The AfterBabyBodyStudy

Muscular changes, exercising, and activity limitations
and their associations with
pelvic girdle pain and urinary incontinence
in the postpartum period

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Gothenburg 2023

Cover illustration: Sabine Vesting

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ISBN 978-91-8069-473-5 (PRINT)
ISBN 978-91-8069-474-2 (PDF)
Available at: http://hdl.handle.net/2077/78568

Printed in Borås, Sweden 2023
Printed by Stema Specialtryck AB

I did not know what I was allowed to do without destroying something. I felt a heaviness in my vagina which I did not know if it should be there, if it meant that I should wait with activities or if it does not matter at all… I had no idea

(Participant)

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ABSTRACT

Aim: Pregnancy and childbirth can lead to several symptoms, changes in the pelvic floor muscles and a diastasis recti abdominis (DRA). This thesis aimed to assess and explore stress urinary incontinence, vaginal heaviness, pelvic girdle pain and muscular changes in the postpartum period, in relation to each other, and in relation to exercising, activity limitations and women's experiences.

Methods: This thesis comprises four papers based on a prospective longitudinal cohort study (n = 504) and a qualitative study (n = 14). The cohort study included questionnaires and clinical muscle assessments at 3, 6, 9 and 12 months postpartum, with double initial assessments (n = 222) to assess inter-rater reliability (Paper I). The questionnaires included measures to assess pelvic girdle pain (Papers II+III), stress urinary incontinence, vaginal heaviness and exercising (Paper III) and activity limitations (Paper IV). The qualitative study involved interviews regarding women's experiences of physical changes and recovery postpartum (Paper IV). These 14 women were not included in the cohort study.

Results: Good inter-rater reliability was shown for the assessment of maximal voluntary pelvic floor muscle contraction using vaginal palpation and for measuring DRA width with a caliper, but only fair inter-rater reliability for the assessment of pelvic floor muscle relaxation (Paper I). There were associations between weak pelvic floor muscles and DRA width ≥35 mm and increased pelvic girdle pain severity at 3 months postpartum. Participants with lower pelvic girdle pain severity showed no statistically significant decrease from 3

to 12 months postpartum (Paper II). Participants who engaged in low-impact exercise 2-4 times/week within the first 3 postpartum months experienced reduced pelvic girdle pain and stress urinary incontinence severity at 12 months compared to 3 months postpartum. Those who did not exercise experienced increased stress urinary incontinence at 12 months postpartum (Paper III). Women experienced activity limitations, e.g., running, exercising, and lifting/carrying, due to pain, vaginal heaviness, and urinary incontinence in the first 6 months. While most of these limitations were temporary, 41% of women continued to experience difficulties with running 12 months postpartum (Paper IV-cohort). The women were surprised by the physical changes postpartum. They expressed a need to understand whether these changes were permanent or temporary (Paper IV-interview).

Conclusion: Several symptoms and physical changes naturally diminish during the first year postpartum. However, urinary incontinence and pelvic girdle pain can result in activity limitations. Women can feel surprised and insecure about these physical changes and seek support and practical advice on how to manage them. Primary care physiotherapists could play an important role for women with persistent symptoms and activity limitations in assessing their pelvic floor and abdominal muscles, encouraging and adjusting exercise, and helping to restore function in muscle groups associated with pain and urinary incontinence.

Keywords: activity, clinical assessment, exercising, experience, pelvic floor disorders, pelvic girdle pain, physiotherapy, postpartum, primary health care, urinary incontinence, vaginal heaviness

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Sammanfattning på svenska

Efter barnafödande upplever många kvinnor förändringar i kroppen, till exempel en svagare bäckenbotten och att magmusklerna har delats. En del kvinnor upplever också symptom som urinläckage, tyngdkänsla i underlivet och bäckensmärta. Dessa besvär kan göra att de söker vård hos en fysioterapeut. Det finns dock kunskapsluckor kring kliniska undersökningsmetoder samt vilka träningsråd som bör ges. Det saknas även kunskap om kvinnors upplevelser av dessa förändringar efter barnafödandet.

Det övergripande syftet med denna avhandling var att undersöka förändringar i bäckenbotten och magmuskulaturen och om det finns samband mellan förändringar och upplevda symtom under första året efter barnafödande. Avhandlingens fokus var kliniska undersökningsmetoders tillförlitlighet, hur dessa och fysisk träning är relaterade till urininkontinens, tyngdkänsla i underlivet och bäckensmärta samt kvinnors upplevda aktivitetsbegränsningar och återhämtning.

I en studie följdes 504 kvinnor under året efter förlossning. Deras bäckenbotten och magmuskulatur undersöktes vid fyra tillfällen och de svarade på frågeformulär om sina symptom, om fysisk träning, samt om aktivitetsbegränsningar. Efter att den första studien var klar rekryterades ytterligare 14 kvinnor för individuella intervjuer kring upplevelser av kroppsliga förändringar och återhämtningen efter barnafödandet

Avhandlingen visade att fysioterapeutiska undersökningsmetoder för bäckenbottenstyrka och för mätning av magmuskeldelning har bra tillförlitlighet, medan bäckenbottenavspänning var svårare att bedöma. Bäckenbottenstyrka och magmuskeldelning var kopplade till bäckensmärta efter graviditet. Lugna träningsformer, såsom regelbundna promenader, verkar bidra till förbättringar av bäckensmärta och urinläckage vid 12 månader. Däremot upplevde de kvinnor som var inaktiva en viss ökning av urininkontinens från 3 till 12 månader efter barnafödandet. För få kvinnor tränade löpning för att i avhandlingen kunna uttala sig om det finns ett samband mellan löpning och besvär. Avhandlingen fann att urinläckage och smärta efter barnafödandet kunde begränsa kvinnors deltagande i vissa aktiviteter, särskilt löpning. Många kvinnor uttryckte förvåning över kroppens förändring efter barnafödande och osäkerhet kring om dessa förändringar var permanenta eller om de kunde påverkas.

Sammanfattningsvis visar avhandlingen att många symptom avtar naturligt efter barnafödandet, medan andra symptom kan påverka kvinnors möjligheter till att delta i aktiviteter och fysisk träning. Kvinnorna i intervjustudien efterfrågade mer stöd och önskade att få konkreta råd. För kvinnor som har kvarstående besvär efter barnafödande kan fysioterapeuter i primärvården spela en viktig roll genom att undersöka muskulära förändringar, främja och anpassa fysisk träning, samt ge råd och övningar för att hjälpa kvinnor att återställa funktionen i muskelgrupper som kan påverka smärta och urinläckage.

List of papers

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

I. Vesting, S, Fagevik Olsén, M, Gutke, A, Rembeck, G, Larsson, MEH. **Clinical assessment of pelvic floor and abdominal muscles 3 months post partum: an inter-rater reliability study.** *BMJ Open 2021, 11(9), e049082. doi: 10.1136/ bmjopen-2021-049082.*

II. Vesting, S, Gutke, A, Fagevik Olsén, M, Praetorius Björk, M, Rembeck, G, Larsson, MEH. **Can Clinical Postpartum Muscle Assessment Help Predict the Severity of Postpartum Pelvic Girdle Pain? - A Prospective Cohort Study.** *Physical Therapy 2022, 103(1), pzac152. doi: 10.1093/ptj/pzac152*

III. Vesting, S, Gutke, A, Fagevik Olsén, M, Rembeck, G, Larsson, MEH. **The impact of exercising on pelvic symptom severity, pelvic floor muscle strength and diastasis recti abdominis after pregnancy: a longitudinal prospective cohort study.** *Physical Therapy 2023, 103. In press.*

IV. Vesting, S, Rembeck, G, Fagevik Olsén, M, Gutke, A, Larsson MEH. **Surprised by the transition to an unknown body: Quantitative and qualitative aspects of physical changes and activity limitations during the first year postpartum.** *In manuscript.*

Contents

Abbreviations

ANOVA	Analysis of variance
BMI	Body mass index
CI	Confidence interval
DRA	Diastasis recti abdominis
EMG	Electromyography
ICC	Intraclass correlation coefficient
ICF	International Classification of Functioning, Disability and Health
ICIQ-UI SF	International Consultation on Incontinence Questionnaire-Urinary Incontinence short form
IQR	Interquartile range
IRD	Inter recti distance
MDC	Minimal detectable change
MIC	Minimal important change
MVC	Maximal voluntary (pelvic floor muscle) contraction
OASIS	Obstetric anal sphincter injuries
PFM	Pelvic floor muscle
PGQ	Pelvic girdle questionnaire
PGP	Pelvic girdle pain
PSFS	Patient-specific functional scale
SD	Standard deviation
SEM	Standard error of measurements
SUI	Stress urinary incontinence

Definitions in short

Antenatal	Before birth
Caliper	A (dial) caliper is an instrument that measures the distance between two opposite sides.
Clinical assessment	A standardised way to gather information about an individual's health using one or more clinical tests (Frawley et al., 2021).
Covariate	A variable that has a potential relationship to the outcome variable (Field, 2009).
Diastasis recti abdominis	An increased distance between the two parts of the rectus abdominis muscles (Mota el al., 2018)
Diastasis recti abdominis bulging	A slackened linea alba that bulges due to increased abdominal pressure (Lee & Hodges, 2016).
Disability	Umbrella term for impairment, activity and participation limitation (WHO, 2001).
Exercising	Physical activity that is planned, structured, and repetitive, aiming to maintain or improve one or more components of physical fitness (Caspersen et al., 1985).
Functioning	The opposite of disability, describing body function, activity, and participation from a healthy perspective (WHO, 2001).

Intraclass coefficient	A correlation coefficient that assesses consistency or agreement between data points by measuring variance among subjects compared to total variance (Field, 2009).
Interquartile range	Measure of data's middle spread, between 25th and 75th percentiles (Field, 2009).
Low back pain	"Pain and discomfort, localised below the costal margin and above the inferior gluteal folds, with or without leg pain" (van Tulder et al., 2006).
Long-term pain	Pain that persists ≥3 months. (Treede et al., 2019)
Lumbopelvic pain	An umbrella term encompassing both pregnancy-related low back and pelvic girdle pain or a combination of both (Wu et al. 2005).
Maximal voluntary muscle contraction	The voluntary effort to generate the maximum force by a muscle contraction (Knuttgen & Kraemer ,1987).
Multiparous	A female who has given birth two or more times.
Muscle strength	"The maximal force a muscle or muscle group can generate at a specified velocity" (Knuttgen & Kraemer ,1987).
Muscle endurance	The ability to exert force through many contractions or to sustain a single contraction over time (Caspersen et al., 1985).
Nulliparous	A female who has not given birth.

Pelvic girdle pain	Pain experienced between the posterior iliac crest and the gluteal fold, particularly around the sacroiliac joints. The pain might radiate into the thigh and can also occur alongside or independently in the symphysis. (Vleeming et al., 2008).
Perinatal	Time period before and soon after childbirth.
Physical activity	All bodily movement produced by skeletal muscles resulting in energy expenditure (Caspersen et al., 1985)
Postpartum	After delivery; refers to the mother in contrast to "postnatal", which often refers to the baby (WHO, 2010).
Predictor	A variable that is used to try to predict values of the outcome (Field, 2009).
Prevalence	The number of cases or individuals in a population who have a specific disease or health condition during a specific time or interval of time (Rothman et al., 2008).
Primiparous	A female who has given birth once.
Psychometrics	The quantification of various attributes that determine the quality of a measurement instrument (Mokkink et al., 2010).
(Functional) recovery	The return to full functional ability after childbirth (Tullman & Fawcett, 1988).

Reliability	The consistency and dependability of a study, test, or instrument when reproduced under different circumstances, such as by different raters, or at different times (Field, 2009).
Responsiveness	The ability of an instrument to detect change over time in the construct to be measured (Mokkink et al., 2010).
Stress urinary incontinence	Complaint of any involuntary urine leakage during physical exertion or when sneezing or coughing (Abrahms et al., 2010).
Urinary incontinence	The complaint of any involuntary loss of urine (Abrahms et al., 2010).
Validity	The ability of a study, assessment or test to measure what it is intended to measure (Mokkink et al., 2010).
Vaginal heaviness	Sensation of lacking pelvic organ support
Vaginal palpation	A method where fingers or a hand are used to gather information about the tissue or muscle (Bö et al., 2016).

Introduction

The idea for this thesis started from the clinical observation that an increasing number of women are scheduling an appointment with a primary care physiotherapist to undergo a check-up of their muscle function, specifically the pelvic floor and abdominal muscles, after pregnancy. Women want to know if they are recovering and are concerned about symptoms such as urinary incontinence, the sensation of vaginal heaviness and pelvic girdle or low back pain. They also want to know when they are allowed to start exercising after pregnancy. This increased patient flow may be linked to increased body awareness over the past decade. This trend might be due to individual motivation or could be influenced by various factors, including social media campaigns (e.g., #alltserfintut), coverage in newspapers and television programmes, and the growing presence of physiotherapists and personal trainers who share postpartum recovery information through their social media channels.

It is known that pregnancy and childbirth are associated with pelvic floor disorders with an increased risk for urinary incontinence and pelvic organ prolapse.[1,2] Pain in the pelvis and lower back is common during the childbearing years.[3,4] Historically, these issues were often perceived as inevitable postpartum consequences. However, several reports from the Swedish Agency for Health Technology Assessment and Assessment of Social Services have highlighted knowledge gaps in the assessment and treatment of pelvic girdle pain,[5] birth injuries[6] and diastasis recti abdominis.[7]

While the treatment of pelvic girdle pain and urinary incontinence is established in physiotherapy, the field of postpartum check-ups is relatively new for physiotherapists in primary care. Only a limited number of physiotherapists in Sweden have received additional training in assessing pelvic floor muscles through vaginal palpation, and the assessment of diastasis

recti abdominis is primarily taught by private providers without scientific support.

Traditionally, midwives and, in more complicated cases, gynaecologists conduct postpartum follow-ups. They have profound knowledge about pregnancy, childbirth, and related factors such as hormonal influences, pelvic floor tearing, and breastfeeding. For physiotherapists, this territory is relatively uncharted, requiring them to define their role in preventing and addressing postpartum pain and dysfunction without encroaching on the expertise of gynaecologists and midwives. However, there exists knowledge gaps concerning the clinical assessment methods used and the advice we can provide regarding the resumption of exercise, considering weakened muscles and symptoms such as pelvic girdle pain and urinary incontinence. Some of these gaps will be addressed in this thesis.

The postpartum period

The time period following childbirth is called the "postpartum period", derived from the Latin words post (after) and partum (giving birth). The initial two phases of the postpartum period are clearly defined: the acute period, encompassing the initial 6–12 hours following childbirth; and the subacute period, which spans the initial 6 weeks after giving birth.[8] In the subacute period, the body largely returns to its pre-pregnancy state in terms of most of the bodily adjustments brought on by pregnancy, for example hormonal adjustments and uterus size, and metabolic functions.

However, recovery after childbirth includes more than just the restoration of organs. Muscles and tissues, but also everyday functions, such as household, social and occupational activities, need a longer time to return to normal.[8,9] This recovery mostly occurs in the third and final phase of the postpartum period, which is less precisely defined. The first 3 months after childbirth are often described as the "fourth trimester",[10,11] – a phase of increased need for attention and support, primarily due to factors such as sleep deprivation, breastfeeding demands, stress, and the physical and emotional aftermath of childbirth.[11] The third postpartum phase has also been defined as the first 6 months after childbirth[8] and is often associated with the cessation of breastfeeding.[12] Here, it is important to note that even women who are not breastfeeding experience postpartum changes. Moreover, many physical, psychological and social adaptations continue beyond 6 months postpartum.[8]

Therefore, some experts[13,14] have proposed extending the definition of the postpartum period to at least 1 year.

Postpartum care

The majority of women in Sweden give birth at a hospital, with an average postpartum stay of 2.2 days.[15] This includes women who have given birth by cesarean section. After the delivery, the hospital is responsible for the women's health for 7 days.[16] Approximately 30-50% of hospitals offer a follow-up visit within these 7 days; this can also be done by phone and, in rare cases, via a home visit. After this period, responsibility shifts to midwives at the primary care maternal health care centre who also manage the antenatal care. The care provided includes a postpartum follow-up at these centres, planned at approximately 6–12 weeks after delivery (see *Figure 1*). Before this visit, the mother contacts the children's health center, but here the focus is on the newborn, apart from screening for postpartum depression.

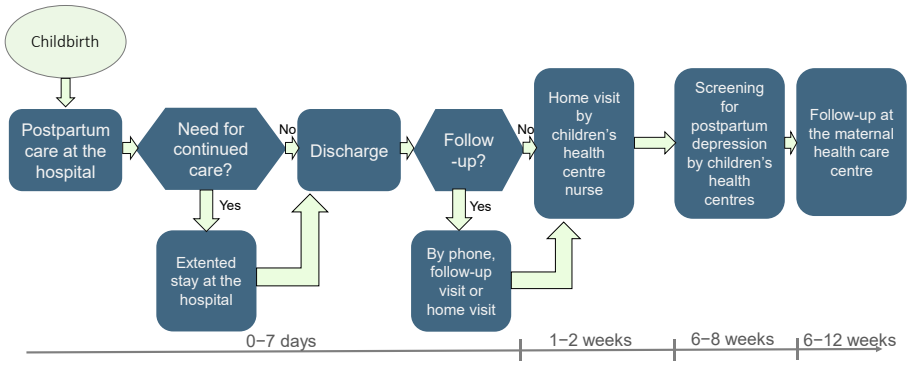

Figure 1. The postpartum care chain in Sweden, as presented by the Swedish Board of Health and Welfare,[16] translated for this thesis.

