice of treatment and preventive measures. The goal of classification is to have a diagnosis that may explain the cause of the syndrome/disease, give a prognosis, assist in the choice of therapy, and predict the outcome of a specific therapy.

The only accepted classification of nonspecific LBP is the duration of pain. Acute LBP is when the duration is less than 6 weeks, subacute LBP is when the pain duration is 6-12 weeks, and persistent LBP is classified when pain duration is more than 12 weeks (242). This classification is not enough for guiding management and it may not be relevant for classification of LBP in pregnancy. Another way to classify LBP is according to the severity of the complaints that may be of importance for understanding the course (58). This

appears to be an important classification, but from a clinical perspective, it should be made within the subgroups of patients with LBP.

There is no anatomically-specific diagnostic tool for possible pain sources of PGP. Additionally, no objective findings for PGP on X-ray, MRI, or in blood samples have been identified (84). From a clinical point of view, a diagnostic triage that differentiates between serious pathology (red flags), nerve root problems, and nonspecific LBP is the first step to take for patients with LBP (111, 242). The majority of patients with LBP fall into the category of nonspecific LBP and a further classification is needed in order to choose treatment strategies. This classification does not necessarily need to include explanation of the cause.

Based on current knowledge and existing guidelines for PGP (258) and LBP (242), clinical evaluation of pregnancy-related LBP should include pelvic pain provocation tests, a neurological examination, take known characteristics of PGP and lumbar pain into account, and be sufficient enough to identify discogenic pain and red flag conditions.

Many different pelvic pain provocation tests and criteria have been used for classifying PGP (2, 14, 115, 164, 165, 180, 181, 226, 228, 264). No conclusions can be drawn as to which criteria or clinical tests should be used for PGP. Regarding criteria for the number of positive pelvic pain provocation tests, 1 (2, 183), 2 (164, 264), and 3 (165) positive pelvic pain provocation tests have been suggested or used as diagnostic criteria for PGP. In another study, the best discriminatory ability was achieved by the combination of 5 pain provocation tests, which was reported to have a sensitivity of 67%, specificity of 84%, and predictive value of 57% when identifying women with LBP in the lumbosacral region (115). Furthermore, it was shown that pregnant women without PGP mostly had negative pain provocation tests (0-15%) despite ligament laxity due to the pregnancy. Despite no LBP there was palpable tenderness over the symphysis in 35% of the women which makes the test questionable.

Classification of PGP requires exclusion of lumbar causes (258). Several tests for examination of the lumbar spine in pregnancy have been described (115, 183, 228). However the test reaction in terms of pain or stiffness is not specific enough to exclude intervertebral disc pathology, which is probably the most common structural source of nonspecific LBP (26, 215). There is no difference

in disc abnormality prevalence between pregnant and nonpregnant populations (250). It is therefore important to also examine possible discogenic problems in a pregnant population with LBP.

Many classification systems exist for patients with LBP; the strengths and weaknesses have been discussed in reviews (22, 192, 205). Several classification systems for LBP patients have been identified, which are relevant for physiotherapists (53, 69, 142, 191, 218). The Mechanical Diagnosis and Therapy (MDT)(142) has been identified as a well described classification system. It is commonly used (13, 77) and includes a standardised history, neurological examination, and evaluation of red flags. Within the protocol, symptom response during and after repeated movements is evaluated, and this procedure has shown promising results in reliability studies (110, 141, 201). If, as a result of repeated movements or positions, the radiating symptoms regress proximally (centralisation) or the opposite, progress distally (peripheralisation), the symptoms are considered discogenic and have shown a high prognostic value (56, 57, 252). Furthermore, pelvic pain provocation tests were evaluated within the MDT protocol, with a reported sensitivity to detect SIJ syndrome of 0.91 and specificity of 0.83 (124). It was argued that positive SIJ tests, in the absence of centralisation, are safer in diagnostic triage than pelvic pain provocation tests alone.

CAUSES OF PREGNANCY-RELATED PELVIC GIRDLE PAIN

Discussed causes of pregnancy-related LBP in the pelvis are mainly based on biomechanical and hormonal changes during pregnancy. Hippocrates (c 460-c 377 BC) had already hypothesised that an irreversible relaxation of the pelvis occurs during pregnancy. Radiological studies in the early 20th century confirmed relaxation of the pelvic joints, and showed that it was dependent upon normal biological processes that began in the early stages of pregnancy (90, 268). Towards the end of the 1920s, it became methodologically possible to study the role hormones played with regard to increased mobility. Relaxin is one pregnancy-related hormone studied, considered to play a role in the mobility of the pelvic joints. The hypothesis that a high level of relaxin correlates with PGP has been confirmed in some studies (117, 135), but not in others (4, 190).

The early reports of increased mobility in the symphysis, as well as in the posterior pelvic joints, are probably the basis for the hypothesis that PGP is

mainly due to hypermobility. Yet, in the mid-1990s, at the time of the planning of the present thesis, this was an established belief among caregivers. However, it had already been shown with roentgen stereophotogrammetry that the quantity of SIJ mobility was the same in women with and without PGP (227). A pregnancy-induced physiological increase in laxity of the symphyseal soft tissue had been reported. However, no evidence was found that the degree of symphyseal distension determines the severity of pelvic pain in pregnancy or postpartum (25). It has been suggested that asymmetric laxity of the right and left SIJ during pregnancy is a predictor for persistence of moderate-to-severe pregnancy-related PGP postpartum (51).

Muscle function in relation to lumbopelvic stability

Only in more recent years has the contribution of muscle function towards lumbopelvic stability been discussed. According to Bastiaanssen et al. (2005) (11) Lehmann et al. (1861) and Snelling et al. (1870) were the first to mention that great physical and/or muscular weakness were causes of the painful "sensations" in the pelvis. Over the 100 years following these early studies, very few authors have discussed the importance of muscles. "Re-education" of the back muscles, after days of treatment with complete bed rest, has briefly been mentioned (268). Genell (1949) discussed the cause of a positive Trendelenburg's test in severe cases and considered loosening of the SIJ and symphysis to be so extreme that the muscles could not hold up the nonsupported half of the pelvis (75). Farbrot (1952) discussed the importance of the long hip extensors and the abdominal muscles which prevent a horizontal position of the sacrum (65). Likewise, the wasting of the abdominal wall muscles was mentioned as a probable cause of PGP. Furthermore, the value of "systematic exercise" was discussed as a prophylactic measure. In another study, it was stated that "a more or less functional insufficiency of musculature of the pelvic girdle has its place in the symptomatology" (238).

The lumbopelvic region needs to be stable in order to permit load transfer from the trunk to the lower extremities. At the same time, there must be a certain amount of mobility in order to achieve locomotion. Static and dynamic stability are achieved when the active, passive and control systems work together (188). A biomechanical model of a self-locking mechanism of the pelvic joints, based on the principles of form and force closure, has been described (221, 260). Form closure refers to the closely fitting sacroiliac joint surfaces. Force closure refers to the compressive forces needed in addition to

the form closure in order to withstand the vertical load on the relatively flat surfaces of the SIJ. The musculoligamentous system, governed by the nervous system, is responsible for force closure. The muscles may be divided into 2 functional muscle systems: a deep/local and a superficial/global system (16). The local muscles are thought to provide control and fine-tuning of intersegmental motion that is not specific to the direction of force whereas the global muscles control the orientation of the spine and direct movements. The concept of motor control, where the deep muscle corset and the global muscles work in concert, determine the lumbopelvic stability (92, 203, 220).

Several studies suggest an association between nonpregnancy-related PGP and decreased stability of the pelvis, probably due to dysfunction of the muscles which contribute to force closure of the pelvic joints (96, 184, 198, 204, 243). When the muscular capacity and the tension of the ligaments are inadequate, decreased compression across the SIJ will occur, insufficient stability will follow, and optimal load transfer between the back and legs becomes compromised (198).

The erector spinae, the biceps femoris and the gluteus maximus are important muscles for force closure of the SIJ (243, 259). Other muscles of importance in stabilization of the lumbopelvic area are the transverse abdominals (204) and the pelvic floor muscles (212). Strength and endurance of muscles in the lumbopelvic area have not been tested in pregnant women. However, it has been reported that, compared to healthy controls, patients with LBP have lower endurance in the back extensors (1, 95) and hip extensors (middle-aged women) (106), deficiency in trunk muscles strength (233), and poorer ability to sense a change in lumbar position, especially after fatigue (232).

Muscle function in pregnancy has been investigated in 1 study using electromyography (217). The results indicated that reduced back muscle activity at the beginning of pregnancy leads to more pain and disability throughout the pregnancy. Low endurance of back and hip muscles has been reported in women with longstanding PGP and lumbar pain after pregnancy (168). It was indicated that muscular insufficiency may be an important factor regarding persistent problems. It is unknown if the reported insufficiency developed due to longstanding problems or if the women already had muscular insufficiency early on in the pregnancy.

Pregnancy causes biomechanical and hormonal changes to the stabilising system of the lumbopelvic area for all women, however not all get LBP. The previously suggested "hypermobility hypothesis," as a cause of PGP, can be translated into the inability of the musculoligamentous system to compensate for the increased laxity of the pelvic joints through dynamic stabilization. It is possible that the relations are not linear, but rather are related to a certain threshold.

Gait

Gait, with its unilateral loading, requires lumbopelvic stability. A prerequisite for stability is adequate muscle function and there are indications that muscles and their biomechanical conditions change during pregnancy. Pregnant women are sometimes described as having an altered gait pattern, "a waddling gait,"(150) defined as an increased base of support (23). By waddling, the women avoid rotation of the lumbopelvic region and thereby decrease demands on stability.

The natural customary walking speed for adults is from 1.0 to 1.67 m/s (248). In healthy pregnant women, comfortable walking speed has been reported in some studies to be lower compared to nonpregnant women (161, 266), and not changed in another (68).

Women with PGP report activity limitation in walking (66, 85, 136, 150, 264). Maximum gait velocity during walking was studied on a treadmill in 9 women with persistent PGP postpartum (265). Maximum attainable walking speed varied greatly in women with PGP (0.17 -1.50 m/s) as compared to healthy controls, where all women reached the highest level (1.50 m/s). The author speculated that muscle coordination parameters were perhaps responsible for the difference.

CONSEQUENCES OF PREGNANCY-RELATED LOW BACK PAIN

In back pain research, recommended study domains include generic health status, pain, back-specific function, work disability, and patient satisfaction (29).

Health-related quality of life

According to the World Health Organisation (WHO), health is "a state of complete physical, mental and social well-being, and not merely the absence of disease" (254). Health outcome research has restricted to using the concept "health-related quality of life" (HRQL) that addresses the consequences of disease and/or impairment, rather than a specific assessment of pathology, disease or impairment that is at the organ or body system level (102). HRQL includes the perception of an individual of his or her degree of physical, psychological and social well-being and the impact the illness has on daily life (87, 102).

In a Swedish population survey, women reported a significantly lower HRQL than men; specifically in the age groups 20-29, 30-39 and 60-69 years (37). During normal pregnancy, HRQL is reportedly decreased (94). Well-being in pregnancy is affected by several symptoms such as nausea (33), sleeping disorders (209) and LBP. Only 2 pregnancy-related LBP studies were identified that measured HRQL. In late pregnancy, women reported lower HRQL than nonpregnant healthy women (173). Women with back pain reported the most impaired HRQL. In a 2-year follow-up of a randomised controlled trial with treatment for persistent PGP, women who improved in pain and disability reported comparable HRQL scores on the Short Form 36 Health Survey (SF-36) to normal scores from a general Norwegian population (226). On the contrary, the control group demonstrated lower scores of physical health but normal scores of mental health on the SF-36. It would be interesting to evaluate how pregnant women estimate their HRQL in early pregnancy and compare the impact on health for different types of LBP experienced during pregnancy. Since economic analysis of PGP hitherto is limited to sick leave costs, there is a need for an instrument that can be used in formal decision analysis and cost-effectiveness analysis, where PGP can be related to other conditions. There is a lack of knowledge regarding HRQL in early pregnancy in women with different types of LBP.

Pain

Pain is a subjective experience and includes several components. Pain intensity, duration and localisation are included in the sensory-discriminative component, and it is influenced by emotions (affective-motivational component) as well as thoughts, beliefs and previous experiences in life (evaluative-cognitive component)(147, 148). Measures of pain severity are

different from measures of pain affect (261). Pain severity is a global construct measured by pain intensity and interference with activities. Pain affect is the degree of emotional arousal or changes in action readiness caused by the sensory experience of pain. Pain is thus a multidimensional construct and no consensus exists as to how to measure or classify pain. Chronic pain has been defined as "…that which persists beyond the normal time of healing"(98). Persistent back pain has been defined as pain that is present most of the time for a period of 6 months or more during the prior year (81). However, recurrent pain episodes that last less than 6 months may be a form of persistent pain (261). Throughout this thesis, the term persistent pain is used instead of chronic pain and is defined as recurrent episodes or pain present most of the time ≥12 weeks.

The frequency in which pain should be measured in order to obtain an accurate picture of the pain experience is a matter of discussion. Mean present pain intensity scores have been shown to correlate (≥0.80) with average pain intensity scores from the previous week (52). However, it is still controversial as to whether or not the use of a single rating of current pain is more appropriate than the use of an average pain rating over a specific period (28, 52). A pain drawing is an outline of the body on which to mark pain locations (200). It is commonly used to evaluate and describe pain locations, which have been shown to be related to disability (172).

Pain intensity in pregnant women with back pain has been evaluated at one or several time points during pregnancy (85, 116, 175, 228), as well as postpartum (166, 176, 182). Few authors have classified back pain and reported pain intensity among patients subgrouped for different types of pain. In pregnant women, no difference in pain intensity was identified among the three patient pain subgroups: thoracic pain, lumbar pain and posterior pelvic pain (228). However, some women belonged to 2 subgroups and there was large spread in the number of gestational weeks (12-40), which makes the results difficult to interpret. In another study, at 7 months postpartum no difference in pain intensity was found between patients grouped according to the following types of pain: posterior pelvic pain, lumbar pain, mixed pain and no pain localisation (166). There is a lack of knowledge regarding pain intensity in early pregnancy in women with different types of LBP.

Disability

The consequences of LBP are related to the functioning of patients. Functioning is a general term for all body functions, activities, and participation from the healthy perspective according to the International Classification of Functioning, Disability and Health (ICF) (ICF 2001)(255). Disability is a general term for impairment, activity limitations, and participation restrictions from the problematic aspect.

Evaluation of consequences of LBP in terms of disability is important in the rehabilitation process for identifying target areas in treatment strategies. In one of the most commonly used back-specific measures of self-reported functioning, the Oswestry Disability Index (ODI) (29), disability is defined as "the limitations of a patient's performance compared with that of a fit person" (according to Garrad and Bennett (1971) in Fairbank's article)(64). This definition is reasonably confined to disability according to the WHO definition.