At the follow-up visit at the maternal health care centre, the midwife follows up a woman's physical and psychological health including her experience of childbirth and, if applicable, breastfeeding, as well as providing contraception counselling, and checking health parameters such as blood pressure and weight.[16] It is also recommended to assess the pelvic floor muscles (including the ability to contract the pelvic floor) and tears during the follow-up and inform the woman about pelvic floor exercises to prevent and treat urinary incontinence.[16]

Several reports and studies, both in Sweden and in other high-income countries, have highlighted that this follow-up is not enough and often does

not meet the women's specific concerns and issues.[11,17-19] In the US, a study revealed that 80% of women seek health care for postpartum-related problems during the third postpartum period (here defined as 61–365 days).[20] Tully et al.[11] report that while during the time until childbirth the number of health care visits escalates, in the postpartum period the focus shifts from the mother to the child, leaving the mother to her own devices to handle her transition to motherhood.

Six interacting themes have been identified that influence the women's postpartum period:[11] mood and emotional wellbeing; medications, substances and exposures; physical recovery after childbirth; sleep and fatigue; sexuality, contraception and birth spacing; and infant care and feeding. The focus of this thesis will be physical recovery from childbirth, which includes symptoms and muscular changes related to pregnancy and childbirth. Women often do not know where to seek help for these problems,[11] and the physiotherapist can play an important role.

Physiotherapy in postpartum care

Today, but not at the start of this thesis, regional medical guidelines are available in Region Västra Götaland advising midwives to refer women with pelvic floor problems (leakage, vaginal heaviness, discomfort, or pressure) or pelvic girdle pain to physiotherapy in primary care.[21] This information is also available on the Swedish health information website 1177.se.[22] Despite this region-specific medical guideline, primary care physiotherapists have no defined role in the Swedish postpartum care chain. However, a recent Swedish report revealed that 50% of surveyed women expressed a desire for consultations with a physiotherapist following pregnancy.[19] In Sweden, primary care physiotherapy does not require referral, allowing individuals to directly schedule appointments with physiotherapists when rehabilitation is required.[23]

Swedish registered physiotherapists work in accordance with scientific evidence and proven experience.[23] Their focus is on improving movement and function according to the International Classification of Functioning, Disability and Health (ICF) framework.[24] As stated in this framework,[25] health is influenced by three aspects: body structure/ function, activities, and participation. Any impairment in one of these aspects can restrict overall function and impact the other two aspects. The ICF framework, based on the biopsychosocial model, considers the interplay between a patient's personal

attributes and their environmental context. Both of these factors can influence body structure/function, activities, and participation.

Pelvic floor disorders and pain conditions after pregnancy can influence the woman's activity and participation. This thesis specifically focuses on urinary incontinence, vaginal heaviness and pelvic girdle pain, acknowledging that sexual pain, anal incontinence, pelvic organ prolapse, and defecation problems can also significantly impact women's lives during the postpartum period.[2] Assessing pregnancy and childbirth-related changes in body structure and functions, such as those in the pelvic floor and abdominal muscles, can be important in the evaluation of these problems. Moreover, a clinical observation is that an increasing number of women seek consultation solely for the clinical assessment of pelvic floor and abdominal muscle changes without presenting with specific symptoms.

The physiotherapist's role is to clinically assess, evaluate and treat changes in body structures and functions, and activity and participation limitations.[23] Physiotherapists also give advice, for example about the resumption of physical activity and exercise. However, there are several knowledge gaps in how to assess, treat and advise women who book a postpartum appointment with a primary care physiotherapist, as will be explained in detail below.

Urinary incontinence in the postpartum period

Pregnancy and childbirth significantly raise the risk of urinary incontinence, with odds ratios of 1.5 for caesarean deliveries and 2.3 for vaginal deliveries compared with nulliparous women.[26] Urinary incontinence has been defined by the International Continence Society[27] as "complaint of any involuntary loss of urine".

There are three main subcategories of urinary incontinence:[27]

- Stress urinary incontinence which is the "complaint of involuntary loss of urine on effort or physical exertion including sporting activities, or on sneezing or coughing".
- Urgency urinary incontinence which is the "complaint of involuntary loss of urine associated with urgency".
- Mixed urinary incontinence, which is a mix of the above two.

These symptoms are a significant issue in women's health and are not limited to pregnancy. About 8–15% of nulliparous women aged 20–49 experience

problems with urinary incontinence.[26] In the postpartum period, these numbers are increased, with 30% of women experiencing some degree of urinary incontinence during the first year after childbirth.[28] Urinary incontinence affects daily activities and participation, including physical activity.[29] An earlier definition of urinary incontinence was the "involuntary loss of urine that is a social or hygienic problem".[27] This definition can be used in studies evaluating bothersome urinary incontinence.

It is important to differentiate between the different types of urinary incontinence as they have different pathophysiological mechanisms. Urgency urinary incontinence is explained by an increased nerve activity or detrusor overactivity[30] whereas stress urinary incontinence is associated with decreased urethral closure pressure.[31] While urethral closure pressure is influenced by both the structural support of the urethra (ligaments and fascia) and the pelvic floor muscles, DeLancey[31] highlights that in postpartum women, the pelvic floor muscles are the most important component. In the hammock hypothesis,[32] he explains how the urethra is pressed against the supportive structures, the endopelvic fascia, the vaginal wall and the levator ani muscles (a part of the pelvic floor muscles) during abdominal pressure. As pregnancy and childbirth affects the structural support and the pelvic floor muscles,[33,34] stress urinary incontinence is closely associated with childbirth while this is less certain for urgency urinary incontinence.[35] For this reason, the focus in this thesis is on stress urinary incontinence. Yet, the broader term "urinary incontinence" is also used when comparing with other research, for example, in the discussion of our results. This is because only a few studies distinguish between the subcategories, and our participants did not make this distinction when describing their symptoms.

Vaginal heaviness in the postpartum period

Another common pelvic floor disorder that many women seek primary care for during the postpartum period is the sensation of vaginal heaviness or pressure. In contrast to stress urinary incontinence, vaginal heaviness in the postpartum period is only scarcely described in the literature. A search in databases such as PubMed and Google Scholar identified 47 articles describing this symptom in the postpartum period, in relation either to pelvic organ prolapse[36] or to exercising.[37,38] While there is no specific point prevalence for vaginal heaviness during the postpartum period, in a cohort of recreational runners, 27% of women who resumed running postpartum reported experiencing it.

Meanwhile, 34% of those who did not return to running reported the same, measured at an average of 1 year postpartum.[38]

Vaginal heaviness could be an early symptom of pelvic organ prolapse; a question about this symptom is therefore part of a validated pelvic organ prolapse questionnaire.[39] Pelvic organ prolapse is characterized by a sensation of a "bulge" or of "something coming down" towards or through the vaginal introitus.[30] However, one study[40] indicated that the sensation of vaginal bulge is not associated with pelvic organ prolapse in the postpartum period. This may lead to the hypothesis that vaginal heaviness and bulging after childbirth is different from the same sensations at the beginning of a pelvic organ prolapse.

Clinically, vaginal heaviness after childbirth is not always described as a bulge or as the feeling of something physically coming down; rather, it is described as the sensation of lacking pelvic organ support, of a heaviness, dragging and sensation of weakness often in relation to standing or to physical activity and exercising. Similar symptoms to vaginal heaviness such as dragging and pelvic heaviness are described in relation to pelvic floor myofascial pain[41], and complaints with vulvar and perineal veins.[42] Other hypotheses are that it is related to the pelvic floor muscles,[38] which are weakened and overstretched during the first 6 months postpartum.[34,43] It could also be a result of the partial damage or oedema related to pelvic floor muscle tears.[44]

Changes in the pelvic floor muscles

As described above, the body structure, pelvic floor, changes during pregnancy and childbirth as a result of hormonal and biomechanical influences.[1] The pelvic floor is a connection of different ligaments, muscles and fascia securing the pelvic organs in the pelvic cavity. In the following, the focus is on the muscular part of the pelvic floor, as its changes are important to the aim of this thesis. To simplify the comprehension, this muscle group can be divided into two layers: a superficial layer and a deeper layer, even though these layers are closely interconnected with each other.[45]

The superficial layer contains the sphincter muscles, the perineal body and muscles attached to the perineal body (bulbospongiosus muscle, transverse perineal muscles (superficial and deep)),[45] see *Figure 2*. During childbirth, these muscles can tear. Where no muscle tearing has occurred the tear is graded as a 1st degree tear (involving only the vaginal mucosa or perineal skin). Muscular tearing is graded as follows:[46]

- 2nd degree tear (involving the vaginal mucosa and perineal muscles), including episiotomy which is a surgical cut in the superficial layer of the pelvic floor (perineal muscles) to facilitate childbirth.
- 3rd degree tear (involving the vaginal mucosa, perineal muscles, and anal sphincter)
- 4th degree tear (involving the vaginal mucosa, perineal muscles, anal sphincter, and rectal mucosa)

Third to 4th degree tears are described as severe tearing[46] and in Sweden their prevalence per county is reported in a statistical database. The prevalence in Sweden was 4.6% for primiparas and 1.1% for multiparas who delivered vaginally in 2019.[47] Such databases do not exist for 1st and 2nd degree tears. However, even minor pelvic floor tears can lead to symptoms such as sensation of wide vagina, bearing down, bowel symptoms and sexual dysfunction.[48] A Swedish cohort study[49] showed that about 78% of primiparous women who receive standard care have a 2nd degree tear.

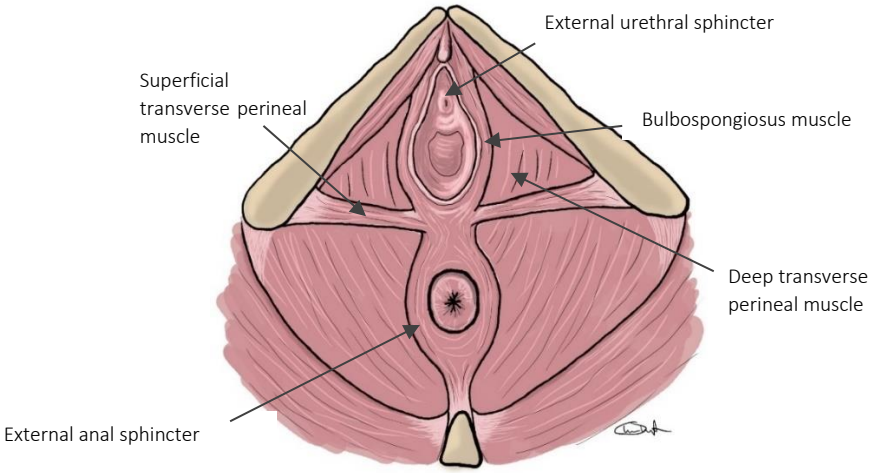

Figure 2. The superficial layer of the female pelvic floor muscles.
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The deeper layer of the pelvic floor muscle contains a muscle group, called the levator ani muscle, see *Figure 3.* The nomenclature of the different parts of the levator ani muscle varies in the literature.[50] In this thesis, the focus is on the three parts involved in incontinence and providing pelvic organ support:

- Pubovisceral muscle (also referred to as "pubococcygeal muscle") which originates from the pubic bone and inserts into the vaginal wall (pubovaginalis), perineal body (puboperinealis) and anal sphincters (puboanalis).
- Puborectalis muscle, which shares the same point of origin and forms a sling around the rectum.
- Iliococcygeus muscle, which originates from the tendinous arch of the levator ani muscle and inserts into the iliococcyceal raphe.

The puborectalis and pubovisceralis contain primarily type I muscle fibres, known for their fatigue resistance, to maintain a constant tone to keep the urogenital hiatus closed. However, these muscles can also contract rapidly in response of increased intra-abdominal pressure, such as during coughing.[1]

The length of the urogenital hiatus is increased already during pregnancy.[33] During a vaginal delivery, the pubovisceral and puborectal parts of the levator ani muscle stretch with a stretch ratio of 3.26 and 2.28, respectively.[1] The levator ani muscle can be torn,[1] which often remains hidden, but even without a tear, the muscle's morphology and function is changed in the first few months after birth. Staer-Jensen et al.[34] report that the hiatal area in women who deliver vaginally is increased at 6 weeks postpartum compared with pre-delivery levels and also compared with women who deliver by caesarean section. This increased hiatus is narrowed during the first 6 months, but not all women reach their pre-delivery level at 12 months postpartum.[34] An experimental study[51] has shown that even the reflex activation of the levator ani muscle as reaction to intra-abdominal pressure was reduced after childbirth.

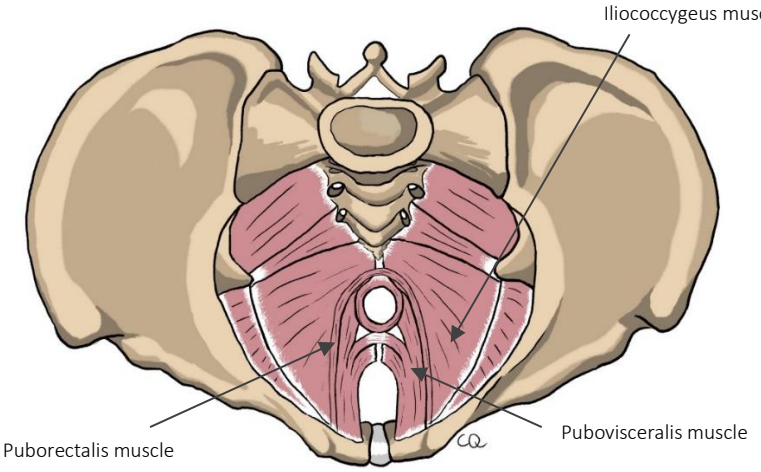

Figure 3. The deeper layer of the female pelvic floor muscles.
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Department of Physical Therapy at Hospital Östra, Sahlgrenska University Hospital

The pelvic floor muscles have several functions. A systematic review[52] highlights that researchers frequently use diverse terminology to describe these functions without adequately establishing their conceptual definitions. In this thesis, pelvic floor functions will be defined as follows: "maximal voluntary contraction" is defined as "the voluntary effort to generate the maximum force by a muscle contraction".[53] This maximum force plays a crucial role in ensuring continence during moments of rapidly increasing intra-abdominal pressure.[32] This contraction should occur automatically and leads to the next aspect of pelvic floor function, which is involuntary pelvic floor muscle contraction, defined as an inward-upward lift of the pelvic floor muscles as reflex response to increased intra-abdominal pressure.[54] The pelvic floor muscles also act as postural muscles,[55] providing stability to the pelvic organs and maintaining continence even without rapidly increased intra-abdominal pressure. Here, the 55-70% type I muscle fibres are instrumental in maintaining a constant tone.[32,56] "Pelvic floor muscle endurance" is defined as the "capacity to sustain a contraction for a specified duration or execute multiple repetitions of it".[52] The pelvic floor muscles also need the capacity to relax, for example during defecation. Voluntary relaxation signifies the conscious capability to intentionally relax the pelvic floor muscles following a contraction upon request.[54]

In *Papers I* and *II* of this thesis, the above terms were used; however, throughout the subsequent text, I have also used the term "pelvic floor muscle

strength" to describe the function of maximal voluntary contraction, consistent with the prevailing terminology in most research.[52]

Clinical assessment of pelvic floor muscles

There is as yet no gold standard for the assessment of pelvic floor muscle function postpartum. Several objective measurement method, such as perineometer, dynamometer, electromyography (EMG) and ultrasound, have been tested.[57] However, each of these methods has its limitations as they primarily offer indirect strength measurements, lack adaptability for assessing muscles in different positions, and can be affected by cross-talk from other muscle groups.[57,58]

Vaginal palpation stands out as the most frequently used method to assess pelvic floor muscle function, as it has been utilized in 49% of studies.[57] Vaginal palpation and observation are also the most common methods used in primary care physiotherapy,[59] which is the focus of this thesis. Both assessment methods were initially described by Kegel in 1956.[60] He report that a correct contraction can be observed as an inward movement of the perineum and that it can also be felt by inserting one finger to the middle third of the vagina, feeling the contraction of the pubovisceralis muscle as squeeze around the finger with an inward lift (*Figure 4*).[60] In later literature, it is described that the lifting component is even a result of contraction of the puborectalis and iliococcygeus muscles.[1] Kegel did not use any rating scale for assessment of the contraction.

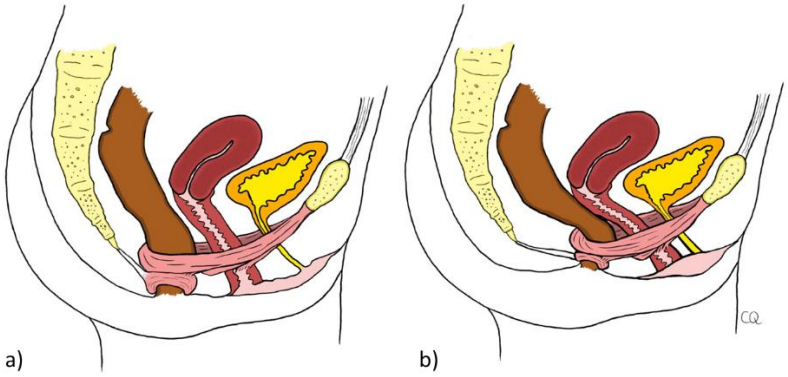


Figure 4. The pelvic floor muscles in a) relaxed and b) contracted position. Illustration reproduced with kind permission of the illustrator Clara Qvick, Department of Physical Therapy at Hospital Östra, Sahlgrenska University Hospital

In contemporary research,[57] vaginal palpation is primarily used to assess muscle strength, while observation only can be used to see if the contraction is correct. Pelvic floor muscle strength can be quantified using various scales, of which the most established one[57] is the modified Oxford scale developed by Laycock & Jerwood.[61] However, despite its popularity, both in clinical practice and in research, it has weak inter-rater reliability.[62-64] The proposed reason for this is that it is too difficult to rate both the squeeze and the lifting component of the pelvic floor muscle contraction in one scale,[59] while this, on the other hand, is the advantage of vaginal palpation compared with all technical measurement methods.[58] As physiotherapists need a reliable method to clinically assess pelvic floor muscle strength in primary care, there is a need to develop a reliable assessment method and rating scale.