Pregnant women reported restrictions in activities of daily life, however pregnant women with back pain reported significantly more restrictions in physical abilities (173). LBP in pregnancy is sometimes looked upon as a normal consequence of pregnancy (72, 134). Yet, a third of pregnant women report LBP as a severe problem which interferes with activities of daily life and compromises their ability to work (116, 138, 177). Pregnant women who consulted physical therapists because of PGP, reported a considerable level of complaints in activities of daily living such as walking, standing, sitting, lying down, and changing positions (210). In another study, a high proportion of women with PGP could no longer carry out activities such as lifting, carrying, and vacuum-cleaning by themselves (121). On the contrary, in a small study, low-grade disability was reported by the majority of women with back pain in late pregnancy (186).

Consequences of pregnancy-related LBP have thus primarily been reported in terms of activities that produce or increase pain (66, 85, 136, 138, 177, 210) as well as in terms of pain intensity and sick leave (109, 183, 231). Accordingly, consequences on disability and HRQL were mainly not described with established measurement tools at the planning of the present study. Furthermore, there is a lack of knowledge regarding disability and HRQL in early pregnancy in women with different types of LBP.

DEPRESSION

From research on nonpregnancy-related LBP, it has been shown that psychosocial factors play a role in LBP (8, 79, 114). In a general Swedish community, the annual incidence of first time depression in women was reported as 7.6 per 1000 person years (208). Among female patients in primary healthcare in the Nordic countries, the reported prevalence of depression was 9.9-14.2% (158). Although it is not clear which comes first, depression or LBP, it has been shown that a depressed mood increases the risk for pain problems and that psychosocial variables are clearly linked to the transition from acute to persistent pain disability (129). The risk of suffering from depression when having back pain has been reported to increase by 1.40 to 2.06 in a general population (144). One aim of the physical therapy examination is to identify or exclude conditions that can contraindicate treatment or reduce the effectiveness of intervention (83). It has been reported that primary health care physicians (196), as well as physiotherapists (83), do not accurately identify symptoms of depression.

According to the Diagnostic and Statistical Manual of Mental Disorders-IV classifications (7), depressive symptoms are defined as the following: depressed mood, loss of interest or pleasure, altered appetite, weight or sleep patterns, psychomotor agitation/retardation, fatigue/loss of energy, feelings of worthlessness, self-reproach or inappropriate guilt, diminished ability to think, concentrate or indecisiveness and recurrent thoughts of death or suicidal ideation. A major depression is defined as 5 or more of the depressive symptoms that have been present during a 2-week period and include at least depressed mood or loss of interest or pleasure.

Postpartum depression

Depression is approximately twice as common in women as it is in men, and there is a peak in depression debut during the childbearing years (251). Emotional problems in relation to pregnancy may fall into 3 categories that range from the lighter maternal blues, over postpartum depression, into the more severe psychosis. Maternal blues are considered a relatively mild, self-limiting mood state that occurs in the early postpartum period, and affects between 50-80% of mothers. Postpartum psychosis is, on the contrary, a rare condition affecting 0.1-0.4% of mothers (223, 251). Around 10–20% of women suffer from depressive illness during pregnancy or the first year postpartum (46, 76, 104). Most women experience the depression onset within 6 weeks

postpartum, and the duration is typically 2 to 6 months (43). If left untreated, it may still persist for 1 year after delivery in up to 25% of women (32).

When studying postpartum depression, it is essential to exclude items that might reflect physical discomfort and thereby confuse depression with the somatic effects of pregnancy and childbirth. This is a primary feature with the Edinburgh Postnatal Depression Scale (EPDS)(45, 104). Although the EPDS is not diagnostic, it is a valid screening measure (86). Five of the items in EPDS are concerned with dysphoric mood itself, two with anxiety, and one each with guilt, suicidal ideas and noncoping.

In a postal survey in Australia, pregnancy-related back pain was found to be associated with a 2.2 increased risk of postpartum depression (35). In a treatment study for postpartum PGP, no difference in mental disorders was found between women who had received specific or nonspecific treatment strategies for PGP (226). Furthermore, postpartum depression has been associated with sick leave in pregnancy due to pregnancy-related complications (103). In the Scandinavian countries, back pain is the most frequent reason for sick leave during pregnancy (230, 264). Therefore it is also relevant to evaluate the association between LBP and depression. Clinical classification of the experienced LBP would give additional information regarding possible differences in depressive symptoms between types of LBP.

In conclusion LBP is one of the most common complications of pregnancy, with negative consequences for the affected woman, as well as for society. The consequences need to be better described for the different subtypes of LBP. There are biomechanical changes that influence lumbopelvic stability during pregnancy and some indications that there may be interindividual differences in muscular adaptation to the changes. Identification of women who are at risk for persistent postpartum LBP is of value for clinical management. Likewise, evaluation of possible influences on comorbidity is important.

AIMS OF THE THESIS

The overall aims of this thesis were the following:

- to investigate if there were differences in health-related quality of life, pain intensity, disability, depressive symptoms or muscle function, in subgroups of low back pain in relation to pregnancy,

- to identify predictors for persistent pregnancy-related pelvic girdle pain or combined pain postpartum.

The specific aims of this thesis were the following:

- to describe the prevalence of clinically classified subgroups of low back pain in a cohort of women during pregnancy and postpartum (I & IV),

- to evaluate if there was a disparity in the course of clinically classified subgroups of low back pain in pregnancy and postpartum, and to predict early on in pregnancy who was at risk for persistent pregnancy-related pelvic girdle pain or combined pain (IV),

- to evaluate the consequences of pregnancy-related low back pain in terms of health-related quality of life, pain intensity, and disability for different subgroups of low back pain during pregnancy (I),

- to evaluate if there was an association between low back pain postpartum and depressive symptoms and to evaluate if there was a difference in the prevalence of depressive symptoms among different subgroups of low back pain (II),

- to evaluate muscle function during pregnancy and postpartum in women without low back pain and in subgroups of women with low back pain (III).

MATERIALS AND METHODS

DESIGN

The study consisted of 2 parts: a prospective cohort study and a RCT where women with persistent postpartum PGP or combined pain were followed for 2 years after pregnancy. This thesis comprises data collected in the prospective cohort study at the evaluation during gestational weeks 12-18 and at the evaluation 3 months postpartum (Figure 1).

Even though PGP may start, on average in the 18th gestational week (267) it was the intention to evaluate as early as possible during pregnancy but past the point of highest risk for miscarriage. Another limiting factor for the time point of inclusion was that the women needed to be able to perform the muscle tests before the growing abdomen hindered the testing. Additionally, it was desired to study potential predictive factors early on in pregnancy when symptoms were less established. The second evaluation was at three months postpartum since little improvement from pregnancy-related PGP occurs after 3 months (112, 176, 182).

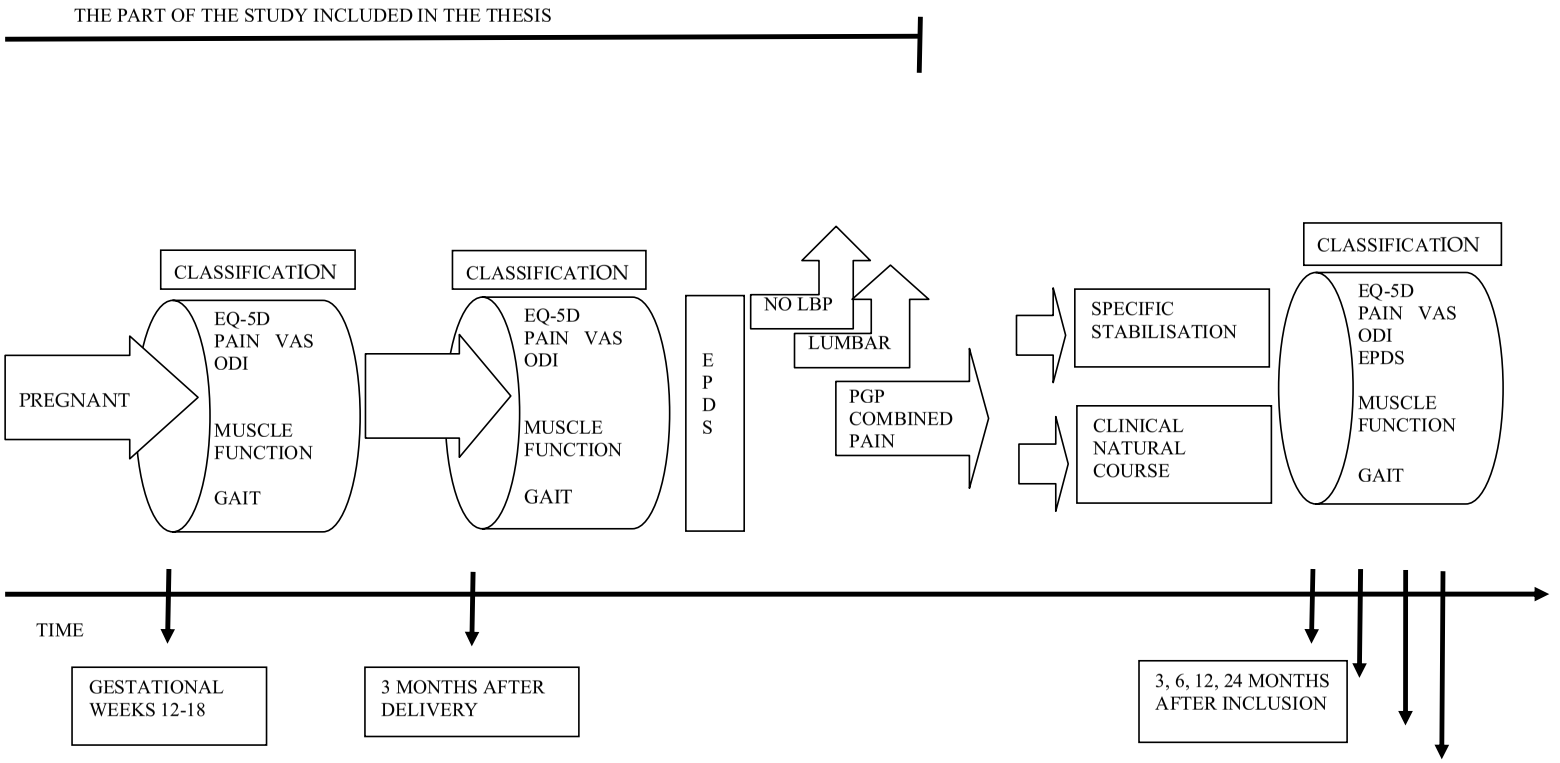

Figure 1. Flow chart of the study.

STUDY POPULATION

The prenatal healthcare system in Sweden serves almost 100% of the country's pregnant women, providing regular physical and psychological health check-ups during pregnancy and postpartum. Six midwifes at 2 prenatal healthcare clinics, housed in a sociodemographically diverse community of 26000 people, were involved in the recruitment process that lasted 2 years. The studied cohort was comprised of all pregnant women consecutively registered at the 2 prenatal healthcare clinics. Swedish-speaking women with an expected normal pregnancy (as determined by the midwives) were approached for participation during gestational weeks 12-18. Women were excluded if they had a systemic locomotor disease, a verified diagnosis of a spinal problem during the previous 2 months, or a history of fracture, neoplasm, or previous spinal, pelvic or femur surgery.

MEASUREMENTS AND PROCEDURES

One physiotherapist, (AG) scheduled the participants for assessment and did all the evaluations at 1 primary health care clinic. All participants completed questionnaires and were physically evaluated during gestational weeks 12-18 and 3 months postpartum. Each full assessment took approximately 1.5 hours to complete.

Self-reported questionnaires

First, when choosing a measurement tool, it is necessary to assess whether or not the instrument measures the appropriate construct under study and if it is appropriate for the particular population (face validity). Prior to the study, the questionnaire was examined by an expert in PGP and filled in by 5 women with PGP, who confirmed the face validity.

The questionnaire included background data, as well as questions regarding urinary incontinence, activity level (71), employment status, work dissatisfaction, and HRQL. Participants who had previously experienced nonspecific LBP also answered questions about sick leave due to LBP, whether LBP had hindered their work during the past 5 years, present pain intensity, and disability. The postpartum questionnaire was the same as the questionnaire in gestational weeks 12-18 except for specific questions

regarding delivery, such as mode of delivery, delivery position, vaginal cuts at delivery, baby weight, breast feeding as well as questions about treatment and treatment effect in the case of LBP. Also, postpartum, a depression scale was added. The participants had the opportunity to ask questions regarding the questionnaire, if needed.

Health-related quality of life

The European Quality of Life 5 Dimensions Questionnaire (EQ-5D) (199, 234) was used for measuring HRQL. The development of EQ-5D for the assessment of HRQL within population surveys, aimed at creating a health state classification through which an overall index could be derived using preferences from the general population, and thereby enabling calculation of Quality Adjusted Life Years (QALYs). QUALYs are quantitative estimates reflecting how individuals value health states, and are typically scaled from 0 to 1. QUALYs can be used in economic analyses (42).

The EQ-5D consists of two parts that monitor HRQL. The first part involves a health state classification scheme of 5 items with 3 response categories (1 = no problems, 2 = moderate problems, and 3 = severe problems). The questions involve the following dimensions: mobility, self care, usual activities, pain/discomfort, and anxiety/depression. There are 243 (3^5) possible distinct health states. Each health state has a preference value attached to it and possible values range from -0.59 to 1.0 where 1.0 is optimal health. The second part of EQ-5D is a vertical 20 cm VAS ranging from 0 (worst possible health state) to 100 (best possible health state), on which the respondents rate how they perceive their health on that particular day. The VAS is not used when deriving the preference value. The minimal important difference (MID) for the EQ-5D score has been reported to range between 0.09-0.22 and for the EQ-5D VAS, the estimates range from 3.82 to 8.43 (216).

Pain

Pain intensity was measured in the questionnaires on 2 separate 100 mm horizontal VAS, with the ends labeled as the extremes of pain i.e. “no pain” to “worst imaginable pain” (97). The first VAS was used to assess present pain intensity and the second VAS was used to assess average pain intensity during the past week (52). Pain intensity was also measured with a plastic VAS ruler with a sliding marker, before and after each physical functioning test. A previous study has shown that the score changes with the best cut-off points

for discriminating between improved and nonimproved patients was 10-18 mm on the VAS (17). In another study, a pain score of at least 7 mm less than the preceding assessment was reported as decreased pain (39).

In our study pain location was self-assessed by the women on a pain drawing in the questionnaire (200). The extent and distribution of pain reported on pain drawings have been found to be reasonably stable over time (139) and to have high criterion, construct, and content validity (171).

Disability

The Oswestry Low Back Pain Disability Questionnaire (ODI)(63) was used to measure back-specific functioning, that is activities of daily living that might be disrupted by LBP. The revised version (2.0) (145) was used in this study since the items regarding sexual life and pain intensity, rather than pain medication, were considered important in the studied population. The women rate their perceived disability on 10 different items: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sexual life, social life and travelling. The items are scored from 0 to 5. The scores of all items are added up, giving a possible total score of 50. The total score is doubled and expressed as a percentage, where 0% represents no disability. The ODI scores of patients can be divided into categories: having minimal or no disability (0-20%), moderate disability (20-40%), severe disability (40-60%), crippled (60-80%), or bed-bound or exaggerating the symptoms (80-100%) (63).

Two experts in the field of pregnancy-related LBP considered the ODI to be suitable for measuring the desired qualities of PGP. A pilot study was performed on 5 patients with PGP. The suitability of the instrument was confirmed, thereby justifying the face validity of the ODI. A gold standard for measuring status in LBP patients is not available, therefore validity of a measurement instrument must be judged by direct comparison. The purpose of functional status questionnaires is to assess limitations in performing movements and actions. It is important to evaluate whether the questions are capacity-or performance-based. The correlation of ODI to physical signs showed a wide range (0.12-0.74) (18). When relating patient behaviour to the ODI, 2 items (sitting and walking) showed good correlation with performance, whereas lifting correlated weakly (67). A later study, reported moderate correlation between the self-report of ODI and performance-based measures (202). Good reliability of the ODI has been reported (64, 78). The minimal important change in score of ODI has been reported to 4-6% (17). If one or

more items of ODI were missing, the recommendation to calculate a percentage with a smaller denominator was followed.

VAS and ODI scores were used for group comparisons, as well as for dividing the cohort into women exhibiting or not exhibiting consequences due to their syndromes. A score of 0-10 mm on the VAS and an ODI disability score of 0-10% were defined as no consequence (269). Three groups were compared using the above cut-offs; 1) those participants having neither pain nor disability, 2) those participants having either pain or disability, and 3) those participants having both pain and disability.

Postpartum depression

The EPDS is a 10-item self-reported scale specifically designed to screen for postpartum depression in community samples. Each item is scored on a 4-point scale (0-3) with a total score ranging from 0 to 30 where 0 is no depressive symptoms. The scale rates the intensity of depressive symptoms (7) present within the previous 7 days. Cox et al. (1987) proposed a cut-off score of ≥10 if the test was to be used for screening purposes in primary healthcare, as in the present study (45). A cut-off score of ≥13 was recommended for evaluating probable depression. Although the scale cannot confirm a diagnosis of depression, when using the threshold of ≥10, the sensitivity for detecting major depression has been reported to be 100%, with a specificity of 82% (86). The sensitivity of the Swedish version of the EPDS (cut-off score of 11.5) has been reported to be 96%, with a specificity of 49% (256). In our study internal missing values of items excluded the EPDS measure. Good reliability has been reported for the EPDS (45). Four points on the EPDS is considered a clinically significant change in postnatal depression (140).

Classification of the cohort

The description of the evaluation procedure is presented in table 2. Participants were assigned to 1 of the 4 following groups based on the type of pain experienced: no LBP, lumbar pain, PGP, or combined PGP and lumbar pain (combined pain). Assignment to 1 of the 3 LBP groups was made following examination by a specialised physiotherapist (AG). Only women who experienced some type of LBP were examined. The examination started with a standard history that focused on known characteristics of lumbar pain (142), as well as PGP (150, 180, 228), and the responses/tolerance to different

positions and activities of daily life such as bending, sitting, standing, walking, and lying. Range of motion of the back was evaluated during standing flexion, extension, and lateral flexion. Five pelvic pain provocation tests were done in the sequence described below. In order to consider a pelvic pain provocation test positive, the test must reproduce the participant's familiar pain regarding location and quality.

1. **Distraction test**. The participant lies supine. The examiner applies a posteriorly directed force to both anterior superior iliac spines (123).
2. **Posterior pelvic pain provocation test**. The participant lies supine with 90 degrees of flexion at the hip and knee on the tested side. The examiner stabilizes the contralateral side of the pelvis over the superior anterior iliac spine. A light manual pressure is applied on the patient's flexed knee, along the longitudinal axis of the femur. The test is performed bilaterally (181).
3. **Gaenslen's test**. The participant lies supine near the edge of the table. One leg hangs over the edge of the table and the hip and knee of the other leg are flexed towards the patient's chest. The examiner applies a pressure to the flexed knee towards the chest and a counter pressure to the knee of the hanging leg towards the floor. The test is performed bilaterally (123).
4. **Compression test**. The participant is sidelying with the hip and knee flexed to approximately a right angle. The examiner kneels behind the participant on the table. The examiner applies a pressure vertically downward on the upper iliac crest (123).
5. **Sacral thrust**. The participant is prone. The examiner applies a light pressure vertically downward on the sacrum (123).

In order to exclude problems from the hip, a rotation range of motion test was performed in prone. The active straight leg raising test (149) was performed followed by a neurological examination (muscle testing, reflex testing in the lower extremities, sensation, and the straight leg raising test). The mechanical assessment of the lumbar spine was based on the MDT protocol (142). The participant performed flexion and extension in standing and in the lying position in sets of 5-10 repetitions. If needed, lateral flexion was added to the protocol. Baseline symptoms were noted, as were the effects on symptoms during and immediately following the movements. The MDT classification relies on the patients reported response to the movements. This has shown promising results for classification of pain (141) and is reliable in the hands of experienced testers (110, 201, 206). Separate pain provocation tests used in the present study have shown high specificity (0.81-1.00), but a wide range for

sensitivity (0.04-0.93) in pregnant women (2, 181). Incorporating pain provocation tests into standardized mechanical assessment of the lumbar spine is of greater diagnostic value than pain provocation tests alone (124).

Criteria for the cohort classification

Participants were assigned to the "no LBP" group if they had no subjective LBP or fewer than 2 positive pelvic pain provocation tests, and no lumbar pain or change in range of motion from repeated movements, according to the MDT classification.

Criteria for being assigned to the PGP group were pain experienced between the posterior iliac crest and the gluteal fold, with or without radiation in the posterior thigh and calf, and with or without pain in the symphysis. The pain needed to be reproducible for at least 2 out of the 7 pelvic pain provocation tests performed. No centralisation or peripheralisation during repeated movement assessment could be experienced as well as no lumbar pain or change in range of motion from repeated movements, according to the MDT classification. PGP onset needed to be during pregnancy or within 3 weeks after delivery (150).

The criterion for being assigned to the lumbar pain group was pain experienced in the lumbar region, with or without radiation to the leg. Additionally, reproducible pain and/or change in range of motion from repeated movements or different positions of the lumbar spine, or experience of centralisation and/or peripheralisation during examination, and fewer than 2 positive pelvic pain provocation tests needed to occur.

Participants in the combined pain group experienced pain in the lumbar region, as well as between the posterior iliac crest and the gluteal fold, with or without radiation in the posterior thigh and calf, and with or without pain in the symphysis. They had 2 or more positive pain provocation tests, as well as pain and/or a change in range of motion from repeated movements or different positions of the lumbar spine, or experienced centralisation and/or peripheralisation.

Table 2. The description of the evaluation procedure.

1. Participants filled in questionnaire
2. Standard history by the physiotherapist according to MDT protocol
3. Standing flexion, extension, lateral flexion of the back
4. Pelvic pain provocation tests
5. Hip range of motion test (at evaluation during pregnancy)
6. Active straight leg raising test (ASLR test)
7. Neurological examinations (muscle testing, reflex in the lower extremities, sensation and the straight leg raising test)
8. Mechanical assessment of the lumbar spine according to the MDT protocol
9. Gait test
10. Isometric hip extension test
11. Isometric endurance of back flexor muscles
12. Isometric endurance of back extensor muscles (only 3 months postpartum)

Reliability of the classification procedure

In a nonpublished study, 31 pregnant women (mean age 28 years, range 20-36; median gestational week 26, range 13-38; median pain intensity VAS 38 mm, range 0-87) with some type of LBP were examined according to above protocol by 2 independent examiners, specialised in LBP. The physiotherapists' years of clinical experience in management of LBP ranged from 17 to 19 years. Agreement between examiners for the 3 syndromes (lumbar pain, PGP, combined pain) was 87% (27/31), giving a substantial kappa coefficient of 0.79 (120). Reliability depends on the experience of the observer. Interpretation of the kappa value is dependent on the number of categories (i.e. more categories give lower kappa values), on the prevalence of scores (i.e. skewed distributions give lower kappa values), and finally, on the presence of systematic differences (i.e. slightly increases kappa values). No systematic differences were seen, however, 16/31 women were classified with PGP, 6 with lumbar pain, and 9 with combined pain.

Physical functioning

No study was identified that described test of endurance or strength for the muscles of the lower back, hip or pelvis in a pregnant population. The choice of test included several considerations. For the hip test, a nonweight-bearing

of test included several considerations. For the hip test, a nonweight-bearing position was chosen in order to decrease the risk of pain provocation. A pilot study on 12 healthy women in fertile age was undertaken. Two women with PGP were tested and the positions were found to be appropriate. Prior to all testing, it was emphasized that the subjects could discontinue each test at anytime or decline a test completely. During testing, 2 corrections for technique or position were allowed before the tester discontinued the test. The participants rated their pain intensity on a 100 mm horizontal VAS ruler with a sliding marker, before the physical performance test, after each completed test, and a couple of minutes after all tests.

Back flexor muscles endurance

To test isometric endurance of the back flexor muscles, participants laid supine with arms crossed over the chest, hands on the opposite shoulders, hips bent, and knees and feet apart. Participants were asked to nod forward and continue to lift their head and shoulders until the inferior angle of the scapula was lifted from the table, and to then maintain the position as long as possible, modified from McQuade et al. (1988)(143). The number of seconds that the position was maintained was recorded up to a maximum of 120 s. No reference value for pregnant women was available. Therefore the known values for healthy women and women with nonspecific LBP (131, 132) were used to set maximal times based on clinical judgement and taking into consideration their pregnancy/3-month postpartum status. Reported reliability for static abdominal endurance was low/poor (ICC 0.51) in some studies (132, 156) and high in another (0.90-0.95)(100).

Back extensor muscles endurance

To measure isometric endurance of back extensor muscles, participants laid prone with arms crossed and the trunk horizontal outside the table. The pelvis was fixed to the table by straps and the lower legs were fixed by the tester, modified from Biering-Sörensen (1984) (21). The time in seconds that this position was maintained was recorded and the test was discontinued after a maximum of 120 s. Since there was no reference value for postpartum women, known values for healthy women and women with nonspecific LBP were adapted (1, 21, 131, 132, 167) and maximal times were set based on clinical experience and the participants postpartum status. The back extensor test was inappropriate to perform during pregnancy due to pressure on the lower abdomen. The test can discriminate between subjects with and without

nonspecific LBP (125). Reported ICCs for subjects with current or previous LBP and asymptomatic were 0.88, 0.77, and 0.83 respectively. Other authors have found the test to be unreliable for healthy subjects (107).

Maximal voluntary isometric hip extension

Maximal voluntary isometric hip extension (Figure 2) was measured with a dynamometer with a fixed sensor (Chatillon CSD 500 strength dynamometer, Ametek, Largo, FL). Each participant held a sling around the thigh at the distal end of the femur and pulled in hip extension. Participants were instructed to "pull the hardest you can until I stop you after 5 s". No encouragement was given during the tests. Participant started with the right leg. Two training repetitions were done and the mean of the next 3 repetitions was analysed. Each repetition consisted of 5 s of activity and 5-10 s of rest. The same procedure was repeated on the left side. The reliability of the hip muscle extension test was investigated in a pilot test-retest study (n=20). Spearman's r was 0.82 for the right leg and 0.88 for the left leg; the ICC (model 2) was 0.87 for the right leg and 0.85 for the left leg. The measurement error was 53 N on the right leg and 50 N on the left leg. The measurement error was 15% of the range of hip extension values.

Figure 2. The hip extension test left side.

Gait speed

Activity limitation with walking was studied in a gait test, modified from Ljungquist et al. (1999) (131). In the study by Ljungquist et al. (1999) the participants walked 20 m, turned around, and walked back. Clinical experience has shown that women with PGP often have increased pain and stabs of pain while turning. Since it was the intention to eliminate pain

provocation, the women in the present study stopped after 20 m. The participants were asked to walk barefoot "at a comfortable speed" on a horizontal indoor floor. The "natural customary walking speed" is considered to result in the least mechanical and physiological expenditure (247). The number of seconds it took to traverse 20 m was recorded. Reliability for comfortable gait speed has been reported to be good (r=0.90) (27).

STATISTICAL ANALYSES

All data were computerized and analyzed using the SPSS (version 11.0-14.0; SPSS Inc., Chicago, IL). Statistical significance was set at 0.05, and reported confidence intervals (CI) were 95%. The statistical methods used for the 4 papers are described in Table 3.

Descriptive statistics were used for demographic data and presented as mean and standard deviation when the assumptions of normality and homogeneity of variance were met and the studied variables were on the ratio level. Data on the interval, ordinal, or nominal levels were analyzed with nonparametric tests and presented as median values with quartiles or range.

Difference between 2 independent groups was measured with the independent samples t-test when the variable was normally distributed, had an equal variance, and was on the ratio level. For analysis of nonparametric data on the ordinal level, the Mann Whitney U-test was used for group comparisons. For data on the nominal level, the chi-squared test or Fisher's exact test was performed when appropriate.

For multigroup comparisons in analyses of continuous parametric variables, a one-way ANOVA was performed. In analyses of nonparametric data on a nominal level, the chi-squared test was used, and for data on an ordinal level, the Kruskal-Wallis test was used. Correction for multiple analyses was made using the adjusted Bonferroni test, or Bonferroni correction.

General Linear Model analyses were performed to evaluate the association between muscle test results and cohort subgroups of LBP, when controlling for pain intensity.

In Paper II logistic regression analysis (enter method) was used to examine the association between depressive symptoms, cohort subgroups of LBP, and

possibly confounding descriptive variables. The dependent variable was depressive symptoms, with a cut-off score of ≥10. The cohort subgroups of LBP were entered as categorical independent variables (no LBP as reference). The covariates were parity (continuous), urinary incontinence (no/yes) and body mass index (BMI) (continuous). The covariates were selected based on the literature and previous association with both back pain and depression (88, 154, 197, 214, 223, 267). Selection was also constrained by the number of possible independent variables (4-5), given the least group of the dependent was n = 44.