KNOWLEDGE GAP:

The inter-rater reliability of the clinical assessment of maximal voluntary contraction in postpartum women using an adapted version of the modified Oxford scale.

In 2005, the International Continence Society published a document to standardize the terminology for pelvic floor muscle function and dysfunction.[54] This document had been updated several times with the most recent update in

February 2021.[65] Besides the clinical assessment of pelvic floor muscle strength by vaginal palpation and the observation of perineum movement, several other clinical assessments for the above described pelvic floor muscle function, namely involuntary contraction and voluntary relaxation, are proposed in this document. However, these clinical assessments have not been defined on a rating scale, nor have they been evaluated for their reliability. In 2009, Slieker-Ten Hove et al.[66] tested rating scales for these functions for their intra- and inter-rater reliability; however, not in a postpartum population. The conclusion of the latest update of the International Continence Society in 2021[65] was that more studies are needed to evaluate the clinical assessments of pelvic floor muscle function.

KNOWLEDGE GAP:

The inter-rater reliability of the clinical assessments of pelvic floor muscle functions, involuntary contraction, pelvic floor muscle endurance and voluntary relaxation in postpartum women

Pelvic girdle pain in the postpartum period

Pelvic girdle pain is a pain condition that is closely related to pregnancy.[67] Pelvic girdle pain is characteristically located around the sacroiliac joints and/or the pubic symphysis and the area between the posterior iliac crest and the gluteal fold, with or without radiation to the upper leg.[67] It can start already in the first trimester but also as late as 3 weeks postpartum. During pregnancy, its prevalence is over 50%.[68] In the postpartum period, the prevalence of pelvic girdle pain confirmed by clinical testing is 17%;[69] however, about 30% of women self-report pelvic girdle pain.[70]

Low back pain and pregnancy-related pelvic girdle pain are closely connected. The umbrella term "lumbopelvic pain"[68] is often used to describe the combination of these two pain conditions, both in research and in clinical settings. As low back pain is defined as "pain between the twelfth rib and the gluteal fold"[71] which can also radiate to the legs, the use of this umbrella term seems convenient as the two pain conditions overlap. However, it is important to differentiate between low back pain and pelvic girdle pain. Low back pain has a prevalence of 11 % postpartum,[69] which is similar to the prevalence reported in a general adult population.[3] Pelvic girdle pain is a different kind of

pain which, in contrast to low back pain during pregnancy, is much more associated with activity limitations such as difficulty climbing stairs, and difficulties with prolonged sitting, standing and walking and heavy lifts.[72] The European guidelines from 2008 on the diagnosis and treatment of pelvic girdle pain[67] recommend using the term "pregnancy-related pelvic girdle pain" to distinguish it from low back pain, and other types of pelvic pain, such as endometriosis and pain due to other gynaecological causes. Consequently, the term "pelvic girdle pain" will be used in this thesis, implying that it refers to pregnancy and encompassing the described activity limitations characteristic of this pain condition.

For many years, pelvic girdle pain was thought to be caused by instability and a relaxation in the joints, related to the hormone relaxin, during pregnancy. However, this hypothesis has been questioned as neither an instability nor increased relaxin levels could be confirmed in women with pelvic girdle pain.[73] Today, researchers[74] agree that the complete aetiology of pelvic girdle pain is still unknown, but that there is a combination of biomechanical and psychosocial factors. This is in line with the aetiology of most pain conditions. Pain is defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage".[75] It is a subjective experience influenced by biopsychosocial factors.

Biomechanical explanation models for pelvic girdle pain

When explaining the biomechanical component of pelvic girdle pain, we need to understand which tissue is stressed or damaged. While absolute certainty remains elusive, the most accepted theory is that the nociceptors in the sacroiliacal joints, dorsal sacroiliac ligaments and pubic symphysis are responsible for the sensation of pain, predominantly experienced in the gluteal area.[76]

These areas can become stressed due to non-optimal load transfer in the pelvis, resulting from muscular weakness, altered motor control, or postural changes during and after pregnancy. The stability and movement of the pelvic builds on two principles:[77] the form closure, which is the anatomical fitting of the ilium and sacrum, and the force closure, which involves optimal dynamic between the global and local muscles around the pelvis, counteracting forces by changing the relative position of the ilium and sacrum to each other to increase tension in the ligaments. If the ilium and sacrum fit together perfectly, no muscle activity would be needed. However, these two bones require some mobility for optimal load transfer.[77] This is ensured by the surrounding muscles

responsible for orchestrating the movement of bones in relation to each other, such as for example the rectus femoris, gluteus maximus and hamstring muscles.[78] Asymmetry or altered motor control in these muscles can influence the load transfer through the pelvis. Decreased hip extensor strength,[79] pain and weakness in hip adductor contraction,[80] and lowered endurance in back flexors[81] have shown to be associated with pelvic girdle pain during and after pregnancy.

Even deeper muscle groups, such as the transversus abdominis and the pelvic floor muscles, contribute directly to the force closure mechanism of the pelvis through pulling forces on the sacrum and ilium, and indirectly by controlling intra-abdominal pressure building the roof (diaphragm), wall (abdominal muscles) and floor (pelvic floor) of the abdominal cavity.[78,82] As the pelvic floor muscles are changed as a result of pregnancy and childbirth, these changes could partly explain persistent pelvic girdle pain postpartum. One study[83] has shown altered motor control in the form of a higher resting tone, reduced reflex activity during coughing, and decreased pelvic floor muscle endurance in pregnant women with low back and pelvic girdle pain, compared to healthy controls. An experimental study[84] has indicated that women with pelvic girdle pain postpartum show less pre-activation and have a later activation timing in their pelvic floor muscles during an active straight leg test. By contrast, Stuge et al[85] report that there is no association between pelvic floor muscle strength and pelvic girdle pain postpartum but, rather, that there is an increase in muscle activity, interpreted as increased muscle tension. While muscle activation patterns are difficult to measure in the primary care context, the question is whether the results of the clinical assessment of pelvic floor muscle function are associated with pelvic girdle pain postpartum.

KNOWLEDGE GAP:

The association between the results of clinically assessed pelvic floor function and pelvic girdle pain in the postpartum period

Another muscle group that is altered because of pregnancy and childbirth is the group of abdominal muscles. The abdominal muscles are part of the force closure mechanism.[78] Changes in the abdominal wall, in terms of decreased or uneven strength, can influence the force closure of the pelvis.

Changes in the abdominal wall

The abdominal wall undergoes changes during pregnancy because of the growing foetus.[86] The abdominal wall is built up of several layers of fascia, ligaments and muscles. As mentioned in the pelvic floor section above, the focus of this thesis is primarily on muscles rather than on ligaments and fasciae. However, in this section, the connecting ligament, the linea alba, will also be described.

Five muscles are responsible for different trunk movement, protecting the internal organs and stabilizing the trunk in various positions.[87] These muscles are the external and internal oblique and transversus abdominis which are, as their names suggest, obliquely and transversely oriented, and the rectus abdominis and pyramidalis muscles, which are vertically directed. All these muscles are connected by the linea alba, a fibrous structure spanning from the xiphoid process to the pubic symphysis.[87] The linea alba represents the central fusion point of the aponeuroses of the external and internal oblique muscles and the transversus abdominis, which envelopes the two parts of the rectus abdominis to form the rectus sheath.

Long-lasting intra-abdominal pressure during pregnancy, stretches the linea alba, and the two parts of the rectus abdominis slide apart.[86] The extent of the abdominal distention varies by individual; however, an increased distance between the two parts of the rectus abdominis muscle is seen in all women at gestation week 35.[88] After the baby is born, the inter-recti distance (IRD) gradually decreases again.[89] According to Mota et al.,[88] an IRD greater than the normal values observed in nulliparous women (1.6 cm) is called a "diastasis recti abdominis (DRA)". Using the cut-off value of 1.6 cm, 39% of women have a DRA at 6 months postpartum. However, in a later study, Mota et al.[90] question this comparison to nulliparous women since the mean IRD among individuals at 6 months postpartum was found to be 2.2 cm. Based on these revised cut-off values, the prevalence of DRA has been corrected to 20%.

The definition of DRA is in most studies[88-92] based primarily on the increased IRD without any additional symptoms. There is no consensus regarding whether a DRA is linked to impaired body function, activity, and participation. Studies[91,92] have shown that women with DRA have weaker abdominal muscles than women without DRA. In these studies, the cut-off value for DRA was set right above the normal value of 2.2 cm,[92] or even higher at 2.5 cm.[91] Whether the reported weakness is related to pain is not known; a systematic review[93] found no significant association between DRA and lumbopelvic and

low back pain, and urinary incontinence, and only weak evidence pointing to an association between DRA and the severity of low back pain. By contrast, a qualitative study[94] in women with a mean DRA of 4.2 cm reports that they experienced cramping in the lower back and a heaviness in the pelvis. In line with the studies about decreased abdominal strength,[91,92] such women experience a weakness and instability in the mid-section of their body.[94] However, whether pain and instability, on the one hand, and DRA on the other are associated or merely co-exist in the postpartum period is still unknown.[93]

Recent studies[89,95] have claimed a need for more research concerning women with severe DRA, suggesting that severe DRA has a greater impact on pain and function. Moreover, to the best of our knowledge, there are only two studies evaluating the association between DRA and the pregnancy-specific condition pelvic girdle pain. An observational study[89] showed no statistically significant difference in pelvic girdle pain at 12 months postpartum between women with and without DRA. However, these results were based on 28 participants who reported pelvic girdle pain using an unvalidated question regarding bothersome pelvic girdle pain and estimated DRA width using finger-width palpation. A matched control study[96] using the recommended assessment methods and questionnaires for pelvic girdle pain, but also assessing DRA using finger-width palpation, showed that participants with pelvic girdle pain had more severe DRA.

KNOWLEDGE GAP:

The association between the results of clinically assessed (severe) diastasis recti abdominis and pelvic girdle pain in the postpartum period

Clinical assessment of the diastasis recti abdominis

The gold standard for the assessment of the DRA is ultrasound.[97] However, as for the pelvic floor assessment, the focus of this thesis was to evaluate methods used in primary care physiotherapy. Measuring the DRA with a caliper is a cost-effective and in primary care available method, with strong correlations with ultrasound measurements (r = 0.85–0.99).[98] This approach surpasses other clinically feasible methods such as finger-width palpation or tape measurement[97] and is recommended as suitable method for measuring DRA width. However, it is used by fewer than 2% of clinicians.[99]

As of the thesis planning stage, only one pilot study (n = 30)[100] had evaluated the intra-rater reliability of caliper measurements in postpartum women. Another study[101] had assessed the validity of caliper measurements in comparison with ultrasound and evaluated intra-rater reliability in both men and women. This latter study[101] raised concerns regarding the potential overestimation of the DRA width when using caliper measurements, primarily due to difficulties in palpating the muscle-tendon junction. Today, a study[98] on the inter-rater reliability of caliper measurement is available.

In the measurement of the DRA width, the location for the measurement points varies from study to study and includes measurement points in the range of 0–12 cm both below and above the umbilicus.[97] In the studies using caliper measurement, the DRA width was measured at the umbilicus,[98,100] as well as at positions 4.5 cm above and 4.5 cm below the umbilicus[98,101]

KNOWLEDGE GAP:

The inter-rater reliability of measuring the diastasis recti abdominis with a caliper in postpartum women

Moreover, it is unknown whether the distance between the two parts of the rectus abdominis is the only important measure for the assessment of abdominal wall distension postpartum. An experimental study[102] showed that the linea alba narrows during an abdominal crunch and widens during a transversus abdominis activation. Lee & Hodges stated in 2016[103] that the width of the DRA is a misleading measure as the linea alba changes shape during movements like a sit-up or a transversus activation. They explained that the linea alba can bulge or sink in as a result of abdominal contraction. The sinking in can be explained by less pre-activation activity in the transversus abdominis muscle,[103] while the bulging is a reaction to increased intra-abdominal pressure during exertion.[103,104] Already in 2005, Candido et al.[105] proposed to include abdominal bulging as a criterion for the classification of DRA severity. Since then, several studies have used their classification scale,[89,106] but without testing it for its reliability and validity. Even clinically, physiotherapists assess different aspects of the DRA by different methods, such as palpation across the linea alba and observing a bulging during abdominal pressure, but without having any evidence for these clinical assessments.

KNOWLEDGE GAP:

The inter-rater reliability of the clinical assessments of diastasis recti abdominis depth and bulging in postpartum women

Physical activity and exercising in the postpartum period

The above described symptoms and muscular changes can limit daily activities, such as lifting and carrying, on account of pain,[72] while social participation may be hindered by issues such as urinary incontinence.[27] Additionally, these postpartum symptoms and muscular changes can impede women from returning to their pre-pregnancy level of physical activity and exercising.[37]

However, women are not physically inactive in the postpartum period, using the definition for physical activity of "any bodily movement produced by skeletal muscles that results in energy expenditure".[107] Their light physical activities, such as strolling and child care activities, gradually increase and their sedentary time decreases in the postpartum period.[108] Only their participation in exercising or moderate to vigorous-intensity physical activity is lower than pre-pregnancy [109] or compared with women without children.[110] Exercising is defined as "physical activity consisting of planned, structured, and repetitive bodily movements done to improve one or more components of physical fitness".[107] The important difference between physical activity in daily living and exercising is that exercising is intended to improve health and fitness,[111] while the everyday physical activity of a mother can mean carrying and lifting a baby, which may have less positive health effects. Exercising can help to strengthen and recover the body and is an important part of rehabilitation.[111]

In the American College of Obstetricians and Gynecologists (ACOG) guidelines [112] the recommendation is to resume exercising as soon as possible after giving birth. Health care providers should encourage women to exercise as the postpartum period is seen as a window of opportunity to adopt a healthier lifestyle. The World Health Organization (WHO)[113] recommend gradually increasing postpartum physical activity to reach the recommended 150 minutes per week of moderate-intensity aerobic activity, including various aerobic and

muscle-strengthening exercises. Those who used to exercise with vigorous intensity pre-pregnancy can continue to do this in the postpartum period.

To cover all events, the authors of the ACOG guidelines[112] have added the words "as soon as medically safe" without defining what this means. One review[12] about postpartum exercise guidelines found that pregnancy guidelines on exercising after childbirth are often only brief and lack specifics about type and intensity of exercising. The review refers to the Australian guidelines cautioning against activities such as running that impose a ballistic load on the pelvic floor, the Canadian guideline which recommends an increase in exercise "depending on discomfort" and the Norwegian guidelines emphasizing that a woman's self-perception should guide her exercise choices. A Swedish educational platform[114] for health care providers advises that activities such as running, jumping and heavier exercising should be avoided until the pelvic floor regains strength, which, according to the platform, can take several months to 1 year. None of these guidelines or information sources give concrete advice regarding pelvic girdle pain, stress urinary incontinence or vaginal heaviness, and neither does an updated review.[115] The international Olympic Committee[116] concluded that too little research is done to draw any conclusion about when it is safe to resume exercising after pregnancy, and how. Bø& Nygaard[117] have proposed two contrary hypotheses regarding the effect of exercising on the pelvic floor:

(a) General exercise is positive for the recovery of pelvic floor function in the presence of symptoms such as stress urinary incontinence and vaginal heaviness. General exercising such as walking or running demands a co-contraction of the pelvic floor, which leads to muscle strengthening and better support. This hypothesis builds on knowledge from sport science that muscles need loading to recover,[118] and is supported, for example, by a study by Leitner et al.[119] showing the reflective reaction of the pelvic floor muscles on running.

(b) The contrary hypothesis is that weakened and stretched pelvic floor muscles cannot withstand the increased intra-abdominal pressure during exercising. In this case, general exercising leads to a lowering of the pelvic floor and increased symptoms such as stress urinary incontinence and vaginal heaviness, which may be an early symptom of pelvic organ prolapse due to an overload of a still weakened pelvic floor. This hypothesis builds on the increased prevalence of pelvic floor disorders in high-impact and high-intensity exercisers.[120]

Whether these hypotheses are even applicable to the recovery of the abdominal wall and pelvic girdle pain is not known. However, health care providers in the US are careful not to put strain on the DRA and some use or recommend binders during exercising and performing strenuous activities,[99] a strategy that is uncommon in Sweden. Pelvic girdle pain often increases after long walking and standing,[68] while at the same time a systematic review[121] has indicated that exercising during pregnancy might have a positive impact on the development of postpartum pain.

KNOWLEDGE GAP:

The association between resumption of exercise within the first 3 months postpartum and changes in pelvic floor and abdominal muscles, pelvic girdle pain, stress urinary incontinence and vaginal heaviness

Changes in body perception in the postpartum period

Beside the above described physical health problems and bodily changes, the women's own perspective on changes and recovery is an important part of the postpartum period and the assessment by the physiotherapist. Previous studies and reports[11,19,122] have shown that current postpartum information and advice are not in line with what women need and expect. This can be explained by the fact that women are generally in good health after childbirth,[123] and that the above described symptoms are often of mild to moderate severity.[28,68] In many cases, women have good physical function despite their reported pain.[69,70] This discrepancy can create a gap between health care providers' perceptions of the issues and what women actually anticipate. Martin et al.[122] showed that health care providers tend to focus primarily on severe postpartum complications, paying little attention to issues they see as normal consequences of childbirth. By contrast, women often consider these "normal" issues as major concerns. They seek information on how postpartum symptoms progress and will affect their daily lives, while health care providers may feel somewhat uncertain about addressing these questions.