In Paper IV, forward stepwise logistic regression analysis was performed on some of the measures taken during gestational weeks 12-18 and used to determine predictors of persistent PGP or combined pain 3-months postpartum. The initial choice of independent variables was based on the hypothesis of an association between muscle dysfunction and PGP, as well as the PGP literature (5, 11, 121, 154, 245). Two variables were excluded due to low response rate (exercise frequency prior to LBP, similar LBP during the previous 5 years). With logistic regression analysis it is crucial that all subjects included respond to all the questions in the model, and in this study, perform all the physical tests. These requirements reduced the model to 154 participants. Civilian status was excluded because only 3 of 154 participants were single. In order to minimize the risk of multicollinearity, a correlation matrix was analysed. Univariate analyses for each independent and dependent variable were carried out to compute crude estimates. Fourteen independent variables were entered into a forward stepwise logistic regression analysis. The final model included significant predictors with an accepted statistical significance level of $p<0.05$. The forward stepwise logistic regression analysis was confirmed by a backward stepwise logistic regression.

Table 3. Statistical methods used in the different papers in the thesis.

Statistical method	Paper I	Paper II	Paper III	Paper IV
Kruskal-Wallis test	x	x	x	
Mann-Whitney U-test	x			x
Chi-squared test	x	x	x	x
Fischer's exact test	x	x		x
Independent samples t-test				x
One way ANOVA		x	x	
General Linear Model Analysis			x	
Logistic Regression		x		x

ETHICAL CONSIDERATIONS

The women received written and verbal information about the study from their midwife before giving oral consent to allow the project leader (AG) to contact them by telephone. Thereby, the women were given time to consider their participation. When contacted by the project leader the women had the opportunity to further ask questions about the study. It was emphasized that their participation was purely voluntary and that they could discontinue their participation at any point without explanation and without consequences on their management. The women gave their oral consent to the project leader. The project leader was not involved in the healthcare management of the participants.

The women were pregnant at the first evaluation in the study. This required some special considerations with regard to safety for the unborn child and the mother in the muscle tests. The midwives excluded women with complicated or risk pregnancies. In order to make sure that all included measurements were appropriate for pregnant women with an expected normal pregnancy, 2 obstetricians were initially consulted to review and approve the study design. Likewise, at the second evaluation the women were only 3 months postpartum. Temporary discomfort could arise during the classification procedure, however, it was explained to the participant that the pain provocation was needed in order to classify the symptoms. During physical functioning tests, pain provocation was possible, therefore it was emphasised during the evaluation that the woman could decline any test or terminate her participation at any point. An advantage with the participation in the study was that the women, at an early stage in pregnancy, as well as postpartum, received a thorough examination by a specialist in LBP and PGP.
The regional Ethical Committee in Gothenburg approved the study (ö 414-00). An amendment was approved for the reliability study of the classification procedure (T 352-06).

RESULTS

PREVALENCE OF LOW BACK PAIN IN PREGNANCY AND POSTPARTUM

A cohort of 457 pregnant women attended the 2 maternity care units between August 2001 and September 2003, of whom 313 were included in the study (17% declined participation) (Figure 3). The studied cohort was a representative community for Sweden, although the parity was somewhat higher than for Sweden in general (1.8 children per women vs. 1.6 in general), and there was a lower degree of higher education among the women (21% versus 30%).

At the evaluation between gestational weeks 12-18, 119 participants were assigned to the "no LBP" group and 194 to 1 of the 3 LBP groups: PGP (n=104, 54%), lumbar pain (n=33, 17%), and combined pain (n=57, 29%). In order to analyse the physical performance tests in pregnancy, 12 participants were excluded (3 participants were diagnosed with exclusion criteria, 2 participants were ≥18 gestational weeks at inclusion, 7 participants were not able to perform the muscle tests). Thus, there remained 301 participants for the muscle analysis (Paper III) and 308 for analysis of predictors (Paper IV). The PGP group reported a significantly higher level of sick leave at baseline than the group with no LBP group ($p=0.001$) whereas the groups with lumbar pain and combined pain did not (Table 4). With regard to the demographic data, women with lumbar pain and women with combined pain reported having had significantly more experience of back pain before their first pregnancy than women in the "no LBP" group ($p<0.001$). Women with lumbar pain had significantly more previous experience of back pain than those with PGP ($p=0.001$, Table 4).

Table 4. Characteristics of the cohort in gestational weeks 12-18.

Variables in pregnancy weeks 12-18	Total n=308	No LBP n=118	Lumbar pain n=33	PGP n=101	Combined pain n=56
Age (yr) median (range)	29 (17-44)	29 (20-40)	30 (19-37)	28 (18-44)	28 (17-41)
Gestation week at inclusion median (25,75 quartile)	15 (14-16)	15 (14-16)	15 (14-16)	15 (14-16)	15 (14-16)
BMI median (25,75 quartile)	24.5 (22.6-27.4)	24.6 (21.7-27.4)	23.6 (21.6-26.3)	24.4 (22.9-27.6)	25.0 (23.0-27.9)
Parity median (range)	1 (0-4)	1 (0-4)	1 (0-2)	1 (0-4)	1 (0-3)
Urinary incontinence n (%) yes	63 (20)	23 (20)	1 (3)	20 (20)	19 (34)
no	244 (80)	95 (80)	32 (97)	80 (80)	37 (66)
Full time employment n (%) yes	155 (49)	65 (55)	20 (62)	45 (45)	25 (46)
no	150 (51)	53 (45)	12 (38)	55 (55)	30 (54)
Work dissatisfaction n (%)yes	19 (7)	4 (4)	2 (7)	8 (8)	5 (10)
no	270 (93)	110 (96)	27 (93)	87 (92))	46 (90)
Sick leave at inclusion due to back pain n (%) yes	19 (8)	0 (0)	1 (3)	14 (15)	4 (7)
no	231 (92)	67 (100)	31 (97)	81 (85)	52 (93)
LBP before 1st pregnancy n (%) yes	124 (40)	30 (26)	25 (76)	38 (38)	31 (55)
no	183 (60)	87 (74)	8 (24)	63 (62)	25 (45)
Previous pregnancy-related LBP n (%)					
Never pregnant before	123 (41)	50 (43)	15 (47)	41 (42)	17 (31)
No LBP in a pregnancy	70 (23)	39 (33)	8 (25)	10 (10)	13 (23)
LBP in a previous pregnancy, recovered completely	82 (27)	27 (23)	7 (22)	30 (30)	18 (33)
LBP in a previous pregnancy that persists	28 (9)	1 (1)	2 (6)	18 (18)	7 (13)
LBP hindered work during the last 5 years n (%) yes	94 (55)	29 (63)	17 (68)	28 (45)	20 (53)
no	77 (45)	17 (37)	8 (32)	34 (55)	18 (47)
Activity level last 6 months n (%) 1-3	210 (68)	78 (67)	26 (79)	68 (67)	38 (68)
4-6	97 (32)	39 (33)	7 (21)	33 (33)	18 (32)

Variables Postpartum	Total n=272	No LBP n=183	Lumbar pain n=29	PGP n=46	Combined pain n=14
Weight of newborn (g) mean (sd)	3683 (548)	3672 (528)	3780 (459)	3635 (650)	3777 (624)
Delivery method n (%) caesarean	22 (8)	12 (7)	2 (7)	5 (11)	3 (21)
vaginal	250 (92)	171 (93)	27 (93)	41 (89)	11 (79)
Breast feeding n (%) yes	212 (81)	144 (83)	22 (79)	35 (76)	11 (85)
no	49 (19)	30 (17)	6 (21)	11 (24)	2 (15)
BMI median (25,75 quartile)	25.5 (22.3-24.8)	24.4 (21.9-27.5)	25.8 (23.9-27.7)	26.3 (23.5-29.9)	24.6 (23.6-26.6)

Three months after giving birth, 89/272 participants (33%) experienced some form of LBP: 46/272 (17%) had PGP, 29/272 (11%) had lumbar pain, and 14/272 (5%) had combined pain. Five participants had internal missing values of the EPDS and consequently 267 were analysed for depressive symptoms postpartum. Four participants were not able to perform any muscle test postpartum and 6 participants without any LBP filled in questionnaires at home, which reduced the postpartum evaluation of muscle assessment to 262 women.

Paper I included 313 pregnant women during gestational weeks 12-18.
Paper II included 267 women postpartum.
Paper III included 301 pregnant women and 262 women postpartum.
Paper IV included 308 pregnant women and 272 women postpartum. In the predictive model, 154 participants were included.

Drop-out analysis

Five participants miscarried or had an interrupted pregnancy due to disease of the fetus. Thirty-one participants delivered but were not included in the postpartum analysis. Of these 31 participants, 19 (6.5%) declined to participate due to lack of time, fatigue, or no given reason. Also, these 31 participants differed from the other participants with regard to 4 variables. The civilian status was to a higher degree single ($p<0.02$), they had lower endurance of the back flexor muscles (21 s vs. 33 s $p=0.009$), lower HRQL (EQ-5D score 0.74 vs. 0.80, $p=0.03$), and higher pain intensity (36 mm vs. 22 mm, $p=0.03$) in gestational weeks 12-18.

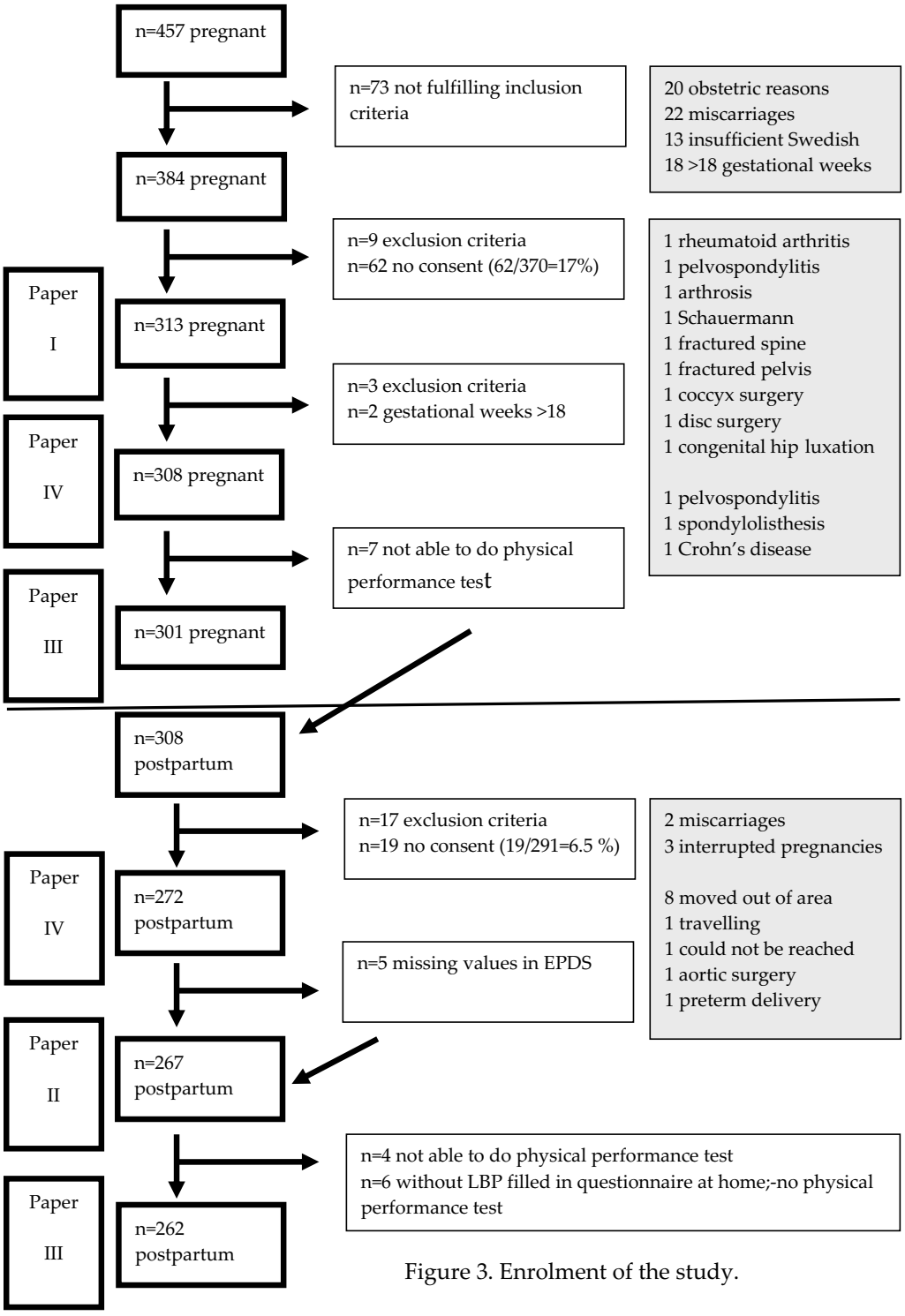

Figure 3. Enrolment of the study.

THE COURSE OF LOW BACK PAIN

The cohort subgroups during gestational weeks 12-18 and 3 months postpartum are presented in Table 5.

Table 5. Cohort subgroups at gestational weeks 12 to 18 and 3 months postpartum.

n	Subgroups of LBP 3 months postpartum				
Subgroups of LBP in gestational weeks 12-18	**No LBP**	**Lumbar pain**	**PGP**	**Combined pain**	
No LBP	**89**	9	9	**0**	107
Lumbar pain	21	**1**	4	**3**	29
PGP	56	8	**18**	**3**	85
Combined pain	17	11	15	**8**	51
Total	183	29	46	14	272

Of the 85 participants with PGP during gestational weeks 12-18, 18 (21%) had PGP 3 months postpartum. Women with PGP recovered from their LBP to a higher degree (56/85, 66%), as compared to 17/51 (33%) of the women with combined pain. Only 1 participant with lumbar pain during gestational weeks 12-18 had lumbar pain 3 months postpartum. The majority of participants (21/29, 72%) who experienced lumbar pain during gestational weeks 12-18 did not have LBP postpartum. Eighteen (7%) participants who did not have LBP during gestational weeks 12-18 had LBP (9 PGP, 9 lumbar pain) 3 months postpartum. Although a small group, the 18 participants had a higher BMI (27.4 vs. 24.7, p=0.04) in gestational weeks 12-18 than participants who where without LBP in gestational weeks 12-18, as well as 3 months postpartum. Two of the 9 women who had PGP postpartum, developed it after giving birth. None of the participants in the "no LBP" group in gestational weeks 12-18 had combined pain 3 months postpartum, but 3 participants in the PGP group and 3 participants in the lumbar pain group had combined pain postpartum.

Compared to participants who had LBP at gestational weeks 12-18 and recovered postpartum (n=94), women with persistent LBP (n=71) had higher disability scores on ODI (18 vs. 12, p=0.02), lower self-rated HRQL (EQ-5D score 0.73 vs. 0.80, p=0.001), more sick leave during the preceding 12 months (24% vs. 13%, p=0.03) and a greater number of positive pelvic pain provocation tests (3.4 vs. 2.9, p=0.04) during gestational weeks 12-18. They also tended to have lower endurance of the back flexor muscles (27 s vs. 36 s p=0.07).

PREDICTORS FOR PELVIC GIRDLE PAIN OR COMBINED PAIN

The logistic regression model included 154 participants, 122 of which had no LBP and 32 of which had PGP or combined pain. The 4 factors that were significantly associated with PGP or combined pain postpartum were the following: 1) work dissatisfaction, 2) combined pain in gestational weeks 12-18, 3) older age (i.e. for every year older, the risk of PGP or combined pain postpartum increased by 1.20), and 4) low endurance of the back flexor muscles (i.e. for every 10 s lost in endurance, the risk of PGP or combined pain postpartum increased by 1.18) (Table 6). These variables accounted for 30% of the variance (Nagelkerke r^2). The 154 participants included in the regression analysis did not differ from the 89 participants who were not included, except in 3 variables. The 89 excluded women were at a later gestational week of their pregnancy at the time of inclusion in the study ($p<0.001$), had more problems with urinary incontinence ($p=0.03$), and had higher BMI ($p=0.04$) than the 154 participants who were included in the regression analysis.

Table 6. Predictors for persistent PGP or combined pain postpartum

Independent variables	**Dependent variable: PGP and combined pain 3 months postpartum**		
	odds ratios	**95% CI**	**p-value**
Low endurance of back flexors	1.18	1.01-1.37	0.04
Older age	1.20	1.07-1.36	0.002
No LBP (ref)	1		0.02
Lumbar pain	1.51	0.32-7.20	0.61
PGP	2.17	0.69-6.81	0.19
Combined pain	7.70	2.16-27.44	0.002
Work dissatisfaction	10.06	2.16-46.91	0.003

HEALTH-RELATED QUALITY OF LIFE IN EARLY PREGNANCY

In gestational weeks 12-18, the women with some type of LBP reported significantly lower weighted health status index as compared to the women

without LBP (EQ-5D score 0.73-0.80 vs. 1.0, p<0.001). Concerning the self-rated health status (EQ-5D VAS), the women with PGP and the women with combined pain reported significantly lower values than the women without LBP (EQ-5D VAS 71-80 vs. 87, p<0.001, Table 7). However, the self-rated health status showed no significant difference between the women without LBP and the women with lumbar pain. The women with combined pain reported the lowest weighted health status index and the lowest self-rated health status. Women with lumbar pain reported the highest health status (EQ-5D score and EQ-5D VAS) of those suffering from any type of LBP. The women with combined pain exhibited significantly lower health status compared to the women with lumbar pain (EQ-5D score and EQ-5D VAS p=0.02-0.008). Two women had internal missing values on the EQ-5D and were withdrawn from the analysis.

Table 7. Pain VAS, ODI, and EQ in pregnancy weeks 12-18.

Variable median (25, 75 percentile)	**1= No LBP** **VAS n=69** **ODI n=64** **EQ n=116**	**2= Lumbar Pain** **n=32** **n=33** **n=33**	**3= PGP** **n=100** **n=101** **n=103**	**4= Combined pain** **n=57** **n= 57** **n= 56**	**Group comparisons p-value corrected for multiple test with adjusted Bonferroni**
Pain intensity VAS (mm) at present	0 (0-21)	23 (4-36)	26 (7-46)	36 (22-62)	1 vs. 2,3,4 **<0.001** 2 vs. 3 ns 2 vs. 4 **0.007** 3 vs. 4 **0.017**
Average pain intensity VAS (mm) previous week	3 (0-22)	20 (8-37)	28 (11-52)	43 (28-62)	1 vs. 2,3,4 **<0.001** 2 vs. 3 ns 2 vs. 4 **0.002** 3 vs. 4 **0.003**
ODI score (%)	4 (0-8)	10 (6-20)	14 (8-26)	18 (11-30)	1 vs. 2,3,4 **<0.001** 2 vs. 3 ns 2 vs. 4 **0.007** 3 vs. 4 ns
EQ-5D score	1 (0,80-1)	0.80 (0,73-0,80)	0.76 (0,69-0,80)	0.73 (0,62-0,80)	1 vs. 2,3,4 **<0.001** 2 vs. 3 ns 2 vs. 4 **0.016** 3 vs. 4 ns
EQ-5D VAS	87 (80-91)	80 (68-94)	75 (65-85)	71 (51-80)	1 vs. 2 ns 1 vs. 3 **<0.001** 1 vs. 4 **<0.001** 2 vs. 3 ns 2 vs. 4 **0.008** 3 vs. 4 ns

PAIN AND DISABILITY IN EARLY PREGNANCY

In gestational weeks 12-18, the women with some type of LBP reported significantly higher pain intensity (median 23-36 mm vs. 0 mm, p<0.001) and higher disability (median ODI 10-18% vs. 4%, p<0.001) compared to the women without LBP (Table 7). The women with combined pain reported the highest pain intensity and the highest level of disability and the women with lumbar pain reported the lowest of those suffering from LBP. The women with combined pain exhibited significantly higher pain intensity and a higher levels of disability compared to those with lumbar pain (p-values ranging from 0.007 to 0.002, Table 7). Twelve women reported "moderate disability" (ODI> 40%), 7 of whom had PGP and 4 of whom had combined pain.

Dividing the cohort according to both pain intensity and level of disability revealed that 15% of women with PGP and/or lumbar pain reported no consequences due to their syndromes (Table 8). In the PGP and combined pain groups, 2/3 (PGP 57%, combined pain 70 %) reported disability >10% on the ODI, as well as pain >10 mm (VAS) compared to the lumbar pain group, where only a 1/3 (30%) reported pain and disability (Table 8).

Table 8. Consequences of having lumbar pain, PGP or combined pain on pain and disability.

Subgrouping according to consequence	Pain≤10 mm ODI≤10%		Pain>10 mm OR ODI> 10%		Pain>10 mm AND ODI>10%		Total
	n	%	n	%	n	%	n
Lumbar pain	7	21	16	48	10	30	33
PGP	18	18	25	25	56	57	99
Combined pain	3	5	14	25	40	70	57
Total	28	15	55	29	106	56	189

POSTPARTUM DEPRESSIVE SYMPTOMS

After delivery, 267 women responded to the EPDS. Using a cut-off score of ≥10, 44/267 women (16%) experienced depressive symptoms postpartum. Out of these 44 women, 27 (61%) were classified with LBP. Thus 27/267 women, 10% of the cohort, had both LBP and a total score ≥10 on the EPDS. Women with LBP had higher prevalence of depressive symptoms than those without LBP (p < 0.001, Table 9). Twenty-two women (8% of the cohort) scored ≥13 on the EPDS (Table 9). The prevalence of depressive symptoms was higher

among women with lumbar pain compared to women without LBP when applying a cut-off score of ≥10 (p=0.002) or ≥13 (p=0.001). There was a higher prevalence of depressive symptoms among women with PGP compared to women without LBP only when using a cut-off score of ≥10 (p=0.01). The strongest associations were found between depressive symptoms and the 3 subgroups of LBP. The associations remained significant after adjusting for parity, urinary incontinence, and BMI (odds ratio 3.58 to 5.98, Table 10). Five women had internal missing values of items and were excluded from the analyses.

Table 9. Depressive symptoms evaluated 3 months postpartum using the EPDS with cut-off scores of ≥10 and ≥13, respectively. The significant group comparisons are shown.

EPDS	Total cohort n=267	1 No LBP n=180	2+3+4 LBP n=87	2 Lumbar pain n=29	3 PGP n=44	4 Combined pain n=14	Group comparisons p-value
EPDS ≥10							EPDS ≥10
n (%)	44 (16)	17 (9)	27 (31)	11 (38)	12 (27)	4 (29)	p <0.001
(95% CI)	(12 to 20)	(5 to 13)	(26 to 36)	(20 to 56)	(14 to 40)	(5 to 53)	1 vs. 2 0.002
							1 vs. 3 0.01
							1 vs. (2,3,4)<0.001
EPDS ≥13							EPDS ≥13
n (%)	22 (8)	7 (4)	15 (17)	8 (28)	5 (11)	2 (14)	p <0.001
(95% CI)	(5 to 11)	(1 to 7)	(9 to 25)	(12 to 44)	(2 to 20)	(5 to 23)	1 vs.2 0.001
							1 vs. (2,3,4)<0.001

Table 10. Results from the logistic regression analyses (enter method). The dependent variable was the result from the EPDS with a cut-off score of ≥10. The classifications of LBP were entered as categorical independent variables (no LBP group as reference). The covariates were parity (continuous), urinary incontinence (yes-no), and body mass index (BMI) (continuous).

Dependent EPDS with cut-off scores ≥10	df	p-value	odds ratio	95% CI
Independent variables				
No LBP (reference)	3	0.001	1	
Lumbar pain	1	<0.001	5.81	2.16-15.63
PGP	1	0.008	3.58	1.39-9.22
Combined pain	1	0.009	5.98	1.56-22.97
Parity	1	0.05	1.49	1.00-2.22
Urinary incontinence	1	0.56	0.74	0.27–2.22
BMI	1	0.70	1.02	0.94-1.11

PHYSICAL MEASURES IN PREGNANCY AND POSTPARTUM

Back flexor muscles endurance

In gestational weeks 12-18, the women with PGP had lower endurance of the back flexor muscles as compared to the women without LBP (mean difference 17.9 s p=0.001, Table 11). Postpartum, the women with combined pain had lower endurance of the back flexor muscles as compared to the women without LBP (mean difference 33 s p=0.01, Table 12.

Back extensor muscles endurance

Postpartum, the women with PGP had lower endurance of the back extensor muscles as compared to the women without LBP (mean difference 28.3 s p<0.001, Table 12.

Table 11. Muscle test results in pregnancy in the 4 groups based on type of LBP: no LBP, lumbar pain, PGP and combined pain.

mean (95% confidence intervals)	1 No LBP n=116	2 Lumbar pain n=32	3 PGP n=99	4 Combined pain n=54	Group comparison p-value
Back flexor endurance	n=100	n=27	n=83	n=40	
(s)	52.6 (45.9-59.3)	40.1 (28.4-51.9)	34.7 (28.9-40.5)	41.0 (30.7-51.4)	1 vs. 3 0.001
Right hip extension	n=112	n=31	n=91	n=49	
(N)	275 (254-295)	220 (186-253)	221 (200-242)	216 (188-244)	1 vs. 3 0.001 1 vs. 4 0.006
Left hip extension	n=111	n=31	n=90	n=49	
(N)	254 (233-275)	217 (182-251)	209 (187-230)	204 (177-232)	1 vs. 3 0.02 1 vs. 4 0.04
Gait speed	n=112	n=31	n=92	n=53	
(m/s)	1.33 (1.30-1.36)	1.31 (1.24-1.39)	1.24 (1.20-1.29)	1.25 (1.20-1.30)	1 vs. 3 0.008

Table 12. Muscle test results postpartum in the 4 groups based on type of LBP: no LBP, lumbar pain, PGP, and combined pain.

mean (95% confidence intervals)	1 No LBP n=176	2 Lumbar pain n=27	3 PGP n=45	4 Combined pain n=14	Group comparison p-value
Back flexor endurance	n=166	n=20	n=44	n=12	
(s)	53.0 (47.4-58.6)	56.5 (38.1-74.9)	41.8 (30.9-52.7)	20.0 (9.7-30.3)	1 vs. 4 0.01 2 vs. 4 0.03
Back extensor endurance	n=162	n=17	n=36	n=9	
(s)	79.0 (73.7-84.4)	59.8 (42.9-76.7)	50.7 (39.1-62.3)	56.3 (30.9-81.7)	1 vs. 3 <0.001
Right hip extension	n=172	n=24	n=44	n=14	
(N)	256 (242-270)	265 (219-311)	211 (186-237)	183 (156-210)	1 vs. 3 0.03 1 vs. 4 0.03
Left hip extension	n=173	n=24	n=44	n=14	
(N)	239 (224-254)	261 (209-313)	217 (189-244)	185 (148-222)	ns
Gait speed	n=171	n=21	n=44	n=12	
(m/s)	1.33 (1.31-1.36)	1.27 (1.18-1.36)	1.26 (1.21-1.30)	1.28 (1.21-1.36)	1 vs. 3 0.03

Maximal voluntary isometric hip extension

The women with PGP and those with combined pain had lower values for maximal voluntary isometric hip extension muscle strength (the range of the mean difference 45-59 N for both legs in pregnancy, p=0.001-0.04, Table 11) and for the right leg postpartum (mean difference 45-73 N, p=0.03, Table 12) as compared to the women without LBP. No pattern was found regarding dominant pain side and hip muscle results.

Gait speed

The women with PGP walked at a slower speed as compared to the women without LBP both in pregnancy (mean difference 0.09 m/s, p=0.008, Table 11) and postpartum (mean difference 0.07 m/s, p=0.03, Table 12).

Pain intensity in relation to physical measures

There was no significant difference in pain intensity before and after the physical measures, which implies that the tests did not cause increased pain. The general linear model analyses showed an association between subgroups of LBP and trunk muscle endurance, hip extension muscle strength (bilateral in pregnancy and right leg postpartum), and gait speed (Table 13 and 14). When controlling for pain differences before and after each test, the explanation of the association between muscle function and subgroups did not improve. Thus, the lower values in the physical measures of those women with some type of LBP could not be explained by an increase in pain during testing. When controlling for pretest pain intensity, again, no improvement in the explanation was achieved.

Table 13. Results from the general linear model analyses in pregnancy. The independent fixed factor was the subgroups of the cohort. In crude model 1, the association between muscle test results and the subgroups was analysed. In adjusted model 2, the difference in pain before and after each test was added as a covariate. In adjusted model 3, the pretest pain intensity was added as a covariate. The significant associations are shown.

Pregnancy	Crude model 1	Adjusted model 2	Adjusted model 3
Dependent: ***Back flexors***			
Fixed factor: subgroups of the cohort	0.002	0.001	0.014
Dependent: ***Hip extension (right)***			
Fixed factor: subgroups of the cohort	<0.001	<0.001	0.014
Dependent: ***Hip extension (left)***			
Fixed factor: subgroups of the cohort	0.006	0.006	ns
Dependent: ***Gait***			
Fixed factor: subgroups of the cohort	0.004	0.005	ns

Table 14. Results from the general linear model analyses postpartum. The independent fixed factor was the subgroups of the cohort. In crude model 1, the association between muscle test results and the classification was analysed. In adjusted model 2, the difference in pain before and after each test was added as a covariate. In adjusted model 3, the pretest pain intensity was added as a covariate. The significant associations are shown.