In 2018, the ACOG published an opinion paper[124] stating that postpartum care should be more individualized and woman-centred as it often did not meet the needs of women. However, there is only limited research on how postpartum women experience physical changes and recovery after childbirth. In addition,

the relationship between postpartum symptoms, such as pelvic girdle pain, and activity limitations has only been addressed in a few studies.[69] This knowledge is important for the work of the physiotherapist whose role is to restore function and activity.

KNOWLEDGE GAP:

Perceived activity limitations and women's experiences of physical changes and recovery in the postpartum period

Rationale for this thesis

Women undergo various changes during their transition from pregnancy to childbirth, subsequently readapting to their bodies postpartum. They may experience symptoms such as stress urinary incontinence, vaginal heaviness, and pelvic girdle pain. Their pelvic floor is weakened during the first months postpartum and they need to understand and manage changes in the abdominal wall in the form of an increased distance between the muscle rectus abdominis, which can sink-in or bulge during exertion. Whilst many women can manage these symptoms independently or with guidance from their midwives, who are primarily responsible for postpartum follow-ups, others turn to primary care physiotherapists, either through referrals or of their own accord.

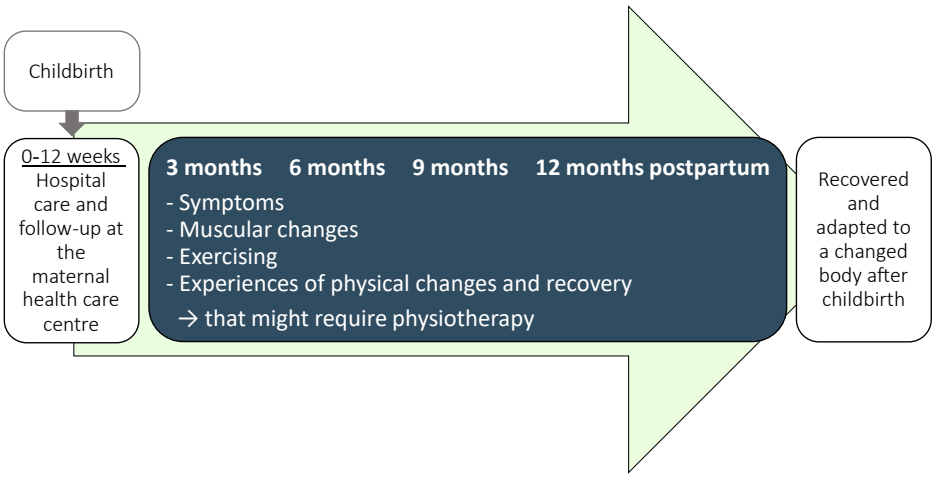


Figure 5. This figure illustrates the thesis's focus on symptoms, associated muscular changes, exercises and women's experiences of physical changes and recovery from 3 to 12 months postpartum.

However, at present, there are several knowledge gaps concerning the reliability of the clinical assessment of muscular changes undertaken by physiotherapists in primary care and how its results are related to symptoms such as pelvic girdle pain in the postpartum period. Additionally, there is a need for greater understanding about how women perceive these changes and the advice they should receive when resuming exercise. Bridging these knowledge gaps is important, allowing physiotherapists and other healthcare providers to give informed assessments, treatments, and recommendations.

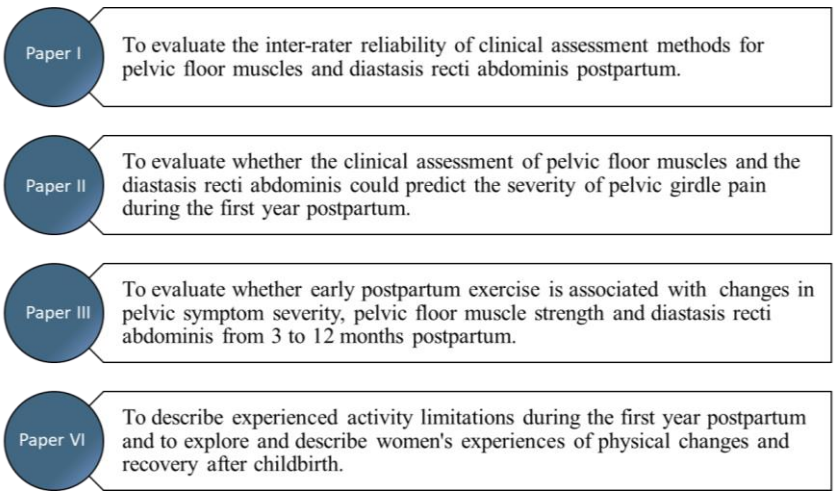
The focus of this thesis will centre on muscular changes, symptoms, exercising, and women's experiences of physical changes that may require physiotherapy during the period from 3 to 12 months postpartum, as shown in *Figure 5.*

Aim

The overall aim of this thesis was:

To assess and explore stress urinary incontinence, vaginal heaviness, pelvic girdle pain and muscular changes in the postpartum period, in relation to each other, and in relation to exercising, activity limitations and women's experiences.

Specific aims:



Methods

Study design

This thesis is based on data from two research studies, a prospective longitudinal cohort study (quantitative data), and an interview study (qualitative data). This sequential explanatory design[125] was chosen, wherein the qualitative study follows the quantitative study, to further explore the phenomena observed in the first. As the analysis of the cohort study highlighted new aspects of symptom severity and women's concerns about physical changes, the qualitative design was required for a deeper understanding of the physical and psychosocial factors influencing postpartum symptoms and changes. The data collection and analysis from the two studies resulted in four scientific papers, as presented in *Figure 6.*

All four papers contain data from the prospective longitudinal cohort study named the AfterBabyBodyStudy (ABB-Study) (Clinicaltrial.gov registration: NCT03703804). *Paper I* reports an inter-rater reliability study based on the first 222 participants who were assessed consecutively by two physiotherapists blinded to each other's assessments. *Papers II* and *III* are longitudinal cohort studies based on the full cohort of 504 participants. For *Paper IV*, only parts of its questionnaires were used. To enrich this material, the interview study was conducted, recruiting 14 additional participants not included in the ABB-study. The ABB-study was open for inclusion from September 2018 to February 2020. The last participants were assessed in February 2021, 1 year after inclusion.

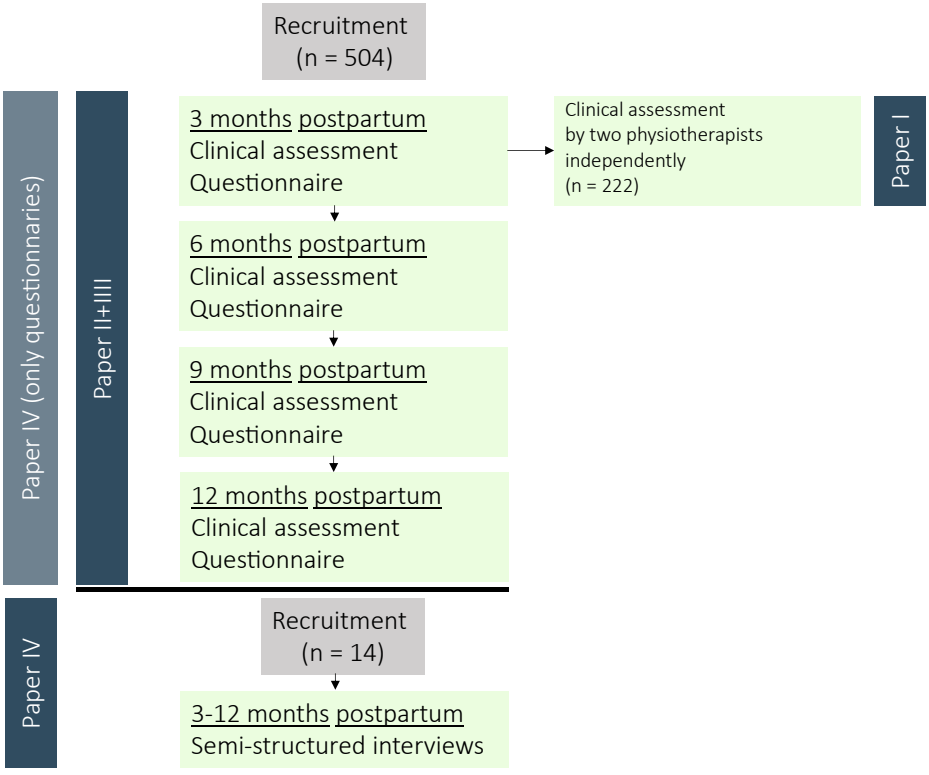


Figure 6. Data collection for the four papers of this thesis, n = number

Inclusion criteria for the ABB study were:

- ≥ 18 years old
- vaginal delivery or caesarean section within the previous 3 months
- ability to understand verbal and written Swedish.

Exclusion criteria were:

- chronic low back pain (defined as pain in the low back for longer than 3 months,[126] not related to the recent pregnancy).
- severe pelvic floor tears (obstetric anal sphincter injuries = 3rd and 4th degree perineal tears).

The enrolment for the interview study took place from September 2022 to April 2023. The study had the same inclusion and exclusion criteria, differing only

in the time after childbirth, which was vaginal delivery or caesarean section within the previous 3–12 months.

Recruitment strategy

The recruitment strategy for the ABB Study was convenience sampling by advertising. Prior to the study start, coordinating midwives were informed about the study and asked to forward information and advertising posters to maternal health care centres in Region Västra Götaland. In addition, several maternal health care centres were visited to provide them with information about the study, with focus on parts of the Gothenburg with lower socio-economic status and the rural areas of Region Västra Götaland. The managers and staff of children's health care centres were also informed about the study, and were given posters for display in their centres' waiting areas. Additionally, we harnessed the reach of a prominent national women's health blog, BakingBabies.se, as a platform to publicize information about the study and used local Facebook groups as an additional channel for recruitment.

As the recruitment strategy in the ABB Study resulted in an over-representation of highly educated women, a different recruitment strategy was planned for the interview study. The strategy here was purposive sampling. We engaged physiotherapists from four rehabilitation centres across Region Västra Götaland to identify postpartum women from their booking system. We also encouraged them to recruit participants during group training sessions in urban and suburban parts of Gothenburg. However, as again only high-educated women responded to this recruitment technique, the recruitment strategy was extended to the national women's health blog BakingBabies.se and local Facebook groups, targeting women from diverse educational backgrounds other than university or college.

Study setting

The ABB Study was conducted at three primary care rehabilitation centres in Region Västra Götaland. These were strategically chosen, one in a suburban, another in an urban and the third in a rural area, to make participation accessible for individuals from different socioeconomic backgrounds. In *Paper I*, we refer to the centres as primary care rehabilitation centre 1 (suburban), primary care rehabilitation centre 2 (urban) and primary care rehabilitation centre 3 (rural).

In 2019, the Region Västra Götaland had a population of 1.7 million inhabitants and 18 992 registered childbirths.[127] Women who were interested in participating in the ABB Study initiated contact with me via email or telephone. All applicants were called to confirm their eligibility and provide information about study details such as the clinical assessments and questionnaires. The exact number of not eligible women was not documented.

Participants who met the inclusion criteria were scheduled for a clinical assessment at one of the three rehabilitation centres. The assessment was booked for about 3 (range 2–3.5) months postpartum. The exact timing of the clinical assessment depended on when the women had scheduled their postpartum follow-up with their midwife as we intended to do our assessment after that visit.

Two physiotherapists at each rehabilitation centre were responsible for the assessments. After the first assessment, participants were booked for three additional follow-up appointments, at 6, 9 and 12 months postpartum. Even for this assessment, there was 2 weeks' flexibility either way, which was extended to 4 weeks during the peak of the COVID-19 pandemic. *Figure 6* and *7* illustrate that each follow-up session comprised both a clinical assessment and a questionnaire. The questionnaire was distributed using a web-based survey generator (esMaker; Entergate AB, Halmstad, Sweden) prior to each assessment. The first questionnaire also included questions about background variables (maternal and obstetric characteristics).

In 2021, altogether 19 170 childbirths were registered in the Region Västra Götaland.[127] Individuals interested in participating in the interview study applied via email, phone, or a quick-response (QR) code linked directly to a registration form. The registration form was used to check applicants' eligibility for inclusion. Included participants were contacted by phone, mirroring the approach of the ABB Study, to inform them about the study and to book an appointment for the interview. Out of 21 applicants, 14 participated in interviews, with non-participation due to various factors: not living in the Region Västra Götaland (n = 1), withdrawing from the study (n = 2), being highly educated (n = 4). Because we used social media for recruitment it is not possible to know how many women were reached by the information about the study but chose to not participate. The interviews were mainly conducted by phone to make participation as easily accessible for new mothers as possible.

Number of participants

An initial power analysis for *Paper I* suggested a total sample size of over 500 participants based on prior studies, indicating a 50% agreement for ratings on the modified Oxford scale.[62,63] However, we encountered practical limitations, such as a low application rate at rehabilitation centre 3, and occasional unavailability of the physiotherapists required for the paired assessments. These circumstances led to a final sample of 222 participants. We aimed for at least 30 double assessments at each centre as recommended by Koo & Li.[128]

No power analysis was conducted for *Paper II*. For *Paper III*, the initial plan was to divide participants into three exercise groups to evaluate changes in stress urinary incontinence, vaginal heaviness, pelvic girdle pain, pelvic floor muscle strength, and DRA. Since all five of these outcomes were equally important, we centered our power calculation on pelvic floor muscle strength. This choice was made on the assumption that detecting changes on a 6-point Likert scale, which potentially exhibit wide individual variations, would be more challenging to detect than changes on continuous scales. To achieve 80% power in detecting a 20% change across four measurements, we needed to include 135 participants who had resumed exercising. With the scarcity of published research on postpartum exercising, the number of participants was informed from a study about vigorous intense physical activity,[129] which showed that about 30−40% of women exercised 3 times/week in the first 3 months postpartum. With an estimated drop-out rate of 10%, we calculated that 500 participants were needed. However, in later analyses, we observed that we had too many participants engaging in low impact exercising and a shortage in the high-impact exercise category. Consequently, we had to restructure our groups, resulting in the subdivision of the low-impact exercise group into "minimal" and "regular" low-impact exercisers. This adjustment expanded the number of groups from three to four.

The number of participants for *Paper IV* was guided by Malterud et al.'s "information power criteria" for qualitative research,[130] considering the research aim (broad/narrow), sample characteristics (specific /general group), utilization of an established theory (deductive/inductive), quality of dialogues (weak/strong), and analysis strategy (cross-case analysis/in-depth analysis). Our study had an inductive approach with a broad aim, but our selective recruitment strategy resulted in a specific sample of women providing comprehensive information about their experience, resulting in inclusion of 14 participants for this part of the thesis.

Participants' characteristics

The characteristics of the participants in both the ABB Study and the interview study are presented in *Table 1*. We obtained relevant data from the National Board of Health and Welfare[127] to contextualize our participants' characteristics, but the initial dataset lacked information on educational levels. To fill this gap, we accessed a larger dataset from the National Board of Health and Welfare, published in 2021.[131] This showed that a significant number of women without university or college education primarily comprise those under 19 years who have not yet had the opportunity for higher education. Among women in the most common age group for childbirth (30–34 years), 66% had a post-secondary education.