Postpartum	Crude model 1	Adjusted model 2	Adjusted model 3
Dependent: ***Back flexors***			
Fixed factor: subgroups of the cohort	0.007	0.008	0.017
Dependent: ***Back extensors***			
Fixed factor: subgroups of the cohort	<0.001	<0.001	ns
Dependent: ***Hip extension (right)***			
Fixed factor: subgroups of the cohort	0.002	0.004	0.031
Dependent: ***Gait***			
Fixed factor: subgroups of the cohort	0.019	0.020	ns

DISCUSSION

PREVALENCE OF LOW BACK PAIN IN PREGNANCY AND POSTPARTUM

When all forms of nonspecific LBP were considered, 2 out of 3 women had some type of LBP in pregnancy and 1 out of 3 had LBP postpartum. Considering the fact that women who had mild symptoms were included in the study, the prevalence found is comparable to 3 identified cohort studies of pregnant women, in which clinical classification of all LBP was performed and the whole cohort of pregnant women was reported (2, 116, 183). The only cohort study that clinically re-evaluated all women postpartum reported an almost identical overall point prevalence as in the present study (31.6% vs. 33%)(116). It has been estimated that the prevalence of pregnancy-related LBP increases by 20% when women with mild symptoms are included (267). The 15% of women in the present study who reported no consequence as a result of their syndromes is comparable to the 20% previously described as afflicted by "a normal discomfort of pregnancy". The no consent rate was low in the present study, however, it is possible that women without LBP were less interested in participating, which may have resulted in a higher prevalence of LBP.

Most prevalence studies do not differentiate between PGP and lumbar pain, neither in pregnancy nor postpartum (12, 66, 128, 138, 154, 169, 174, 176, 182, 185, 235, 236, 263). When classification was performed, PGP was the dominant subgroup of LBP in the present study, as well as in 2 cohort studies of pregnant women that categorized into subgroups comparable to the PGP and lumbar pain groups (2, 183). Clinical examination was performed in another cohort of pregnant women, but only subgroup prevalence of "symptom-giving pelvic girdle relaxation" was reported (14%) (121). Additionally, in 1 cohort study, severe LBP requiring sick leave (9.2%) was examined and 2/3 of the women were reported as having SIJ dysfunction (14). The lower prevalence from these studies compared to the present study is consistent since the criteria are narrower and, thereby, a more affected sample is studied.

In contrast, the postpartum distribution of subgroup prevalence of LBP is not consistent. The present study showed the largest subgroup for PGP and the smallest for combined pain, which is consistent with one study that used similar criteria (168), however, nearly opposite to another (166). Classification based on pain drawings has shown the largest group for lumbar pain (180). A clinical observation is that women have difficulties locating the pelvis on a pain drawing, which might have implications for studies which classify LBP subgroups based on pain drawings. Regarding prevalence of subgroups of LBP postpartum, it is too early to draw conclusions since the present study is the only identified study that clinically classifies and reports prevalence of subgroups postpartum from a cohort of pregnant women.

From cohort/cross-sectional studies, self-reported prevalence of back pain during pregnancy shows a wide range (48-89.9%)(267). Studies with small samples tend to report higher prevalence of LBP, probably due to selection bias. The self-reported overall prevalence of LBP in pregnancy is higher than in studies with a clinical examination, possibly due to the fact that even milder forms are reported.

The self-reported point prevalence of back pain in postpartum cohorts ranges between 44% at delivery to 16% at 6 years postpartum (128, 176, 182). For the present study, the point prevalence for all types of LBP 3 months postpartum (33%) is similar to the self-reported point prevalence at the same time point after delivery (26%-33%) (112, 182). From a large cohort of 7526 pregnant women, a low prevalence for PGP and/or LBP (1.7%) was reported postpartum (12). However, the evaluation was undertaken 2-3 weeks postpartum and it is questionable as to whether the women had fully recuperated normal daily activity, which may have provoked some type of LBP. Apart from the low, unsure postpartum prevalence in this latter study, the self-reported prevalence postpartum is similar to that clinically evaluated. Compared to nonpregnancy-related LBP studies, the prevalence of LBP postpartum in the present study is higher than that self-reported (26%) in the 25-44 year age band (195).

Power

A power calculation was made for the planned RCT study. Initial power analysis was based on primary health care data of nonpregnancy-related LBP patients. With a beta level of 80% and a difference between subgroups in ODI of 10%, 62 patients were required per group in the RCT. When data had been

collected for approximately half of the cohort, a retrospective power calculation was performed, which revealed that 21 participants were needed per group. Estimated prevalence of LBP 3 months post partum was 25%, according to published reports from 1997 when the present study was planned. Thus it was appropriate to include 400 pregnant women in order to obtain 100 women with LBP postpartum for the RCT study. A retrospective analysis was done for the physical performance tests at the end of the study. The power to detect a 20% difference in the back flexor muscles was 52% (pregnant) and 39% (postpartum); for back extensor muscles it was 69% and for hip extensors, it was 94%.

Classification of low back pain

When examining pregnant women with LBP, it is not sufficient to only identify red flag conditions and those with nerve root syndrome and then consider the remainder as a heterogeneous group of non-specific LBP. PGP and discogenic problems also need to be identified since clinical experience and previous research suggest different treatment strategies for PGP and lumbar pain in relation to pregnancy (180, 189). The heterogeneous nonspecific LBP in pregnancy is divisible into at least 3 subgroups; lumbar pain, PGP, and combined pain.

The classification in the present study was based on history, pain location and clinical tests. The numbers of positive pelvic pain provocation tests are seen in Figure 4 and Figure 5. The criteria of 2 positive pelvic pain provocation tests for PGP was chosen based on the study that evaluated the 5 pelvic pain provocation tests used in the present study within the MDT protocol (122). Using either 2 or 3 positive tests for classification of SIJ pain reportedly made no large difference, but 2 is recommended. If 3 positive pelvic pain provocation tests had been used instead of 2, the consequences for the subgroup distribution are seen in Tables 15 and 16. Three positive tests for PGP probably select a more affected group. Women with only 2 positive tests are then classified as “no LBP” or as lumbar pain if there is a positive examination of the lumbar spine, instead of combined pain. On the other hand, the criteria of 2 positive tests, as used in the present study, might imply that the PGP group is “healthier”. van der Wurff et al. (2006) recommended 3 positive tests out of 5 based on a receiver operating characteristic (ROC) curve with a reported maximal area under the curve of 0.799 (239). Since both of the

above mentioned studies were done on nonpregnant samples, the implications on the present evaluation in pregnancy are not fully convincing.

Comparing the classification of 2 versus 3 positive tests in pregnancy and postpartum shows a higher discrepancy in pregnancy. This might be due to higher sensitivity of structures in and around the pelvis in pregnancy. Low rate of false positive pain provocation tests (0-15% (115) and 16-21% (n=2-3 out of 19)(164)) has been reported in pregnant women without PGP. Additionally when calculating the prevalence based on 3 positive tests, we have the same prevalence as studies not including women with mild symptoms.

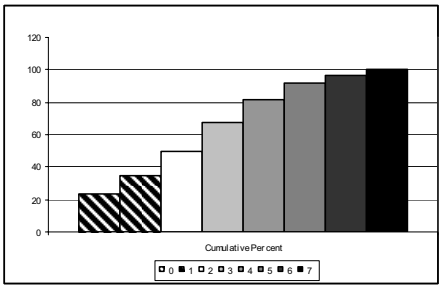

Figure 4. Number of positive pelvic pain provocation tests in gestational weeks 12-18.

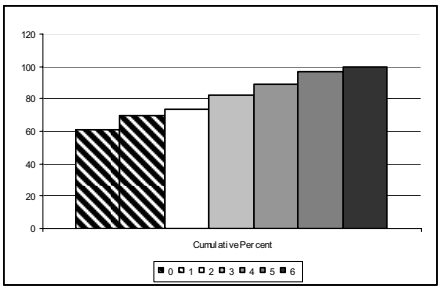

Figure 5. Number of positive pelvic pain provocation tests postpartum.

Table 15. Prevalence of subgroups of LBP when using 2 versus 3 positive pelvic pain provocation tests in pregnancy.

Subgroup	2 positive tests n (%)	3 positive tests n (%)
No LBP	118 (38)	144 (47)
Lumbar pain	33 (11)	43 (14)
PGP	101 (33)	75 (24)
Combined pain	56 (18)	46 (15)

Table 16. Prevalence of subgroups of LBP when using 2 versus 3 positive pelvic pain provocation tests postpartum.

Subgroup	2 positive tests n (%)	3 positive tests n (%)
No LBP	183 (67)	190 (70)
Lumbar pain	29 (11)	29 (11)
PGP	46 (17)	39 (14)
Combined pain	14 (5)	14 (5)

Kokmeyer et al. (2002) discussed the preference of a multiple test regime over a single test for the thigh thrust test that had shown the highest sensitivity (113). The thigh thrust test is similar to the posterior pelvic pain provocation test, with the difference being that the thigh thrust test includes an adduction of the hip and a thrust, rather than a light pressure, as in the posterior pelvic pain provocation test. A thigh thrust test achieved a kappa coefficient of 0.67, while with 3/5 positive tests achieved a kappa coefficient of 0.70. However, the thigh trust test was positive in 5 asymptomatic subjects, whereas a multiple test score of 3/5 tests was found negative by both examiners for every asymptomatic subject. Consequently, the authors recommended a multiple test score.

According to guidelines, classification of PGP requires exclusion of lumbar causes (258). It has been discussed that SIJ pain classification should only be considered after exclusion of patients with discogenic pain, due to risk of false positive pain provocation tests (124). In the present study, women with centralisation/peripheralisation and positive pelvic pain provocation tests were classified as combined pain. The risk for a false positive test is contradicted by results from a nonpublished study that showed that the posterior pelvic pain provocation test was negative in patients with well-defined lumbar diagnoses (n=53), which strengthens the classification of the present study. The posterior pelvic pain provocation test was performed on patients with computed tomography-verified disc herniation(s) waiting for surgery or patients 6 weeks after disc herniation surgery. The sensitivity of the posterior pelvic pain provocation test was 0.88 and the specificity was 0.89. Altogether, it seems important to use classifications for both pelvic and lumbar pain since women with positive pain provocation tests in the pelvis and centralisation/peripheralisation can be a target group that is at risk for persistency, irrespective of the cause to their pain.

A strength in the present study was that the same investigator examined all the patients, which decreased the risk of bias. Also, the reliability study of the classification into subgroups showed a substantial agreement between examiners. According to a recent review, evaluation of symptom response during repeated movements was 1 of few examination procedures used in the assessment of nonspecific LBP that showed promising results regarding reliability (141), again supporting the procedures used in the present study. However, the woman was only examined on 1 occasion, which may have been insufficient to identify some women where the symptoms centralized over the

course of several examinations (253). In regular clinical practice, the centralisation phenomenon might have been detected at a second visit, for example as a result of sending the patient home with a confirmatory exercise, which is a common procedure within MDT. A consequence of this possible weakness of the classification might be that the examiner classified PGP to a higher degree, instead of combined pain. The consequential subgroup difference would not have changed the results for the analysis of HRQL, pain intensity, disability, the depressive symptoms, and the muscle tests. It is unsure if the identification of predictors would be different by this possible weakness of classification. In conclusion, the classification of LBP, as done in the present study, is possible to do throughout pregnancy, and the results show group differences that are important to identify. The cause of LBP is still unknown in the majority of patients, pregnant as well as nonpregnant. Physical examination procedures that show promising results for identifying different homogenous subgroups that require specific guidance for prevention and management (70, 133) are important and of greatest interest for primary health care researchers (30).

COURSE AND PREDICTORS

The present study showed the clinical natural course of subgroups of women with LBP evaluated in early pregnancy and 3 months postpartum. The course differed among the subgroups and the study confirmed subgroup persistency of LBP. Women with combined pain were identified to be a target group since they had the lowest recovery rate and since the classification of combined pain was found to be a predictor for persistent PGP or combined pain postpartum, with possible identification early on in pregnancy. The prevalence of persistent PGP and combined pain 3 months postpartum was 16-21% in this study. Since it has been reported that improvement generally levels off around 3 months postpartum (116, 182), these women may have a poor prognosis. The previously reported long-term persistency of LBP in 20-21% of women at 2-3 years after delivery/postpartum (168, 235), emphasises the persistency. Additionally, women with PGP or combined pain in the present study were those with the greatest consequences of their syndrome in terms of pain and disability in early pregnancy. Severity of complaints at baseline in pregnancy has been reported to correlate with persistent symptoms postpartum (211). Likewise, it has been shown that women with LBP in pregnancy, severe enough to require sick leave, are at high risk for persistent and recurrent LBP

many years after pregnancy (36), which again emphasises the need for special attention to these women.

The prevalence of PGP decreased from pregnancy to 3 months postpartum and the proportion of lumbar pain remained stable. This confirms results from a follow-up questionnaire where it was shown that lumbar pain during pregnancy is similar to lumbar pain reported by non-pregnant women, while PGP is primarily related to pregnancy (180). The results of the present study suggest that pregnancy does not alter the course of lumbar pain. Most previous studies of pregnancy-related LBP did not identify women with lumbar pain or excluded these women, and thereby women with combined pain were not studied either. Consequently, if they had not been identified and included in the present study, these women would have been missed; the combined pain, as well as the lumbar pain group. It is important to study all types of LBP in pregnancy, not just women with PGP, who generally have a good prognosis.

It has been reported that multiple pain localisation is predictive of persistent pain (49, 62, 162). In the present study, pain drawings made by the women with combined pain were compared with an age-matched sample of women with LBP in primary health care (n=78, unpublished data). Lower degrees of both cervical and lumbar pain localisation were found in the women with combined pain and none had drawn pain marks outside the outline of the body on the pain drawing. This indicates that the women with combined pain do not present as a group with widespread pain.

Most postpartum studies have only followed those who had LBP/PGP in pregnancy. Women without LBP in pregnancy sometimes have a debut in relation to delivery and thus are missed in the prevalence report, as well as in follow-up studies. Studies that followed nonclassified LBP in pregnancy and reported persistent LBP postpartum showed a prevalence of 43-54% at 3 to 6 months postpartum (128, 154, 180, 236). In the present study, the lower persistency rate at 3 months postpartum was probably due to the sample in pregnancy including women with mild symptoms.

Studies that have only followed women with PGP reported a wide range of persistent PGP 1-2 years postpartum (8.5-68%) (3, 121, 165). The wide range is probably due to more specific, yet diverse criteria for PGP. An additional explanation for the lower prevalence found in the study by Albert et al. (2001),

is that women with pain of the same intensity or lower than previously experienced before index pregnancy, were considered healthy and excluded from follow-up (3).