Table 1. Background characteristics of the two cohorts included in the two studies of this thesis compared to women who gave birth during 2019

		ABB-study n = 504	Interview study n = 14	Persons who gave birth in Region Västra Götaland 2019 N= 18992
Age (mean, SD)		33.1 (3.6)	33.6 (4.0)	30.6
BMI (mean, SD)		24.5 (3.3)	25.5 (5.8)	25.2*
Recent baby´s birth weight, gram (mean, SD)		3565 (495)	N/A	3483
Educational level, n (%)**				
	Primary education	0 (0)	0 (0)	9802 (9.1)
	Secondary education	46 (9.1)	2 (14.3)	35655 (33.2)
	Post- secondary education	457 (90.6)	12 (85.7)	62064 (57.7)
Parity, n (%)				
	Primipara	315 (62.5)	8 (57.1)	8212 (43.2)
	Multipara	187 (37.1)	6 (42.9)	10 754 (56.6)
Mode of delivery, n (%)				
	Vaginal delivery	438 (86.9)	12 (85.7)	15724 (82.8)
	Instrumental delivery	34 (6.7)	0 (0)	810 (5.2)
	Cesarean section	64 (12.7)	2 (14.3)	3268 (17.2)

BMI = body mass index, n = number, SD= standard deviation, N/A = non applicant

*BMI at registration at the maternal health care center (pregnant), **retrieved from a dataset from 2021[131]

The ABB Study enrolled 504 participants with or without symptoms after childbirth. The drop-out rate remained below 20% despite the fact that this study was largely conducted during a pandemic. The drop-out showed some intricacies. Some participants opted to only complete the questionnaire or took a break from the study during the peak of the pandemic. Later, they agreed to participate again in the clinical assessment (see "Drop-in" in *Figure 7*). The main reason for drop-out was a new pregnancy (n = 5 at 3 months, n = 10 at 6 months, and n = 13 at 12 months postpartum)

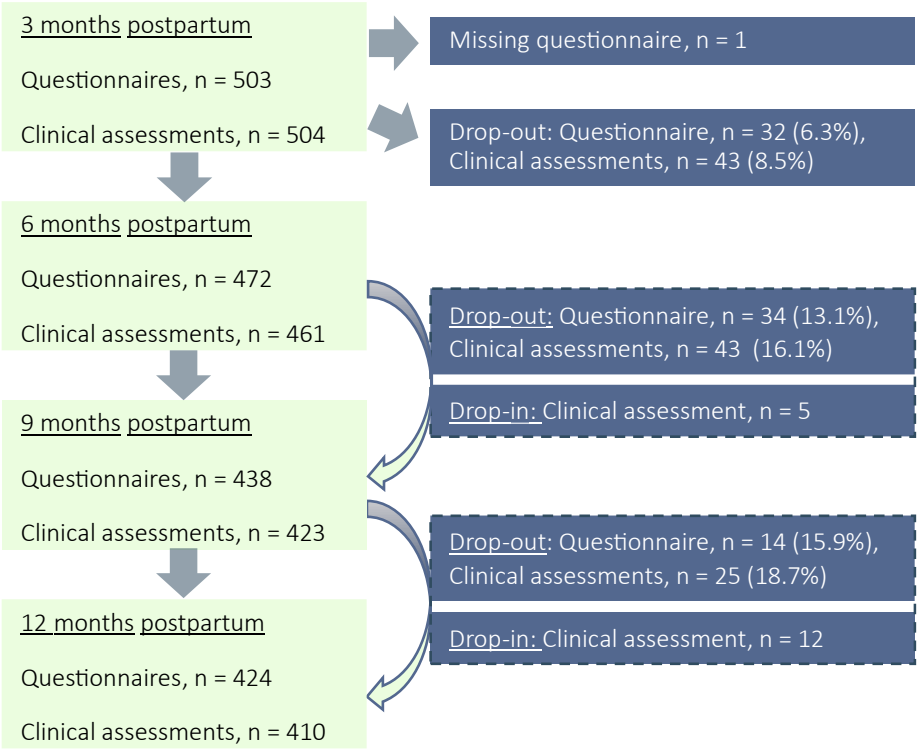


Figure 7. Flow chart of the ABB study, n = number

Data collection

Baseline demographics

In the ABB study, participants provided the following data in the first questionnaire 3 months postpartum: maternal year of birth, maternal weight

and height, educational level, number of children, occurrence of pelvic floor tears (if applicable), date and mode of delivery (vaginal or caesarean) of the most recent child, birth date and weight of the recent baby, breastfeeding status, and antenatal urinary incontinence. Maternal age was calculated as the difference between the birthdate of the most recent child and the mother's birthdate. In *Papers II-IV*, educational level was classified into three categories:

- Primary school, high school, or other (encompassing primary education, upper secondary education [high school or vocational education for 2–4 years], adult education)
- University or college education <3 years
- University or college education ≥3 years

For *Paper II*, general physical activity levels were assessed via self-reported data on weekly physical activity. Participants were asked about their engagement in moderate-intensity physical activity for at least 30 minutes each day per week (question 1), and vigorous-intensity physical activity for at least 20 minutes each day per week (question 2). The sum from question 2 was multiplied by 1.7 and added to the reported days of question 1. A sum ≥5 was defined as sufficient physical activity, according to public health recommendations of the American College of Sports Medicine and the American Heart Association.[132]

In the interview study, participants submitted information via the previously described registration form, including maternal and child age at the time of the interview, maternal weight and height, delivery mode, and presence of pelvic floor tears (if applicable). To ensure a diverse participant pool, additional details were gathered, encompassing general health status, physical activity levels (based on questions from the national health survey conducted by the Public Health Agency of Sweden),[133] educational background, and socioeconomic status.

Clinical muscle assessments

One part of the ABB Study involved the clinical assessment of pelvic floor and abdominal muscles. As previously mentioned, six physiotherapists, two at each rehabilitation centre, performed the clinical assessments. They were blinded to the participants' symptoms, physical activity and exercise level and each other's assessments. However, they knew how many months postpartum the

women were because of the presence of the participants' babies during the assessments and the need to schedule follow-up sessions.

Although they were experienced in assessing pelvic floor muscle function in daily physiotherapy practice, they lacked experience in conducting caliper measurements, assessing DRA depth and identifying DRA bulging. To address this, they underwent 4 hours of standardized training, and practised on each other and also on two to three pilot patients prior to the start of the study. Moreover, for the measurement of DRA width, the first 2 months of the ongoing study (63 participants) had to be seen as a training period to address insecurity about caliper placement and measurement position. After an additional calibration meeting, the assessing physiotherapists were confident in using this method. The clinical assessments followed a standardized protocol developed by our research group, described in the next section.

Pelvic floor muscles

Pelvic floor muscle assessments were conducted through observation and vaginal palpation. All assessments took place in a supine position, with participants' heads resting on a pillow, knees flexed to approximately 90 degrees, 10–20 degrees abducted, and feet on the examination plinth.

Rating scales for voluntary and involuntary pelvic floor muscle contraction and relaxation were used, in line with recommendations from the International Continence Society,[54] and based on studies by Devreese et al.[134] and Slieker-Ten Hove et al.[66] Scales were adapted based on clinical discussions, and shortened to make the assessment feasible for a mother with a newborn child. The following protocol was used:

Observation:

Involuntary contraction

Conceptual definition: Muscle contraction in response to intra-abdominal pressure.

Operational definition: The assessing physiotherapists observed the reflex response on forceful coughing.

Measurement scale: Downward (a perineal descent is observed), No movement (no movement is observed), Upward (a cranial movement of the perineum is observed).

Voluntary contraction

Conceptual definition: Ability to contract the pelvic floor muscles on command.

Operational definition: The assessing physiotherapists observed the muscular response to the command "Try to squeeze to prevent the escape of gas or urine".

Measurement scale: Downward (a perineal decent is observed), No movement (no movement is observed), Upward (a cranial movement of the perineum is observed).

Vaginal palpation:

For vaginal palpation, the physiotherapists inserted their index and middle finger, using non-allergic gloves and lubricating gel, 2–3 cm into the vagina. They palpated the pubovisceral and puborectalis muscles, which are the main muscles responsible for pelvic floor muscle contraction[1] and are located 2–3 cm inside the vagina, palpable through the vaginal wall,[135] see *Figure 8*.

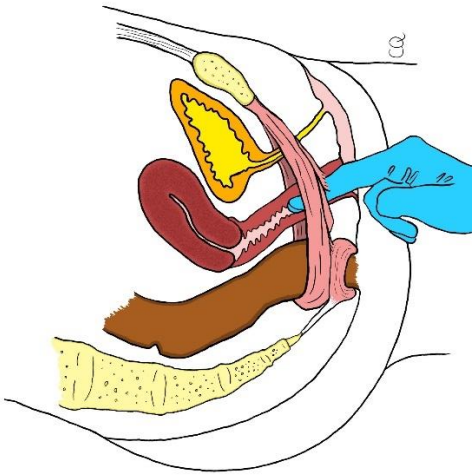


Figure 8. Vaginal palpation of the pelvic floor muscles.
Illustration reproduced with kind permission of the illustrator Clara Qvick, Department of Physical Therapy at Hospital Östra, Sahlgrenska University Hospital

Involuntary contraction

Conceptual definition: Muscle contraction in response to intra-abdominal pressure.

Operational definition: The assessing physiotherapists vaginally palpated the muscular reflex response to coughing.

Measurement scale: Absent (no muscle contraction felt as response to cough), Present (muscle contraction felt as response to cough).

Maximal voluntary contraction (MVC)

Conceptual definition: Maximum force the participant can generate by contracting their pelvic floor muscle. The participants had three attempts and the strongest was rated.

Operational definition: The assessing physiotherapist vaginally palpated the force and displacement of the levator ani muscle with her index and middle finger.

Measurement scale: The MVC was rated on a for this study adapted version of the Modified Oxford Scale. The adaptation is based on earlier studies[62,63] that suggested difficulties in scoring both the lifting and squeezing components of the levator ani muscle contraction on one scale, and in differentiating between the modified Oxford Scores of 4 and 5. In an expert group with two specialised physiotherapists in gynaecology, obstetrics, and urology, we agreed to focus on the lifting component described by Laycock & Jerwood.[61] While this is not included in the scale published by these authors, it is described in their article about this scale. In our scale the lifting component was set as criterion for ≥3. The ability to hold a strong contraction for longer than 5 seconds was set as criterion for a modified Oxford score of = 5. The differences between the original modified Oxford scale and the rating scale used in this study are presented in *Table 2.*

Table 2. Comparison of the Modified Oxford Scale used in this thesis with the original scale by Laycock & Jerwood[61]

Modified Oxford scale by Laycock&Jerwood[61]	Modified Oxford scale used in this thesis[136]
Nil	No contraction
Flicker	Partial contraction, "flicker"
Weak	Weak contraction, no correct lift
Moderate	Good contraction, definite lift
Good	Maximum contraction with lift, not able to hold longer than 5 seconds
Strong	Maximum contraction with lift, able to hold ≥5 seconds

Voluntary contraction endurance

Conceptual definition: Ability to sustain about half of the maximum force until fatigue occurs.

Operational definition: The assessing physiotherapists vaginally palpated the submaximal muscle contraction, and timed its holding time with a stopwatch. As soon as the contraction began to fade or accessory muscles were being used the time was stopped.

Measurement scale: Contraction endurance was measured in seconds. When the participant was still able to hold the contraction for ≥30 seconds the assessment was stopped and noted as ≥30 seconds.

Voluntary relaxation

Conceptual definition: Ability to relax the pelvic floor muscles on command.

Operational definition: The assessing physiotherapist palpated the pelvic floor muscles vaginally and instructed the patient to, "Take a deep breath, relax, and open up" to assess voluntary relaxation.

Measurement scale: Absent (no relaxation felt), Partial (relaxation back to resting state) or Complete relaxation (relaxation below resting state).

Diastasis recti abdominis

Following the pelvic floor muscle assessment, participants were examined in supine position on the examination plinth (removing the pillow), with hips and knees maintaining their previous, flexed position. The measurement points for DRA width and depth were marked with a water-soluble pen at 4.5 cm below, at, and 4.5 cm above the umbilicus. The flat position was essential to facilitate accurate head lift during the assessment as the two parts of the rectus abdominis muscle naturally draw closer together during an abdominal curl-up movement.[102] At the same time, it was not possible to measure participants at complete rest. The active head lift by 2–3 cm enabled the measurement of slightly activated muscles with as little influence on the original width of the DRA as possible.

Diastasis recti abdominis width:

Conceptual definition: The width between the two parts of the rectus abdominis muscle with slightly activated abdominal muscles.

Operational definition: The assessing physiotherapists manually palpated the junction between the rectus abdominis and the linea alba during both concentric and eccentric movements. They provided guidance on correct head positioning (2–3 cm head lift). Subsequently, they measured the palpated DRA using the outside jaws of the caliper (see *Figure 9*) at 4.5 cm above the umbilicus (measurement point 1), at the umbilicus (measurement point 2) and at 4.5 cm below the umbilicus (measurement point 3).

Measurement scale: Measured in millimetres.

Figure 9. Measuring diastasis recti abdominis width at measurement point 1 with a caliper.

Diastasis recti abdominis depth:

Conceptual definition: The resistance of the linea alba during a slight head lift, performed without any prior pre-activation cues.

Operational definition: Using her index and middle finger the assessing physiotherapist manually palpated the resistance of the linea alba between the rectus abdominis at the three measurement points during a slight head lift.

Measurement scale: Good resistance at all measurement points, Resistance at depth (ca. 1–2 cm deep) at one of the measurement points, Bottomless (no resistance at all) at one of the measurement points.

Diastasis recti abdominis bulging:

Conceptual definition: The reaction of the linea alba to increased intra-abdominal pressure during a maximal effort in a sit-up movement.

Operational definition: DRA bulging was observed during a standardized three-step sit-up test.[92] Participants were expected to exert themselves to their individual maximum capability when attempting a sit-up, even if they were unable to complete a full sit-up.

Measurement scale: Bulging, No bulging, or Cannot assess.

Questionnaires and interview

The other part of the ABBS-study were 4 questionnaires sent out to the participants one week prior to each clinical assessment. Two reminder emails were sent in case of non-response and there were also paper versions of the questionnaire available at the rehabilitation centres. The questionnaires contained five patient-reported outcome measures (PROMs), three used in this thesis, as well as an instrument to assess exercising and an additional question about vaginal heaviness.

The data for the interview study were collected by individual semi-structured research interviews: 2 in-person interviews and 12 telephone interviews. An overview of the instruments and methods used, and their characteristics and psychometrics, is given in *Table 3*.

Table 3. The instruments/ methods used to assess and explore the participants' symptoms, exercise habits, and experiences of physical changes in the postpartum period

Assessed variable	Instrument/ method	ICF	Used in	Short description	Psychometrics
Pelvic girdle pain	Pelvic girdle questionnaire (PGQ)[137]	Body function Activity	Paper II+III	Activity scale: 20 questions to evaluate activity limitations due to pelvic girdle pain, such as problems with prolonged sitting, standing, or engaging in sports activities.[137] Symptom scale: 5 questions to assess body functions such as morning/evening pain, stability, and sleep disturbances. All items can be rated from 0-3, yielding a total sum ranging from 0 to 75. This sum is divided by the number of rated items (items 16 and 19 can be rated as "not applicable"). A final step involves multiplying this result by 100, resulting in a final score that ranges from 0 to 100 *The Swedish version of the PGQ, used in this thesis, differs in item 8 from the original version: "walking for more than 60 minutes" was translated as "walking for more than 10 minutes".*[138]*	- Recommended patient-reported outcome measure for assessing pregnancy-related pelvic girdle pain[139] - Internal consistency of both the activity and symptom scale -->pooled Cronbach alpha = 0.83-0.96[139] - Test-retest reliability -> pooled ICC = 0.72—0.98[139] - Minimal detectable change on group level = 2.3[140] - Minimal important change for those with lower pain levels (PGQ<28) = 6[141]
Exercise habits	MoBa questionnaire [142]	Activity	Paper III	Developed for the Norwegian Mother and Child Cohort Study (MoBa study), Norway,[142] translated and culturally adapted for this thesis: - 15 types of exercises and their weekly/monthly frequency were reported for the following postpartum periods: 0-3 months, 3-6 months, 6-9 months, and 9-12 months. - The exercises were rated as: never (0 points), 1-3 times/month (0.25 points), once a week (1 point), twice a week (2 points), and three times or more a week (3 points)	- Statistically significant but low correlation with accelerometer, r = 0.27, p-value <0.01[142]
Vaginal heaviness	Question about vaginal heaviness	Body function	Paper III	The participants were asked if they perceive vaginal heaviness while exercising. The question could be rated as: never (0), seldom (1), occasionally (2), often (3), or always (4).	Not tested

Stress urinary incontinence	International consultation on incontinence questionnaire for urinary incontinence short form (ICIQ-UI short form). [27]	Body function	Paper III	Four questions: - Question 1-3 assess the frequency, severity, and impact of urinary incontinence on quality of life. - Question 4 assesses the type of urinary incontinence. The sum was calculated as follows: question 1 + (2 x question 2) + question 3, resulting in a score ranging from 1 to 21.[27]	- Recommended outcome measure for urinary incontinence, available in over 30 languages.[27] - Inter-item correlation = 0.46 at six weeks postpartum.[143] - Correlates with other instrument for urinary incontinence, r = 0.53 - 0.86, p value <0.01.[144] - Sensitive to changes in different groups (age, BMI).[143] - Minimal important difference (not postpartum population) = 2.52[145]
Activity limitations	Patient-specific functional scale (PSFS)[146]	Activity, Participation	Paper IV	- In the original questionnaire, 5 restricted activities should be reported;[146] in this thesis, the number was limited to 3. - The activity limitation can be scored from 0 (not able to perform) to 10 (no difficulties).	100% of activity limitations reported by patient of a physiotherapy clinic could be mapped according to the ICF classification[147]
Reasons for activity limitations	Free text answers	Body function	Paper IV	The participants reported reasons for the in the Patient-specific functional scale reported activity limitations in a free text field.	Not tested
Experiences of physical changes and recovery	Semi-structured in-depth interviews	Body function Activity, Participation	Paper IV	A method to understand a phenomenon or problem through the narrative of a person who has experienced the phenomenon or problem. - Telephone interviews were used as a method to ensure participants felt comfortable and relaxed[148] (i.e., at home with their newborn). - A semi-structured interview guide was used.	N/A

BMI = Body mass index, ICC = intra class coefficient, ICF = international classification of functioning, disability and health, N/A = non applicant, ROC = receiver operation characteristic curve

* Removing and recalculating our scores without the item 8 caused only slight changes. However, the difference might lead to an underestimation of activity limitations as walking was the most frequently reported activity limitation in the development of the instrument.[137]

Data analysis

Quantitative data in *Papers I–III* were analysed using IBM SPSS Statistics 25 for Microsoft Windows (SPSS Inc., Armonk, NY, USA). In *Paper IV*, Microsoft Excel was used for the quantitative content analysis and NVivo 14 for Microsoft Windows (Lumimvero, Denver, CO, USA) for the qualitative content analysis. An overview of the methods used in *Papers I–IV* is provided in *Table 4* and further described in the text below.