One of the aims of this thesis was to identify predictors of persistent PGP or combined pain postpartum. The main outcome in the predictive model was classification of PGP or combined pain at the 3 month postpartum evaluation. Only 1 woman had the classification of lumbar pain both in pregnancy and postpartum and a high proportion of women with lumbar pain recovered. The results showed that women who were dissatisfied at work, who had combined pain in early pregnancy, who were relatively older, and who had low endurance of the back flexor muscles, had an increased risk of persistency. The predictive model was based on 154 women. The 154 participants included in the regression analysis did not differ from the 89 participants who were not included, except for 3 variables. The 89 excluded women were at a later gestational week of their pregnancy at the time of inclusion in the study, had more problems with urinary incontinence and had higher BMI. An association between BMI and LBP in relation to pregnancy has previously been reported (116, 154, 174). Studying the univariate associations, the consequences might be that the importance of BMI is underestimated in the present study. Multivariate analyses have drawbacks. Correlation and the multivariate models assume linearity, which is often not realistic, and multivariate analysis is sensitive to small deviations in the data, and thus to sampling error. Nevertheless, multivariate analysis is a powerful tool to identify factors that codetermine.

It has been reported that subject characteristics influence the lumbar paraspinal fatigability more strongly at the L4-L5 level than at L1-L2, and that the effect of age and BMI are more pronounced in women than in men (105). Women with high BMI fatigued faster than women with normal or low BMI. One would have presumed that back muscles of heavy and light individuals would have adapted to the demands. However, the results suggested that the low back muscles in women did not undergo adaptive changes to maintain endurance capacity relative to BMI. This is interesting to consider, both in pregnancy and postpartum, when many women do not resume their prepregnancy weight (118).

There may be a subgroup difference regarding predictors that is generally not identified when no classification of LBP is made. Previous experience of LBP is

one of the most frequently reported risk factors for either developing LBP in pregnancy (14, 121, 174, 175, 235) or having persistent LBP postpartum (211, 235, 236). In the present study, previous LBP was not an identified predictor for persistent pain. Nonpregnancy-related LBP, reported in primary health care to have a recurrent course (219, 262), may partly explain the risk factor. A greater number of women with lumbar pain had previous experience of nonpregnancy-related LBP, but since the outcome variable was pregnancy-related PGP or combined pain, this factor did not present. Furthermore, the identified predictor of low endurance of the back flexor muscles may be a covariant factor that partially explains previous pregnancy-related LBP. At the 12-18 gestational week evaluation, most women with PGP had a short duration of symptoms, suggesting that low endurance of the back flexor muscles was present before pregnancy. One hypothesis is that pregnancy-related hormone-induced ligament laxity, in combination with low muscle endurance, impairs dynamic stability of the pelvis and partially explains why women have pregnancy-related PGP.

In the present study, older age was another predictor for persistent PGP or combined pain. Both younger (236) and older (235) age have been reported to be risk factors for persistent LBP. The mean age of the women was lower in a study that reported young age as a higher risk (25.6) compared to studies that reported older age (29-31.8). The association might be bimodal, with the youngest and the oldest women being at a higher risk (267). Although mean age was rather low in comparison to that in primary health care, it turned out to be a predictor. There is little evidence that early treatment can change the long-term course (244), however, the pregnant women are a possible group to target for trials of prevention.

Dissatisfaction with work was identified as a predictor of persistent PGP or combined pain. Likewise dissatisfaction with work has been identified as a predictor of future nonpregnancy-related back pain (130) and future back pain in pregnancy (5, 177). Back flexor muscle endurance has not been reported as a predictor, but there are reports suggesting an association between muscle function and LBP (96, 184, 198, 204, 243). The predictors for persistent PGP or combined pain that were identified in the present study are not unique for pregnant women, but rather have also been reported in other groups of LBP (47, 62, 130).

HEALTH-RELATED QUALITY OF LIFE, PAIN AND DISABILITY

Pregnant women with both PGP and lumbar pain i.e. combined pain were greatest affected, as measured by self-rated HRQL, pain intensity, and disability. There is a risk that highly affected women within the subgroups (illustrated by wide confidence intervals) remained unnoticed due to relatively low median ratings. Furthermore, in evaluations of pregnant women with LBP, where no distinction was made between PGP and lumbar pain, "serious pain" was reported by 25% (116, 186) and "severe disability" by 30-36% (116, 177). In the present study, in the groups with PGP, 2/3 of the women exhibited both pain and disability (PGP 57 %, combined pain 70 %), i.e. twice as many as in the lumbar pain group (30%). The PGP groups reported a higher proportion of pain and disability compared to clinical natural course studies of cohorts of primary health care patients with LBP, of whom 50% still reported pain and disability after 3 months (48, 269). The results of the present study are in accordance with studies showing that, with an increasing number of musculoskeletal conditions, the HRQL deteriorates (194).

Sensitivity can be defined as the ability of an instrument to measure change in a state, irrespective of whether it is relevant or meaningful, whereas responsiveness can be viewed as the ability of an instrument to measure a meaningful important change. Responsiveness, or the minimal important change (MIC) of an instrument, has been defined as a change or minimally clinically important difference (MID) where the change is valuated from a clinical point of view (17, 101). There is no consensus on the most appropriate strategy for quantifying responsiveness, but effect size calculation and ROC curves have been proposed (17, 54, 82).

The MID for the EQ-5D score has been reported to range between 0.09-0.22 and for the EQ-5D VAS, the estimates ranged from 3.82 to 8.43 (74, 216). The reported MID of EQ-5D suggest that the group with PGP and the group with combined pain had a clinically important difference compared to the women without LBP, already early on in pregnancy.

A relevant MID in ODI score between groups has not been reported, but MIC in disability has been proposed to 4-10% on the ODI (17, 146) and a mean ODI of 10% is reported from normal populations (64). The MIC of ODI and the previously reported differences between improved and nonimproved patients on the VAS (10-18 mm)(17), suggest that the group with PGP and the group

with combined pain had a clinically important difference on disability and pain compared to the women without LBP, already early on in pregnancy, although their median group level was low. The lumbar pain group had values closer to healthy women.

Measures of health-related quality of life and disability

The EQ-5D as well as the SF-36 (246) are examples of common generic instruments used to quantify the HRQL in people with musculoskeletal disorders (73). The SF-36 is a self-reported scale with the aim to capture health in its broadest sense. It is a profile instrument describing health status along several dimensions. Since economic analysis of PGP hitherto is limited to sick leave costs, there was a need for an instrument that could be used in formal decision analysis and cost-effectiveness analysis and therefore the EQ-5D was chosen for this study. Recently, preference-based measures have also been derived from SF-36 (31) however inconsistent estimates and over prediction of the value of the poorest health states were reported. On the other hand, ceiling effects of EQ-5D in more healthy populations has been criticized (10, 160).

The most commonly used back-specific measures of self-reported functioning (29) are the ODI and the RDQ (207). The ODI is developed for the *lower* back whereas RDQ is *back* specific, i.e. including at least the thoracic and lumbar regions, which suggests the better suitability of ODI for PGP. Several items of ODI and RDQ evaluate the same activity, but in addition, the ODI includes items on travel and sexual activity which are known to increase PGP (85, 150). When the ODI was compared with the RDQ, the former was considered suitable for a population with a higher degree of disability (64). Given the findings that some women with PGP do become quite disabled, the ODI seems more appropriate for this group. Each item on the ODI is scored on a hierarchical 6-point scale, whereas the RDQ uses yes/no answers. As a result, if there are only small changes in function, the ODI is argued to be more responsive (18). In a later study, the responsiveness of ODI was lower compared to RDQ, whereas the specificity to change was higher in ODI (17). However, the responsiveness for ODI has not been calculated in a group of more severely affected patients. For the assessment of women with pregnancy-related LBP, who seem to have a wide range of degrees of disability, it may be useful to employ both ODI and RDQ, since they complement each other.

In conclusion, the population under study needs to be considered when choosing an instrument for measures of HRQL and disability.

POSTPARTUM DEPRESSION

Clinical experience has shown that treatment strategies target either LBP or postpartum depression. Based on the finding of high comorbidity of these complications of pregnancy, it seems important to screen for both depressive symptoms and LBP at postpartum follow-up or in primary health care, and to consider treatment strategies for both symptoms. Postpartum depression is commonly overlooked by primary health care (43). Studies have shown that 25% of women with morbidity postpartum did not seek professional help, although 49% would have liked more help or advice (34). From a physical therapy perspective, women with depression in addition to LBP need to be identified in order to receive an optimal treatment result. Although it is not clear which comes first, depression or LBP, it has been shown in nonpregnant populations that the presence of depression is associated with poor outcomes (129). In primary health care, it has also been shown that pain and depression predict each other symmetrically, which suggests a possible means of early identification of women at risk for either of the symptoms (80). Although not evaluated in the present study for its accuracy, the EPDS seems to be an adequate and simple screening tool for caregivers who treat women postpartum. High scores do not by themselves confirm depressive illness but rather indicate the need for further assessment.

In the cohort, the overall prevalence of depressive symptoms (cut-off ≥10) was 16%, comparable to that which has been reported (13–20%) in similar studies (46, 76, 104). The prevalence of depression did not differ in studies of postpartum women when compared to a control group of nonpostpartum women from the same population (9, 46, 170). In a larger population-based study, however, the risk of depression was higher for postpartum women than among controls, when controlling for uneven distribution of risk factors (prior depression, high score on the life event scale, and poor relationship to partner)(59).

The prevalence of probable depression (cut-off ≥ 13) in the postpartum cohort was similar to other Scandinavian samples (163, 256), but higher than in England or Australia (35, 46). One postal survey that reported comorbidity of postpartum depression and LBP was identified (35). For comparison, the

results of the present study were analyzed with a cut-off ≥13. Using this cut-off, the risk for having depressive symptoms when classified with lumbar pain (OR 8.44) or with combined pain (OR 6.76) at 3 months postpartum was higher compared to 6-7 months postpartum in the postal survey from Australia (OR 2.2). The prevalence of depressive symptoms (159) and the prevalence of PGP (180) have been shown to decrease a couple of months after delivery. The higher odds may partly be due to the fact that the study was undertaken 3 months after delivery, compared to 6-7 months in the study by Brown and Lumley (2000). Furthermore, the difference in methodology (postal survey versus clinical evaluation), as well as cultural differences, might explain the disparity.

The childbearing years are a period of great adjustment for women. It is important to identify the women at risk of postpartum depression since, if left untreated, in up to 25% of women, it may persist for at least 1 year after delivery (32). Depression has been reported to have a negative impact on women's social adjustment and mother-infant interaction, as well as produce long-term effects such as behavioral problems in the child (159). Sleep disturbances due to pregnancy and/or childcare postpartum compound the risk for depression (35, 209) and possibly the risk of LBP, since disturbed sleep has been shown to result in increased musculoskeletal pain, tenderness, and fatigue in healthy persons (155). These reports demonstrate the vulnerability of women to pain and depression in the childbearing years.

Additionally, the extent of physical functional impairment may not depend on the severity of the postpartum depressive symptoms (50). Da Costa et al. (2005) reported that the experience of even milder forms of depressed mood (i.e. EPDS 10-12) resulted in significant impairment to physical health status. Thus, treatment of even milder forms of depressive symptoms should be considered.

It might have been interesting to evaluate depressive symptoms during pregnancy. However, the EPDS was not validated for prenatal use at the start of the study. Also focus on depressive symptoms was avoided since it might have influenced the postpartum evaluation. In conclusion, even though the risk for depression may not be higher in postpartum women compared to non-postpartum, the prevalence of depressive symptoms is 3 times higher when having LBP.

MUSCLE FUNCTION

The results of the present study indicate an association between muscle function and pregnancy-related LBP that is stronger for PGP and combined pain than for lumbar pain, although the syndromes may have partly the same etiology. The retrospective power calculation showed that the power to detect a difference was low in some of the muscle tests. No statistically significant difference could be found between subgroups of LBP, therefore it is not known if lumbar pain and PGP are different with regard to muscle functioning. Notably, the women with lumbar pain were similar to the healthy group regarding muscle test results postpartum despite high pain intensity. The confidence intervals of the muscle tests strengthen the hypothesis that the PGP groups are different from, at least, the "no LBP" group.

The muscle tests were performed in nonweight-bearing positions, which might be regarded as nonfunctional. However, the test positions were chosen with respect to the risk of pain increasing in standing positions, the position possible with the dynamometer, and the use of recommended muscle test positions (108). In the theoretical model of the self-locking mechanism, the pelvis is described as providing a stable base for movement of the limbs in all positions. Likewise, the recommended functional test of load transfer in the lumbopelvic region is the ASLR test, which is a supine test (258). Muscle differences were noted in the study, in spite of the nonweight-bearing position, which strengthens the hypothesis of an association between muscle dysfunction and, at least, PGP. Additionally, the improvement seen in muscle function, pain, and disability in women with PGP after specific stabilising exercises further supports the hypothesis (60, 225, 226).

The drop-outs in the separate tests were not expected to influence the results since the reasons for not performing a test were mostly nonrelated to the LBP per se, but rather to the pregnancy itself. In pregnancy, 7 women were unable to do any test due to experiencing palpitations (n=1) or being too far along in pregnancy (n=6). Postpartum, 4 women were unable to do any test due to the risk that discogenic problems would become worse, the woman's lack of time, fear of pain or possible kidney problems. The most common cause for not doing a test was reported discomfort in the prone position due to pregnancy, being at most 7/99 of the women with PGP. The highest proportion was lack of time (6/27) in the group with lumbar pain.

One problem with muscle testing is that it might be influenced by perceived pain. Control for the influence of pain was somewhat achieved by allowing the women to estimate pain level on a VAS, before and after each test. No difference in pain level before and after the test was found. Likewise, in the general linear model analyses, an association was noted between subgroups of LBP and trunk muscle endurance, hip extension muscle strength, and gait speed. When controlling for pain differences before and after each test, the explained variance of the association between muscle function and subgroups of LBP did not improve. Thus, the lower values in the tests of those women with some type of LBP could not be explained by an increase in pain during testing. When controlling for pre-test pain intensity, no improvement in the explained variance of the association was achieved.

Pain has a potent effect on motor activity and probably plays a role in the development of persistent problems (222). It has been suggested that the presence of pain leads to inhibition or delayed activation of specific muscles or muscle groups in at least some individuals (91). Altered muscle recruitment has been shown in subjects with nonspecific LBP (93, 240) and in subjects with nonpregnancy-related PGP (96, 184).

Performance motivation is another difficulty to cope with in muscle testing. No encouragement was given during the tests in the present study in order to have as far as possible the same condition for all women. There were large ranges for the different muscle tests. To our knowledge, MID in muscle test analysis is not defined, but a 10% difference between groups is a value used (119, 127). The statistically significant difference in muscle tests of the PGP subgroups was 15-62% of the values of the women without LBP.

Studying muscle function while walking confirmed the gait difficulties previously reported by women with PGP (150, 168). Even early on in pregnancy, the women with PGP walked at a slower speed than the women without LBP. The gait speed was below the cut-off level of 1.3 m/s that has been proposed to differentiate between back patients and healthy persons (131). The statistically significant difference between subgroups must be regarded with caution, however. A clinically important difference for improvement in gait speed after hip fracture has been reported to 0.1 m/s (187). Although the difference between groups in the present study was smaller in general, relevant difference and change are not necessarily equivalent.