Table 4. Data analysis methods used in this thesis, listed in alphabetical order

Statistical test/analysis method	Measure	Paper I	Paper II	Paper III	Paper IV
Chi-square test	Compares the distribution of categorical variables in relation to each other	X	X	X	
Cohen´s (weighted) kappa	Level of agreement between two ratings on nominal or ordinal scales	X			
Friedman´s ANOVA	Differences between several related groups (change over time)			X	
Independent-sample *t*-test	Compares the means of two independent groups		X		
Intraclass correlation coefficient	Degree of agreement and consistency in measurements	X			
Kruskal Wallis test	Differences between several independent groups by ranking	X		X	
Mann Whitney U test	Differences between two independent groups by ranking		X		
Minimal detectable change	The smallest change detectable by the method as a real change and as result of measurement error	X			
Mixed-effects models for repeated measures	The prediction of independent variables on the dependent variable (fixed effect), the variability between the subjects and measurement points		X		

	(random effect) and changes over time (slope)			
One-way ANOVA	Compares the means of three or more independent groups	X	X	
Quantitative content analysis	Systematically coding, categorizing and counting text or interview data to quantify and analyse its content			X
Qualitative content analysis	A process in which meaning units related to the research question are coded and categorised with increasing levels of abstraction and interpretation level to find step by step a broader and deeper understanding of the studied phenomena			X
Standard error of measurement	Degree to which the measurement differ from the actual value due to measurement error	X		

ANOVA = analysis of variance

Descriptive statistics

The baseline characteristics of the participants of *Papers I–IV* are presented as mean and standard deviation (SD) for normally distributed data, number and percentage for nominal and ordinal data, and median and interquartile range (IQR) for non-normally distributed data. The distribution of the data was evaluated using normal Quantile-Quantile (Q-Q) plots and evaluating the null hypothesis of normal distribution using the Shapiro-Wilk test.

In *Paper I*, we presented the mean and SD for DRA width measurements taken at the different rehabilitation centres for both primiparous and multiparous women at 3 months postpartum. In *Paper III*, the prevalence of pelvic girdle pain, stress urinary incontinence and vaginal heaviness and distribution of MVC ≥3 and DRA width ≥35 mm was calculated.

Between-group and within-group differences

In *Papers I–III*, background data were compared between the different rehabilitation centres (*Paper I*), participants with and without pelvic girdle pain

(*Paper II*) and different exercise groups (*Paper III*). We used appropriate statistical tests to compare between-group differences: parametric tests (e.g. one-way analysis of variance [ANOVA], independent-sample *t*-tests) for normally distributed data, non-parametric tests (e.g. Kruskal-Wallis, Mann-Whitney U test) for non-normally distributed or ordinal data, and Chi-square tests for nominal data. Chi-square tests were also used to compare symptom prevalence at 3 and 12 months postpartum in *Paper III.* A p-value ≤0.05 was considered statistically significant.

In *Paper III*, the within-group difference from 3 to 12 months postpartum in four exercise groups was calculated using non-parametric Friedman's ANOVA. The exercise groups were categorized based on health recommendations by the American College of Sports Medicine and the American Heart Association.[132] The first three groups were: no exercising (fewer than twice /week), below-recommendation physical activity (minimal low-impact exercising 2 to <5 times/week), and meeting the health recommendations (regular low-impact exercising 5 or more times/week). The fourth group consisted of high-impact exercisers. However, owing to the limited number of participants performing high-impact exercises at 3 months postpartum, we defined high-impact exercisers as those who exercised at this level at least once a week, considering the potential health benefits even at this low frequency.[149]

Inter-rater reliability and measurement errors

In *Paper I*, we used Cohen's kappa to assess agreement between two assessing physiotherapists' rating on nominal scales, and weighted (linear) kappa coefficients for ordinal scales. The later assessment considers the extent of disagreement.[150] Both Cohen's kappa coefficients quantify the agreement beyond chance and range from -1 (worse than chance agreement) to 1 (complete agreement). For a more detailed scoring, the scoring system defined by Landis & Koch[151] (0=poor, .01–.20=slight, .21–.40=fair, .41–.60=moderate, .61–.80=substantial, and .81–1=almost perfect) was used. Additionally, the prevalence of rated muscle functions was reported because a high prevalence can lead to increased agreement due to chance alone which can reduce the kappa value.[150]

Diastasis recti abdominis width, measured in millimetres, was assessed for inter-rater reliability using an intra-class coefficient (ICC). Intra-class coefficient values quantify how much the variance in measurements is influenced by sources of variance such as number of subjects, assessing

physiotherapists, and agreement, on a scale between 0 and 1.[128] A value <0.5 indicates low reliability, 0.5–0.75 indicates moderate, >0.75–0.9 good and >0.9 excellent reliability. The sources of variance were defined following the guide by Koo & Li,[128] resulting in the use of a two-way mixed-effects model. This choice was made as we used a distinct set of assessing physiotherapists without a randomization process for their selection. The model assessed the agreement of measurement averages (average measures), and quantified the degree of equivalence between assessment 1 and assessment 2 (absolute agreement). As the calculation of the ICC value depends on the variance between the measured individuals, which is not that high in DRA width,[90] it needed to be completed with additional metrics.[152] Standard error of measurement (SEM) and minimal detectable change (MDC) are appropriate measures to complete ICC-values.[153]

Regression analysis

In *Paper II*, we included the muscle functions with the highest kappa values for inter-rater reliability evaluated in *Paper I* as predictors. They were MVC (dichotomized to weak <3, strong ≥3), involuntary pelvic floor muscle contraction (assessed by vaginal palpation), DRA width (measured at measurement point 2) and DRA bulging. We evaluated the associations between the independent variables (muscle functions) and several covariates (as used in previous research[154]) and the dependent variable (pelvic girdle pain) using mixed-effects models for repeated measurements. Multicollinearity among the independent variables was tested through correlation analyses. Normal distribution and homoscedasticity of the standardized residuals were assessed using scatter plotting and histograms.

Mixed-effects models for repeated measurements has the advantage of handling data with varying subject developments. It models the relationship between individual cases, instead of assuming that the relationship between the independent and dependent variables is the same across the entire group.[155] The participants in the ABB-study showed variations in their PGQ score changes during the first year postpartum, as illustrated *Figure 10*, which motivated the choice of method. These individual differences, both in pain severity and in changes over time, were assessed using a two-level mixed-effects model for repeated measurements, nested within individuals. Results were presented as regression coefficient (β) for each effect and its confidence interval (CI).[155]

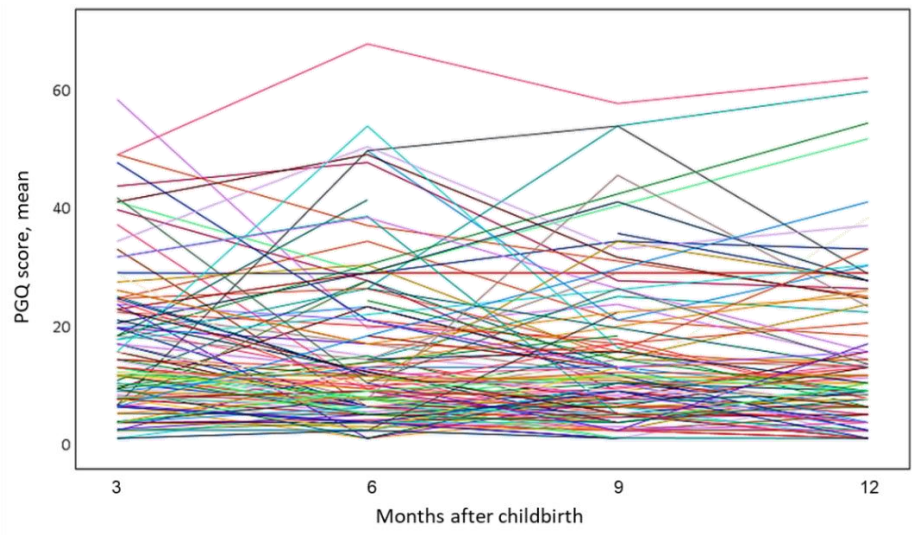


Figure 10. Variation in changes in pelvic girdle pain during the first year postpartum in the 504 participants. PGQ = Pelvic Girdle Questionnaire

Cut-off points in Papers II and III

In the statistical analysis of *Papers II+III*, different cut-off points were used to achieve both high clinical relevance and to meet certain conditions of statistical analysis. Variables used in both papers were MVC, DRA width and pelvic girdle pain:

In *Paper II*'s data analysis, the variable MVC (ordinal scale 0-5) needed to be dichotomized due to a limited number of participants with values below 1 and above 4. Despite a lack of consensus in the literature regarding defining weak or strong pelvic floor muscle strength, we chose to define MVC ≥3 as strong based on the rationale that our definition of the lifting component is in line with the definition of a correct contraction,[58] and further based on a clinical guideline that defined MVC ≥3 as strong enough for activities such as running.[156]

As more research about moderate to severe DRA is required,[89,95] a cut-off point for this criterion was needed. In an earlier study,[105] a DRA width ≥35mm was suggested to signify moderate to severe DRA. Based on the results from *Paper I*, which indicated an SEM of 4–5 mm for caliper measurements, we concluded that a DRA width of ≥35 mm exceeds the SEM above the normal width of 23.8 ± 7.3 cm at 3 months postpartum.[90] Therefore, ≥35 mm was used as cut-off

point for moderate to severe DRA, especially since it also aligned with the cut-off used in a comparable study.[91]

In *Paper II*, the cut-off for pelvic girdle pain severity was derived from a study assessing the ability of the PGQ to detect changes in pain severity from pregnancy to postpartum. This study defined three severity groups: low (PGQ score <28), middle (PGQ score ≥28–63), and high (PGQ score ≥63),[141] which led to the definition of PGQ ≥28 as middle to high pain in *Paper II*.

However, the data analysis in *Paper II* made us reconsider the cut-off for pelvic girdle pain in *Paper III:*

- *Paper II* showed that participants with a PGQ score <28 showed no statistically significant change in pain severity.
- The established cut-off for pain severity and minimal important changes are based on pain levels in pregnancy and within 3 months postpartum[141] and may not be comparable to postpartum pain, which tends to be of lower intensity.[68]
- Individuals with a PGQ score of ≥10-27.99 experienced several activity limitations >1 (on an ordinal scale 0-3), particularly in activities such as running and carrying out sports activities which were of importance for *Paper III* (as visualized in *Figure 11)*.

Based on these considerations, the cut-off point for pelvic girdle pain was lowered to PGQ score ≥10 for *Paper III* to include participants with pain that restricts activity, but with the assumption that a certain level of pain might be considered normal in any population.

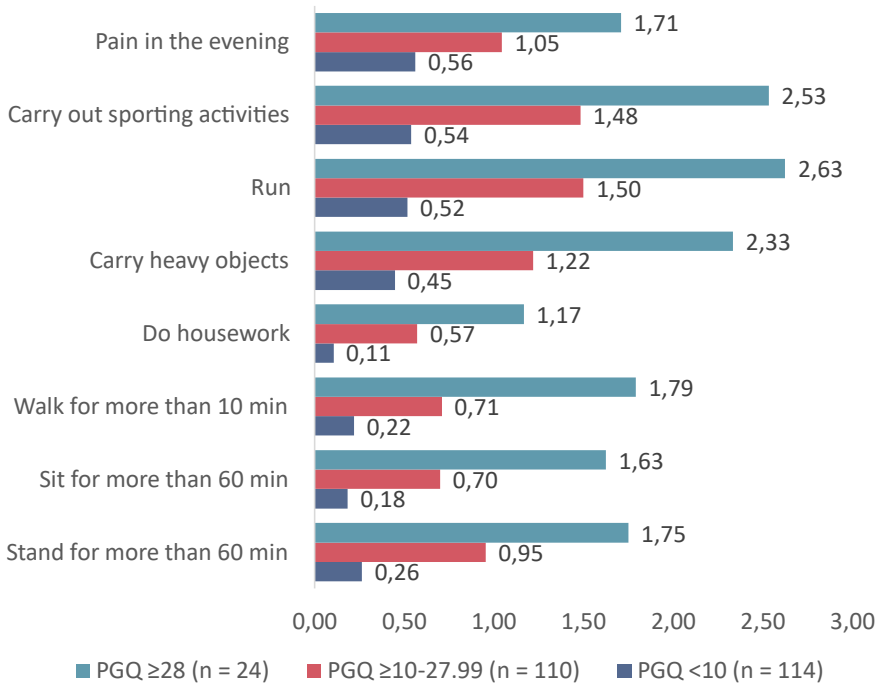


Figure 11. Examples of mean values for reported activity limitations and pain severity due to pelvic girdle pain at 3 months postpartum in the three groups (ordinal scale of 0–3), PGQ = Pelvic Girdle Questionnaire

In *Paper III*, we established a cut-off criterion for stress urinary incontinence using the International Consultation on Incontinence Questionnaire-Urinary Incontinence (ICIQ-UI) scale (0–21). One prior study[157] had defined the ICIQ-UI cut-off values as slight (1–5), moderate (6–12), severe (13–18) and very severe (19–21). However, we adapted our criteria as postpartum urinary incontinence is often slight[28] but can still affect several domains of daily life.[158,159] As we aimed to evaluate bothersome stress urinary incontinence, we defined it based on a rating of ≥1 for question 3, which asks, "Overall, how much does leaking urine interfere with your everyday life?" (Numeric rating scale 0-10).

For vaginal heaviness, no prior studies informed our criteria, leading us to classify “never” and “seldom” as clinically irrelevant. Vaginal heaviness was thus defined as a symptom if it was rated as “occasionally”, “often”, or

"always". Furthermore, a Patient-Specific Functional Scale (PSFS) score of ≥8 (on a numeric rating scale of 0-10) was identified as indicating activity limitations.

Analysis of text data

Paper IV contained two data sets, the first of which originates from the ABB-study (PSFS and free text answers), and the second from the interview study. This approach was chosen to enrich descriptive data of perceived activity limitations postpartum with the women´s experience of physical changes and recovery.

The data from the ABB-study were analysed by inductive quantitative content analysis, a method described by Krippendorf.[160] In this method, textual data — reported activity limitations and reasons— were analysed by condensing them into codes, subcategories, and categories. A small degree of interpretation was required during the coding process when participants' wording varied for the same activities. However, most of the activities were similar, with only a few activities being more difficult to code because of their unique appearance. In the subsequent step, the categorised data were counted and divided by the number of participants at 3, 6, and 12 months postpartum to calculate the frequency of activity limitations. The reported reasons for activity restrictions were divided by the reported activities at 3, 6, and 12 months. In subsequent sections, the results of this analysis will be referred to as "*Paper IV-cohort*".

The data set of the interview study was analysed by qualitative content analysis using a method described by Graneheim& Lundman.[161] The interview text was verbatim transcripted and listen to several times. An inductive approach was chosen, meaning that the analysis was driven by the narratives of the participants and not by a theory or model.[162] To analyse the manifest content, the interview transcript was initially decontextualized by breaking it into smaller meaning units relevant in terms of the research question.[161,163] These units were condensed and coded. In this process, the right amount of content has to be chosen. Meaning units that are too short have the risk of losing content while too broad ones can lose detail.[163] In the next step, codes were re-contextualised into subcategories and categories, uncovering new patterns and gaining a deeper understanding of the researched phenomena with an increasing abstraction level at each stage. An example of our analysis is seen in *Figure 12*.

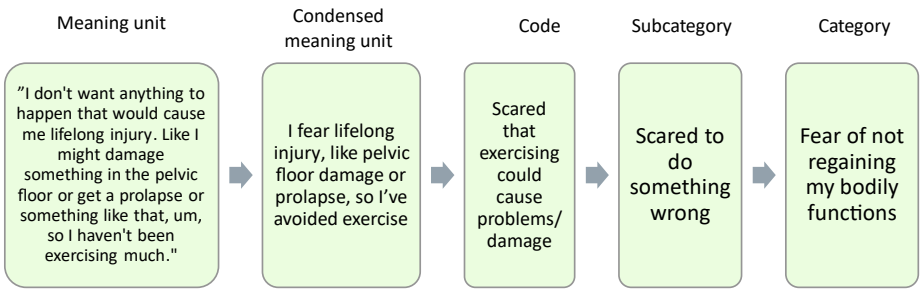


Figure 12. An example of analysis of manifest content in the Interview Study.

The chosen method[161,163] allows to choose a close and concrete approach near to the text to describe a concrete phenomenon; also, it allows a more distant and interpretative approach to explore the underlying meaning of an experience (see *Figure 13*). Our aim was to get a deeper understanding of women's experience of physical changes and recovery, after observing in the ABB study that symptoms were mild and challenging to measure. Therefore, we opted for a distant and abstract approach in the analysis of the manifest content. We also analysed the latent content of the interviews, which was presented in subthemes and themes. The analysis of the latent content is an interpretative step in which we looked for the thread of meaning in the codes, subcategories, and categories through note-taking and discussions with each other. In subsequent sections, the results of the interview analysis will be referred to as the "*Paper IV-interview*"

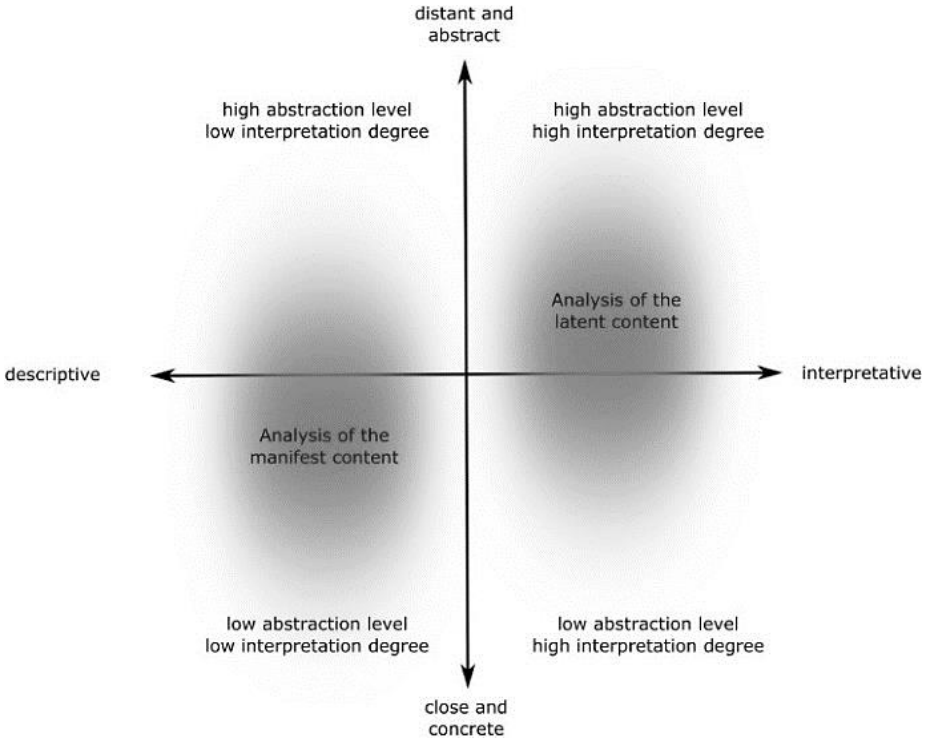


Figure 13. Abstraction and interpretation levels in qualitative content analysis according to Graneheim, Lindgren& Lundman (2017).[162] Reproduced from the Journal Nurse Education Today with kind permission from the authors and Elsevier.