Gait speed might be regarded as a functional test indicating, among other things, the condition of stability over the pelvis. The "waddling gait" seen in pregnant women may be an adaptation in order to achieve stability. Peak transverse plane lumbopelvic rotation occurs at foot strike (213). By waddling, the women avoid rotation of the lumbopelvic region and thereby decrease demands on stability and also the risk of getting or increasing pain. The reported and observed shorter stride length is perhaps due to the same reason since lumbopelvic range of motion increases with stride length (213). Additionally, waddling gait places the centre of gravity of the trunk above the weight-bearing hip and thereby decreases the demands on the abductors. Furthermore, significant increases in hip and ankle kinetic gait parameters have been observed during pregnancy, explaining why gait motion remained relatively unchanged despite increases in body mass and width as well as changes in mass distribution about the trunk. This finding indicates that during pregnancy, there may be an increased demand placed on the hip abductor, hip extensor, and ankle plantar flexor muscles during walking (68). In conclusion, gait may be an indicator of the functional limitation in PGP that probably is related to lumbopelvic stability.

INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY AND HEALTH

When studying consequences of pregnancy-related LBP, the International Classification of Functioning, Disability and Health (ICF), developed by the WHO (255), is a suitable framework. The ICF organizes information as "functioning and disability" and "contextual factors". Within functioning and disability, "body functions" and "body structures" are included. Body functions are the physiological functions of body systems, including psychological functions, whereas body structures are the anatomical parts such as organs, limbs and their components. Problems (significant deviations or loss) in body function or structure are defined as impairments. Also included within functioning and disability are "activity" and "participation" components, which cover domains of functioning from both an individual and a societal perspective. The difficulty an individual may have to execute an activity is defined as activity limitation. The problem an individual may experience in life situations is defined as participation restrictions. The contextual factors are personal, as well as environmental factors.

In the present study, the ICF model was used for structuring variables studied within research of pregnancy-related LBP (Figure 6). The variables were identified in the literature studied for this thesis and within references lists of that literature. At the start of the study, no published study was found where an established measurement tool was used for evaluating disability and HRQL in LBP in relation to pregnancy. Although LBP in pregnancy sometimes is looked upon as transient and unimportant, the impact of pregnancy-related LBP, as reported in the present study and other studies (36, 116, 121, 152, 168, 173, 189) supports the opposite. In recent years, there has been a strong trend to use established measurement tools which are important for comparison between studies. Environmental factors and factors on participation level, such as life situation, are less studied within pregnancy-related LBP. Environmental factors were not evaluated in the present study but need to be better understood in pregnancy-related LBP. Depressive symptoms were studied using the EPDS. The EPDS was placed on the body function dimension, however depression has shown to be difficult to categorise in the ICF model (249), probably because it may be seen as a biological as well as an environmental factor. The combination of a patho-physiological model and a psychosocial model seems important for the understanding of LBP in pregnancy. In conclusion, research within pregnancy-related LBP has expanded extensively during the last decades. When designing new studies, all dimensions of the ICF need to be considered in order to obtain a complete picture of the problem.

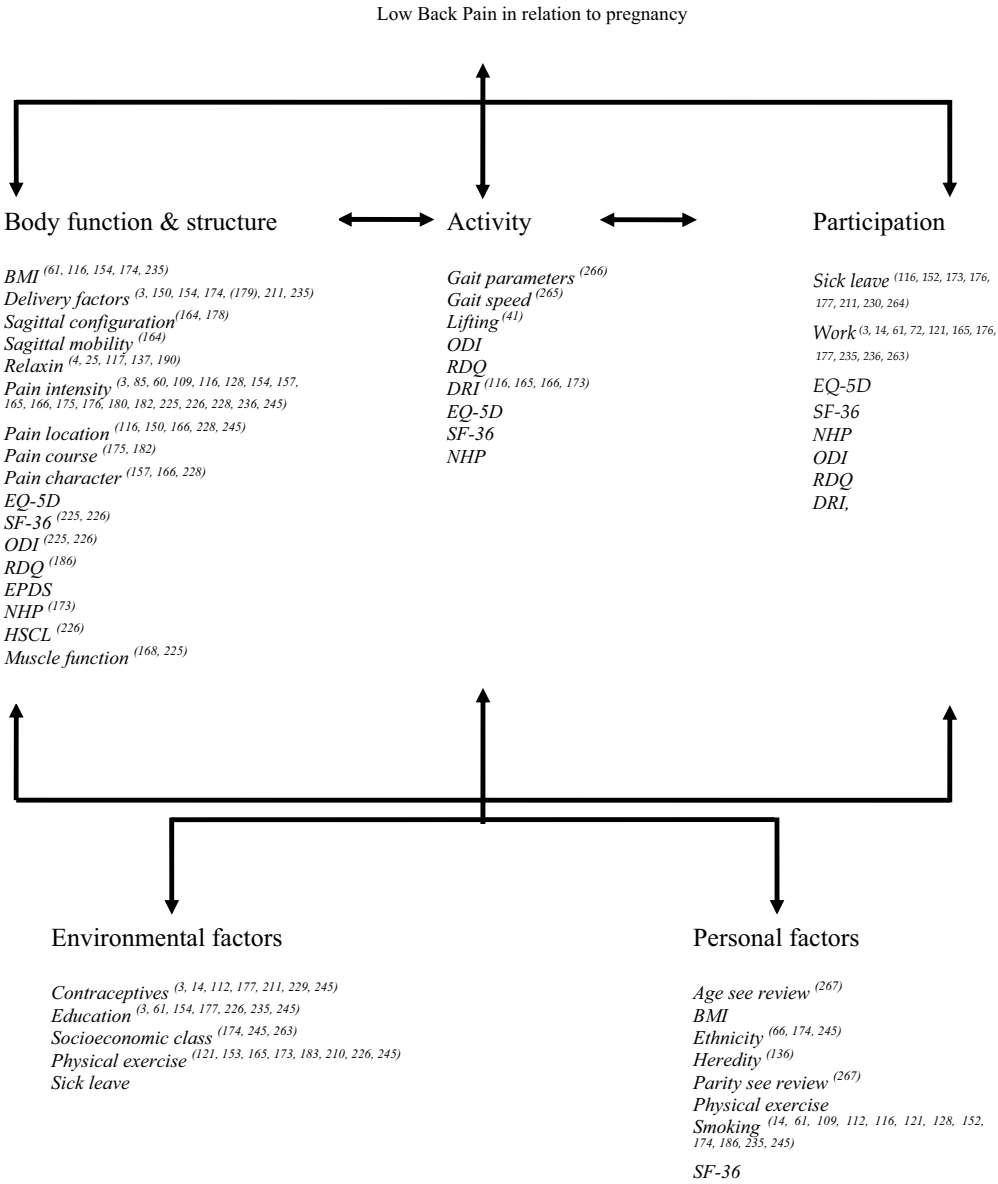

Figure 6. Interactions between the components of the ICF (WHO 2001). Under the components are listed variables studied within research of pregnancy-related LBP. An instrument may have variables from different components and is thereby under several components in the ICF model.

DRI	Disability Rating Index
HSCL	The Hopkins Symptom Check List
NHP	Nottingham Health Profile
QBPDS	Quebec Back Pain Disability Scale

CLINICAL IMPLICATIONS

One clinical implication of this thesis is that the women at risk for persistent pain postpartum may be identified early on in pregnancy using known and well-described classification methods. The identified predictors can be evaluated by questions concerning age and work satisfaction, and with inexpensive methods for measuring endurance of the back flexor muscles. Another clinical implication is that the EPDS seems to be an accurate and simple instrument to use in clinical practise for screening for depressive symptoms. When identified risk women, possible need for multiple treatment strategies should be considered.

In has been shown that only 32% of women with LBP report their morbidity to prenatal caregivers (245). Of those caregivers asked, 75% did not recommend any treatment. The study indicates the need for physiotherapists who can classify the LBP, direct appropriate activity and training levels, and offer treatment when needed.

The question can be asked as to why certain women experience PGP while others do not. No one structural component, e.g. joint, muscle or ligament, is likely to be the sole source of pain. The LBP that women experience in pregnancy is likely to be multifactorial, with one or more factors dominating. Therefore, it would be beneficial to seek common patterns that may be addressed using focused treatments. Attempts to prevent the occurrence of LBP have failed (8) and subsequently comorbidity and negative consequences need to be addressed. Effective treatment should be pursued since evidence suggests that LBP in pregnancy may lead to disability as well a persistent LBP after pregnancy.

FUTURE RESEARCH

Further studies on how to prevent the development of factors that describe persistent pregnancy-related PGP are needed, parallel to studies on contextual factors, as well as psychosocial factors within participation dimensions. One can only speculate on how previous experience of LBP in this population may interfere with expectations of recovery and coping strategies. Women with a LBP debut in relation to a pregnancy, may attribute the LBP to the pregnancy, that in itself has an end and thereby an expectancy of pain relief with it. On the contrary, lumbar pain is often experienced earlier on in life and has a recurrent course. The role of the cognitive-evaluative component may be different for a

woman with recurrent lumbar pain who also experiences PGP. She does not have the experience of LBP that recovers and thereby her expectations might be different when faced with 2 types of pain. Here, it is interesting to apply ideas of pain exacerbation with catastrophising theories and fear of pain. There is growing information with regard to different coping strategies, which are probably applicable to the PGP population, but still poorly understood (84). The social aspect, including family and work situations, seems relevant to evaluate. In addition, there is a young and growing research branch that study sex and gender differences of biological and psychosocial factors in relation to pain and pain mechanisms. The results from theses studies may be important to consider in pregnancy-related LBP.

CONCLUSIONS

- The clinical classification showed an equal prevalence of lumbar pain in pregnancy and postpartum, while the rate of women with pelvic girdle pain or combined pain decreased after pregnancy.

- The clinical natural course of women with combined pain showed the lowest recovery rate among the subgroups of low back pain.

- A target group that is at risk for persistent postpartum pelvic girdle pain or combined pain is women who are dissatisfied at work, have combined pain early on in pregnancy, are relatively older, and have low endurance of the back flexor muscles. Identification of this target group appears possible with the described classification of low back pain in early pregnancy.

- During early pregnancy, women with combined pain experienced greater consequences in terms of health-related quality of life, pain intensity, and disability, than women with lumbar pain alone.

- Postpartum depressive symptoms were 3 times more prevalent in women with low back pain than in those without, yielding a comorbidity rate of 10% in the cohort. Women with lumbar pain tended to have a higher risk for depression than women with pelvic girdle pain.

- The hypothesis of the association between the pelvic girdle pain subgroup and muscle dysfunction was supported by the results which showed low trunk muscle endurance during pregnancy and postpartum.

- Physical therapists treating women with postpartum low back pain need to screen for depressive symptoms.

SUMMARY IN SWEDISH

Nedre ländryggssmärta förekommer i högre grad hos gravida kvinnor än hos kvinnor i samma ålder i befolkningen. Graviditetsrelaterad nedre ländryggssmärta kvarstår 6 år efter graviditet hos 16 % av kvinnorna. Graviditet representerar därmed en specifik risksituation för såväl nedre ländryggssmärta som kvarstående nedre ländryggssmärta efter graviditet. Graviditetsrelaterad nedre ländryggssmärta studeras vanligen som en enhet trots att endast en undergrupp av nedre ländryggssmärta, bäckensmärta, tycks vara relaterad till graviditet. Därmed är möjliga skillnader mellan undergrupper okända.

Avhandlingens syften var följande: 1) att beskriva förekomst av kliniskt klassificerade undergrupper av kvinnor med nedre ländryggssmärta i en kohort (ingen nedre ländryggssmärta, lumbal smärta, bäckensmärta, kombinerad bäcken-och lumbalsmärta (kombinerad smärta)) i graviditet och postpartum och 2) att undersöka om det fanns en skillnad i förlopp, hälso-relaterad liskvalitet, smärtintensitet, funktionsnedsättning, depressiva symtom, eller muskelfunktion i undergrupper av kohorten samt 3) att identifiera prediktorer för kvarstående graviditetsrelaterad bäckensmärta eller kombinerad smärta postpartum.

Konsekutivt inkluderade gravida kvinnor klassificerades i undergrupper genom mekanisk undersökning av lumbalkolumna, smärtprovokationstester för bäckenet, standardiserad anamnesupptagning, och smärtteckningar. Alla kvinnor besvarade frågeformulär (bakgrundsfrågor, EQ-5D). Kvinnor med nedre ländryggssmärta fyllde i Oswestry Disability Index och smärtmått. Edinburgh Postnatal Depression Scale användes för att undersöka depressiva symtom 3 månader postpartum (≥10). Uthållighetstest av bålmuskulaturen, styrketest av höftmuskulatur och gånghastighet undersöktes. Multipel logistisk regression användes för att identifiera prediktorer från självrapportering samt från den kliniska undersökningen.

Vid undersökning i graviditetsvecka 12-18, hade 118/308 (38%) kvinnor ingen nedre ländryggssmärta, 101 (33%) hade bäckensmärta, 33 (11%) hade lumbal smärta och 56 (18%) hade kombinerad smärta. Tre månader postpartum, var 183/272 (67%) kvinnor utan nedre ländryggssmärta, 46 (17%) hade bäckensmärta, 29 (11%) hade lumbal smärta, och 14 (5%) kombinerad smärta. Gravida kvinnor med kombinerad smärta rapporterade högsta påverkan i termer av hälsorelaterad livskvalitet, smärtintensitet, och

funktionsnedsättning. Kvinnor med bäckensmärta och/eller kombinerad smärta hade lägre värden för uthållighet i bålmuskulaturen, styrka av höftextensorer och gånghastighet jämfört med kvinnor utan nedre ländryggssmärta. Depressiva symtom förekom i tre gånger så hög grad hos kvinnor med nedre ländryggssmärta (27/87 31%) jämfört med kvinnor utan nedre ländryggssmärta (17/180 9%). Postpartum hade 16-20% av kvinnor kvarstående bäcken-och kombinerad smärta medan 1/29 hade lumbal smärta. Identifierade prediktorer för kvarstående bäcken eller kombinerad smärta var otrivsel på arbetet, högre ålder, kombinerad smärta i tidig graviditet, och låg uthållighet i bukmuskulaturen.

Sammanfattningsvis identifierades kvinnor med kombinerad smärta som en riskgrupp eftersom de hade det lägsta tillfrisknandet och eftersom klassifikationen kombinerad smärta visade sig vara prediktor för kvarstående bäckensmärta eller kombinerad smärta postpartum. Hypotesen att muskeldysfunktion var relaterad till bäckensmärta stärktes. Baserat på vårt resultat av hög komorbiditet av postpartum depressiva symtom och nedre ländryggssmärta, förefaller det viktigt att screena för och överväga behandling för båda symtomen.

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