Ethical considerations

This section is based on the guide for good research practice of the Swedish Research Council.[164] By law, it is regulated that research on humans has to be approved by an ethical committee. Both studies included in this thesis were approved by the Swedish Ethical Review Authority before study start (Dnr 088-1 and Dnr 2022-01891-0). In the ABB Study some adaptions were made after pilot testing of the planned study protocol. These were changes in the clinical assessment of DRA from manual palpation to caliper measurement, in the assessment of urinary incontinence (Pelvic Floor Impact Questionnaire [PFIQ7] versus the ICIQ-UI short form) and adding the question about vaginal heaviness and the patient-specific functional scale (amendment, Dnr T647-1). In the interview study the recruitment strategy had to be changed, also resulting in an amendment (Dnr 2022-05943-02).

In accordance with the Helsinki guidelines, all participants in the two studies were thoroughly informed about the aim of the study, and about assessments, questionnaires and interviews included. They were given the possibility to ask questions and the contact details of the researchers in case of an adverse event. All participants signed an informed consent prior to the study. Data security was ensured by saving all data on a password-protected server. A data security registration was made prior to the start of the studies. The ABB Study was also registered in clincaltrials.gov.

Research should only be done if it has significant benefits, for example for a patient group.[164] Although the risks of our studies were low, it is essential to acknowledge that our research imposed demands on the participants' time and resources. Healthy women were recruited to participate in four clinical assessments of their pelvic floor and abdominal muscles and to complete four questionnaires. One potential concern was the possibility of discomfort or pain arising from the clinical assessments. The assessing physiotherapist had an important task in explaining the clinical assessment and informing the participants that they could stop the assessment at any time if they felt uncomfortable. When booking their first appointment several participants asked whether the assessing physiotherapists were female, which we could affirm.

Another ethical concern was the fact that our research question was partly based on clinical experience and not solemnly on previous research. For instance, in the clinic, women express concerns about muscular changes, and complaints about vaginal heaviness, but there is a lack of research about this. This could be seen as ethically questionable; on the other hand, it would also be ethically wrong to continue using clinical assessment methods and assessing symptoms that are not based on evidence.

Finally, our recruitment approach in the ABB study, framed by the question "Do you want to know how your pelvic floor and abdominal muscles are recovering after pregnancy?", needs to be discussed. Participants received a record of their pelvic floor strength (ranging from 0 to 5) and the distance, in centimetres, between their rectus abdominis muscles after each visit. No additional explanation was provided regarding whether these results were considered good or bad. This was due to the observational nature of the study. However, during the course of the study, we realized that this approach may have imparted a false sense of security to participants, letting them think that they were receiving check-ups every 3 months. Although the participants were

informed about the fact that the assessing physiotherapists were blinded to their symptoms and that we lacked knowledge about normal values and their relation to symptoms in the postpartum period, the physiotherapists frequently reported that the participants had numerous questions and sought to discuss their issues. To address this issue, we advised these participants to seek help from colleagues at the same rehabilitation centre and included a question about physiotherapy contact in the questionnaires (not yet evaluated). However, there is a risk that some women still did not understand the observational nature of the study and thought that the assessing physiotherapists would mention if something was wrong.

In the interview study, there was a risk that the recounted memories of the first months after birth could revive trauma and hidden emotions. Several women became emotional during the interviews which were mostly conducted by telephone. I consistently asked about their wellbeing, post-recording, and offered the opportunity for further discussion or a follow-up call if emotions became overwhelming or sadness persisted. However, no extern contact with a midwife or other health care providers was offered, and it remains uncertain whether participants would have availed themselves to the offer to contact me again.

Summary of results

Clinical assessment in the postpartum period

Paper I showed that the clinical assessments of voluntary pelvic floor muscle contraction, whether observed or palpated vaginally, had moderate to substantial inter-rater reliability. Vaginal palpation of the MVC demonstrated superior outcomes (κ = 0.69; 95% confidence interval [CI] 0.62; 0.76) compared with vaginal palpation of pelvic floor muscle endurance (κ = 0.49; 95% CI 0.37; 0.61) and observation of a voluntary contraction (κ = 0.45; 95% CI 0.28; 0.62), as presented in *Table 5*. Differences between the three rehabilitation centres were seen, including lower inter-rater reliability in pelvic floor muscle endurance assessment at centre 2 (κ = 0.27; 95% CI 0.09; 0.45) and in voluntary contraction observation assessment (κ = 0.40; 95% CI 0.11; 0.70) at centre 3.

The assessment of involuntary contraction during a forceful cough had moderate reliability with vaginal palpation and slight reliability with observation. The voluntary relaxation assessment showed fair inter-rater reliability. However, even in these assessments, there were variations between the rehabilitation centres. The clinical assessment of voluntary relaxation at rehabilitation centre 2 yielded negative kappa values (κ -0.08; 95% CI -0.23–0.07). Both assessments of involuntary contractions at centre 1 demonstrated slight to fair inter-rater reliability, with confidence intervals extending to negative values.

Table 5. Inter-rater reliability of the eight evaluated clinical assessment methods, grouped using Landis & Koch's[151] classification of kappa values.

Clinically assessed functions	Slight (<0.2)	Fair (0.21–0.40)	Moderate (0.41–0.60)	Substantial (0.61–0.80)
Pelvic floor muscle functions				
Voluntary contraction				
Observation, κ (95 % CI)			0.45 (0.28; 0.62)	
Vaginal palpation of maximal voluntary contraction, κ (95 % CI)				0.69 (0.62; 0.76)
Vaginal palpation of pelvic floor muscle endurance, κ (95 % CI)			0.49 (0.37; 0.61)	
Involuntary contraction				
Observation, κ (95 % CI)	0.10 (−0.02; 0.22)			
Vaginal palpation, κ (95 % CI)			0.51 (0.37; 0.65)	
Voluntary relaxation, κ (95 % CI)		0.26 (0.15; 0.37)		
Diastasis recti abdominis				
DRA depth, κ (95 % CI)			0.43 (0.29; 0.56)	
DRA bulging, κ (95 % CI)			0.51 (0.29; 0.73)	

CI = confidence interval, DRA = Diastasis recti abdominis, κ = kappa value

Following a standardized clinical assessment protocol, the inter-rater reliability of caliper measurement of DRA width was good. The measurement taken at measurement point 2 (umbilicus level) exhibited the highest inter-rater reliability (ICC = 0.83; 95% CI 0.76; 0.83), accompanied by the lowest SEM (4.1 mm) and an MDC of 11.2 mm. The inter-rater reliability at measurement

points 2 and 3 was lower (ICC = 0.73 and 0.80, respectively). The primary care rehabilitation centre, characterized by the shortest training duration and a lower influx of participants (n = 29) throughout the study period, exhibited the highest values for SEM (4.9 mm) and MDC (13.7 mm).

The clinical assessment of DRA depth and bulging showed moderate inter-rater reliability for the total assessment (see *Table 5*). The inter-rater reliability of DRA depth assessment was only fair, evaluating the primary care rehabilitation centres separately. The inter-rater reliability of DRA bulging was fair at primary care rehabilitation centres 2 and 3 (κ = 0.35 and 0.36, respectively).

Association between clinical assessments and pelvic girdle pain postpartum

Paper II revealed that, out of 504 participants, 353 had answered "yes" to the question of whether they had experienced pelvic girdle pain in the last 4 weeks, at least once during the period between 3 and 12 months postpartum. Specifically, 261 participants reported pelvic girdle pain at 3 months, 227 at 6 months, 181 at 9 months, and 162 at 12 months postpartum.

A series of three interconnected mixed-effects models were used to evaluate the relationship between the independent variable MVC ≥3 and involuntary pelvic floor muscle contraction, and the dependent variable pelvic girdle pain. The first model revealed that MVC ≥3 exhibited a statistically significant yet slight association with reduced pelvic girdle pain severity at 3 months postpartum (β = -3.13; 95% CI -5.77; -0.48) but no association with changes in pelvic girdle pain severity from 3 to 12 months postpartum. The first model explained 5.2 % of the variance in the initial pain severity (β = 14.61; 95% CI = 12.46; 16.77) and 11.8 % in the change in severity (β = -0.40; 95% CI -0.77; -0.03).

In the subsequent model, a dichotomous variable distinguishing between low pain (PGQ <28) and middle to high pain (PGQ ≥28) was introduced. This model demonstrated that changes in pelvic girdle pain severity from 3 to 12 months postpartum were statistically significant solely in participants with higher initial pain severity (see *Figure 14*).

To assess whether MVC ≥3 is associated with increased or decreased prediction for individuals with PGQ ≥28, an interaction between these two variables was added in the fourth model. MVC ≥3 had a stronger prediction on

pelvic girdle pain severity (β = -6.39; 95% CI -12.84; 0.07) among individuals PGQ ≥28 at 3 months postpartum. However, it did not significantly predict changes in pain severity. This model accounts for 65.3% of the variance in the dependent variable, with the variable PGQ ≥28 being the primary contributor to this high explanation level.

For an evaluation of the associations between the independent variables DRA width and DRA bulging and the dependent variable pelvic girdle pain, a similar exploratory approach was taken. In a first model, DRA width (in millimetre) and DRA bulging were added to the model, showing no statistically significant association between the predictors and the outcome. In the second model, we applied the defined cut-off point for DRA width (page 48-49). This model demonstrated that a DRA width of ≥35 mm was a statistically significant predictor for pelvic girdle pain severity (β = 5.38; 95% CI 1.21; 9.55) at 3 months postpartum (see *Figure 15*). This model explained 10.6% of the variance in the dependent variable. Birth weight showed a slight prediction on changes in pain severity from 3 to 12 months postpartum: β = -0.53 (95% CI -0.94 to -0.12).

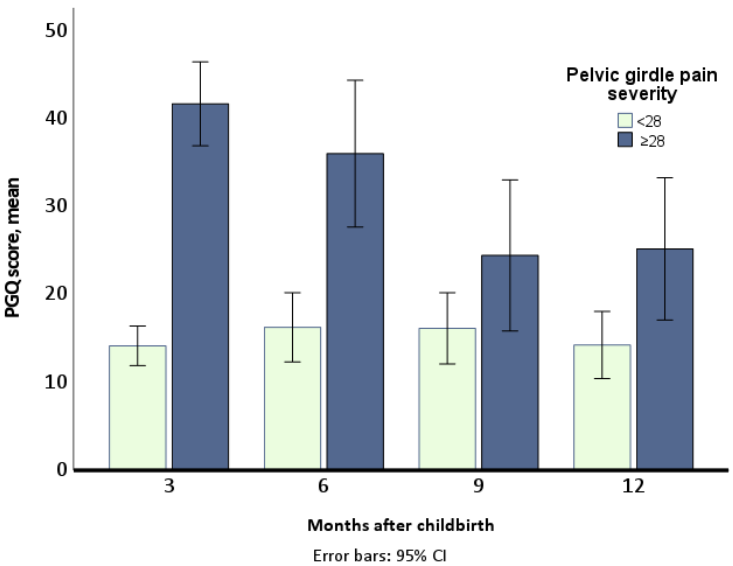


Figure 14. Pelvic Girdle Questionnaire (PGQ) mean scores at 3, 6, 9 and 12 months postpartum, comparing participants with low (<28) and participants with middle to high pelvic girdle pain (≥28) at 3 month postpartum. CI = Confidence interval

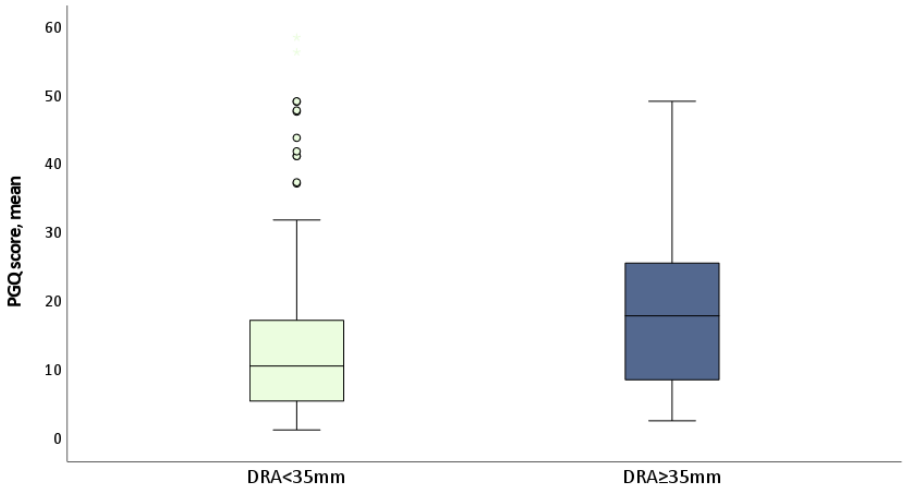


Figure 15. Pelvic Girdle Questionnaire (PGQ) scores in participants with diastasis recti abdominis (DRA) width <35 mm and participants with DRA width ≥35 mm.

However, when comparing participants with pelvic girdle pain (n = 353) and those without (n = 151) during the first postpartum year, no statistically significant differences in the distribution of MVC ≥3 and DRA width ≥35mm at 3 months postpartum were observed, as shown in *Table 6.*

Table 6. Distribution of maximal voluntary contraction (MVC) ≥3 and diastasis recti abdominis (DRA) width ≥35 mm at 3 months postpartum in participants with and without pelvic girdle pain (PGP) during the first year postpartum.

		Participants with PGP (n = 353)	Participants without PGP (n = 151)	p-value
MVC, n (%)	<3*	182 (51.6)	74 (49.0)	.74
	≥3*	166 (47.0)	72 (47.7)	
DRA width, n (%)	<35 mm	269 (76.2)	113 (74.8)	.10
	≥35 mm	41 (11.6)	9 (6.0)	

*rated on a modified oxford scale (ordinal scale 0-5), mm = millimetre, n = number

Recommendation for exercising in the postpartum period

Paper II showed that 26.6% of participants reported pelvic girdle pain, 32.4% had stress urinary incontinence, and 29.0 % reported vaginal heaviness at 3 months postpartum, using the cut-off points described on pages 49-50. By 12 months postpartum, the prevalence of pelvic girdle pain and vaginal heaviness had decreased to 16.5% and 14.2%, respectively, while stress urinary incontinence persisted, affecting 32.8% of participants. *Figure 16* shows that several participants experienced a combination of these symptoms.

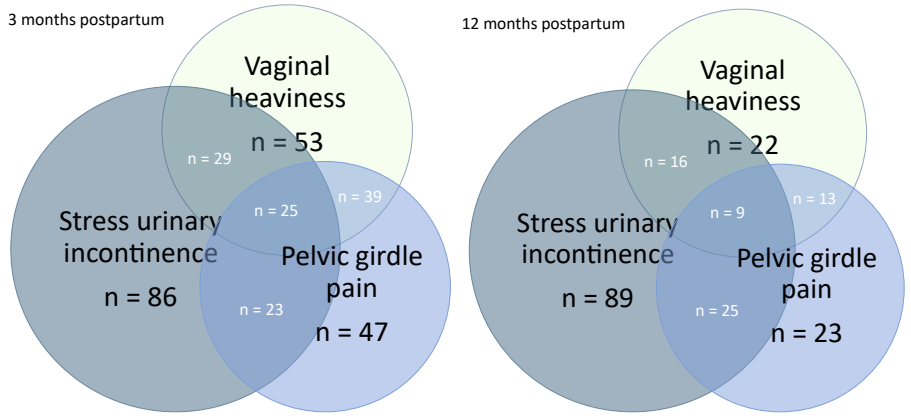


Figure 16. Distribution of stress urinary incontinence, vaginal heaviness and pelvic girdle pain and overlapping symptoms at 3 and 12 months postpartum

The mean pelvic floor muscle strength, measured on the modified Oxford scale (0–5), was 2.5 (95% CI 2.4–2.6) at 3 months postpartum and 3.4 (95% CI 3.3–3.5) at 12 months postpartum. Even though these means are derived from an ordinal scale, they provide meaningful information. Specifically, they show how the percentage of participants with a pelvic floor muscle strength less than 3 (MVC <3) on the modified Oxford scale has changed over time. Initially, 47% of participants had a strength rating below 3 at 3 months postpartum. This percentage decreased to 15% at 12 months postpartum (see *Figure 17*)

The mean value for DRA width was 25.6 mm (SD 7.3) at measurement point 2 at 3 months postpartum, with higher values in multiparous than in primiparous women, as seen in *Figure 18*. At 12 months postpartum, the mean value was 18.3 mm (SD 6.1). At 3 months, 52 of 432 measured participants (12%)

had a DRA width ≥35mm, at 12 months postpartum, the number had decreased to 12 of 410 participants (3%).

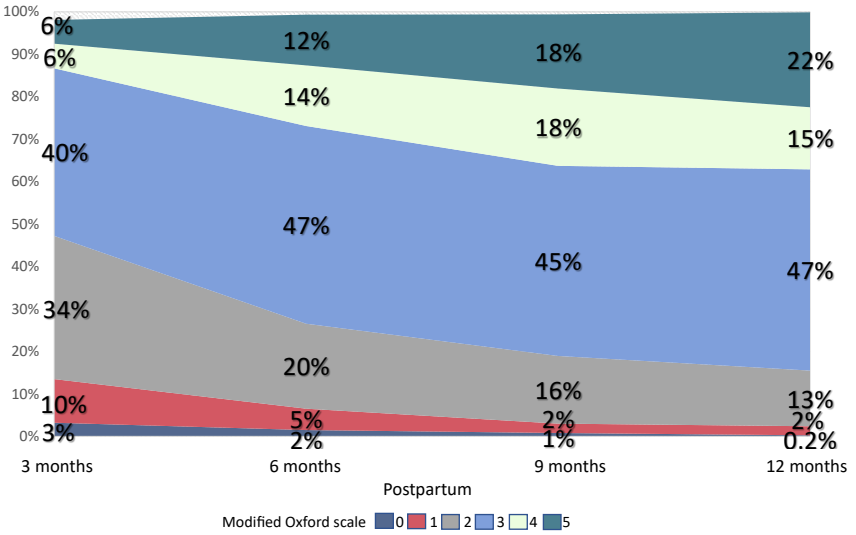


Figure 17. Distribution of maximal voluntary pelvic floor muscle strength at 3, 6, 9 and 12 months postpartum, Ten and three participants were not measurable due to incorrect activation pattern (straining) at 3 months and 6 months postpartum, respectively

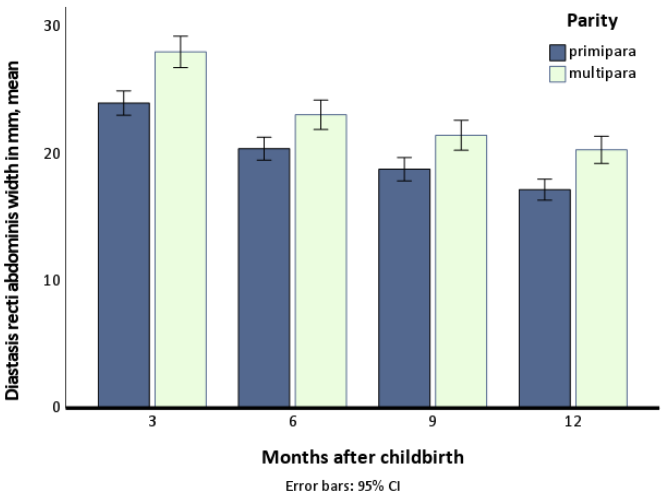


Figure 18. Mean values of diastasis recti (DRA) width in primiparous and multiparous participants measured at the umbilicus at 3, 6, 9 and 12 months postpartum. CI = confidence interval; mm = millimetre

The question in looking at this material was whether exercising in the first 3 months postpartum (with different frequency and intensity) is associated with these changes in pelvic girdle pain, stress urinary incontinence, vaginal heaviness, pelvic floor strength and DRA width.

At 3 months postpartum, non-exercisers (n = 105) reported statistically significant higher pelvic girdle pain severity and weaker pelvic floor muscles compared with the other exercise groups. The within-group analysis showed that non-exercisers showed no statistically significant change in the severity of pelvic girdle pain among the repeated measures from 3 to 12 months post-partum (p-value = 0.63) (*Figure 19*). However, they showed an increase in the severity of stress urinary incontinence during this period (from 4.4 to 5.7; p-value = 0.04) (*Figure 20*). Vaginal heaviness decreased in non-exercisers from 3 to 12 months postpartum.

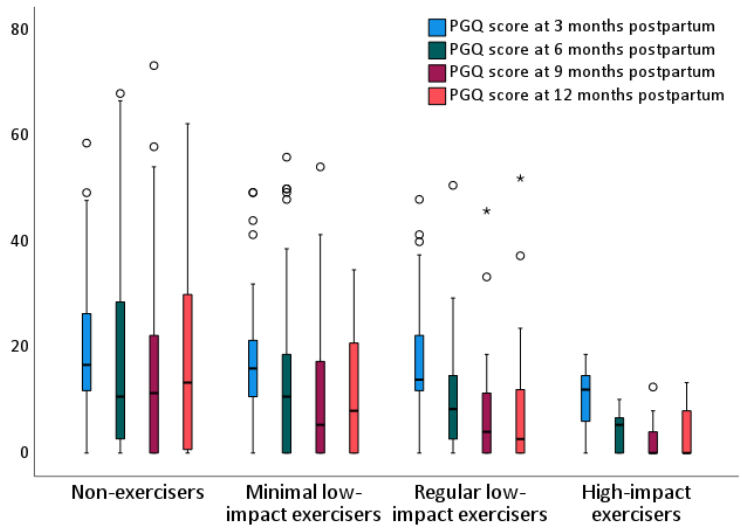
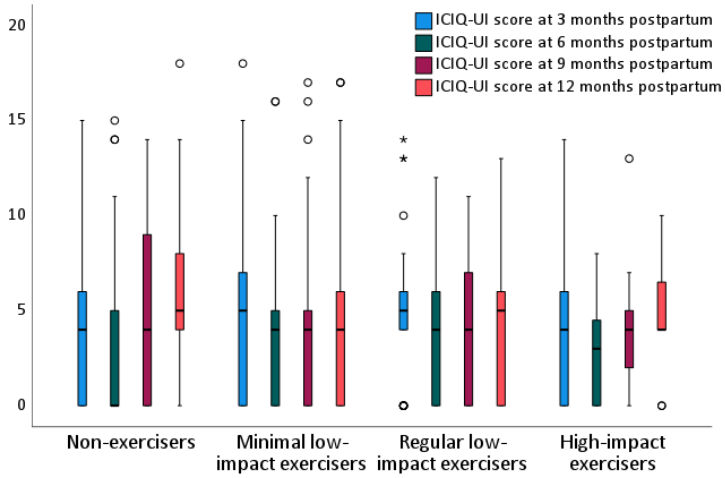


Figure 19. Pelvic girdle pain severity at 3, 6, 9 and 12 months postpartum in the four exercise groups, including participants with PGQ score ≥10 at 3 and/or 12 months postpartum. PGQ = Pelvic Girdle Questionnaire

The other exercise groups showed no between-group differences at 3 months postpartum. In the within-group analysis, minimal low-impact exercisers (n = 249) showed statistically significant decreases in symptom severity in pelvic girdle pain, stress urinary incontinence and vaginal heaviness at 12 compared to 3 months postpartum. As shown in *Figure 20*, the change in stress urinary incontinence was slight.

Regular low-impact exercisers (n = 117) showed the same changes as minimal low-impact exercisers, except for the change in stress urinary incontinence which was not statistically significant in this group. High-impact exercisers (n = 32) had a statistically significant decrease only in vaginal heaviness, and showed a trend towards reduced pelvic girdle pain severity from 3 to 12 months postpartum, but without statistical significance. All groups exhibited statistically significant reductions in DRA width and an increased pelvic floor strength at 12 months compared to 3 months postpartum.



ICIQ-UI - International consultation on incontinence questionnaire for urinary incontinence

Figure 20. Stress urinary incontinence severity at 3,6, 9 and 12 months postpartum in the four exercise groups, including participants with ICIQ-UI score≥1 at 3 and/or 12 months postpartum. ICIQ-UI = International consultation on incontinence questionnaire for urinary incontinence

Activity limitations and experiences of physical changes in the postpartum period

Paper IV-cohort showed that out of the 504 participants in the ABB-study, 297 experienced one to three activity limitations at 3 months postpartum. The most common limitation was high-impact activities such as running or jumping, reported by 244 participants. This perceived limitation persisted throughout the first year postpartum, with 41% of participants still experiencing it at 12 months. Other frequently reported limitations at 3 months postpartum included exercising (21%), lifting/carrying (13%) and walking (11%). By 6 months,

these limitations had decreased by 2–4%, and by 12 months, they were reported by only 5% of participants, with the exception of exercising, which continued to be limited for 12% of participants.

Pain, vaginal heaviness and urinary incontinence emerged as the most commonly reported reasons for activity limitations postpartum. Pain reached a peak at 6 months postpartum, causing 47% of activity limitations. Vaginal heaviness successively decreased as a cause of activity limitations, while urinary incontinence more than doubled as cause, accounting for over 26% of activity limitations at 12 months postpartum.

Paper IV-interview showed that women often found themselves surprised by and unprepared for the physical changes after pregnancy. They knew that a pregnancy would require some adjustment but they did not expect that the postpartum period would bring so many symptoms and limitations.

I wasn't prepared for it at all with my first child. I had read about and was prepared that it would be hard during pregnancy but I wasn't prepared ... yes, for that shock of having a child. (Interview 10)

The **surprising aspect of physical changes and time needed for recovery** was the overarching theme going as a red thread through the stories of the interviewed women. The analysis of the manifest content resulted in seven categories, presented in *Figure 21*.

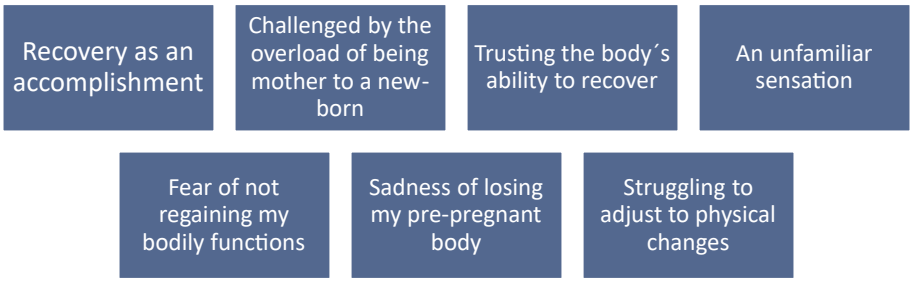


Figure 21. The seven categories resulting from the qualitative content analysis of the interview study.

The category "an unfamiliar sensation" described how the women found it hard to understand whether their symptoms were normal or not as they had never

felt anything like that before. A need for help and guidance to actively handle these unfamiliar changes was experienced. "Trusting the body's ability to recover" showed how the women felt great trust in their body's recovery and were able to adapt to its changes, while "Fear of not regaining my bodily functions" mirrored how they experienced that their body might be damaged after childbirth and were wondering whether it tolerated load, for example during exercising.

It [vaginal heaviness] doesn't hurt. It's definitely something I could, like, ignore ... I could go out for a run, it would just be a little uncomfortable, but uh, I'm afraid that I will injure myself and get problems ... like, for life ... (Interview 3)

Some physical changes had a great impact on daily life, which is shown in the category "Struggling to adjust to physical changes". The women felt they could accept short-term changes. During this period of change, they needed support from peers. Physical changes such as pain and incontinence can be impacted by factors such as sleep deprivation, stress and hormonal fluctuations, as mirrored in the category "Challenged by the overload of being mother to a newborn". Conversely, the women also experienced that pain shaped their first weeks as a mother.

"Sadness of losing my pre-pregnant body" described how the women mourned the loss of their body as it had been before and experienced a sadness that it might never be the same again. They also experienced that they suddenly felt abandoned by health care as all focus had shifted to the baby the moment they had given birth.

I felt "used up" after I gave birth. [During pregnancy] there was a lot of focus on me ... but as soon as the delivery was over, they just left me. (Interview 2)

"Recovery as an accomplishment" describes how the women felt stressed about the physical changes and the perceived need to get into shape again – both something they demanded of themselves and a pressure put on by others. At the same time they felt proud of the power of their body to give birth and heal. They compared their recovery with that of others, often online.

In summary, the women experienced a need to understand what is normal and whether the experienced physical changes would influence their future life, as shown in *Paper IV* and in *Figure 22*.

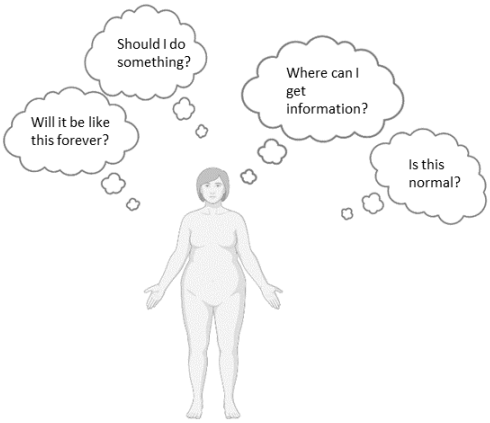


Figure 22. Examples of women's experiences of physical changes and recovery in the postpartum period.

Summary of the four papers: the physical transition to the postpartum body

The four papers in this thesis collectively demonstrated interrelated changes in bodily structures and functions, health problems (stress urinary incontinence, vaginal heaviness and pelvic girdle pain) and activity limitations during the postpartum period. *Paper II* showed that pelvic floor muscle weakness and a moderate-to-severe DRA width were associated with the severity of pelvic girdle pain. *Paper III* indicated that non-exercising was associated with weaker pelvic floor muscles, increasing stress urinary incontinence and no statistically significant changes in pelvic girdle pain severity during the first year postpartum. Concurrently, pain localized in the pelvic region, lower back, hips, and pelvic floor, as well as stress urinary incontinence, emerged as the most frequently cited reasons for activity limitations, as seen in *Paper IV-cohort*.

Many participants exhibited mild symptoms based on to earlier definition of symptom severity; 90% of those reporting pelvic girdle pain had values below 28 on the PGQ scale (0–100), and 52% of those reporting bothersome stress urinary incontinence had values below 6 on the ICIQ-UI scale (0–21).

Paper IV-interview revealed that postpartum symptoms are often unexpected and difficult to understand, as they have never been experienced before. Their perceived severity depended on many factors such as sleep, mood and energy

but also on requirements on the body. The women were uncertain whether their symptoms were normal and should be ignored, or whether they should do something about them. They were often concerned about the body's ability to withstand increased loads or the fear of pain recurrence, which can lead to further activity limitations.

In summary, this thesis indicates that even mild symptoms of pelvic girdle pain, stress urinary incontinence, and vaginal heaviness can give rise to activity limitations and reduced exercising, which could lead to further weakness and more pain and stress urinary incontinence as illustrated in *Figure 23*. These factors can be influenced by the experiences and concerns of the women for example fear of not regaining all bodily functions and the unfamiliarity of a bodily sensation.

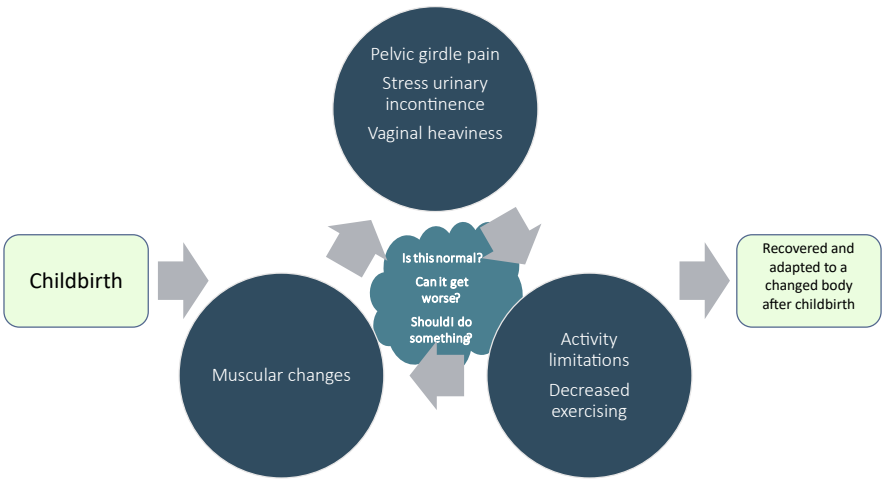


Figure 23. Summarizing how postpartum symptoms and muscular changes, but also the women's experience of and concerns about these, could influence the transition from childbirth to a changed but adapted body.

As shown in *Paper IV-interview*, trust in the body's recovery can help in adapting to physical changes after pregnancy, and many women do not need any help when transitioning to a postpartum body. However, those who feel uncertain about these changes may benefit from support and reassurance to actively engage in their recovery rather than becoming inactive. *Paper I* high-

lighted that primary care physiotherapists have several clinical assessment methods with moderate to good inter-rater reliability to assess muscular changes in the postpartum period. *Paper III* indicated that engaging in low-impact exercises can reduce symptom severity during the first year postpartum.

Discussion

This thesis contributes increased knowledge about how physiotherapists can help women in their physical transition to a postpartum body. Physiotherapists have clinical assessment methods with sufficient inter-rater reliability to assess pelvic floor muscle strength and an increased distance between the rectus abdominis muscles. These muscle functions have a predictive value for increased pelvic girdle pain severity which can be important in the treatment of these women. Moreover, women's engagement in low-impact exercising may be important in decreasing symptoms in the postpartum period. Providing accurate information and empowering individuals to actively manage their muscular changes and symptoms, rather than fearing future consequences, appears to be a vital aspect of the postpartum physical transition.

Urinary incontinence in the postpartum period

The overall symptom severity observed in this thesis, with a mean range of 6.2–6.4, falls within the lower range of what is classified as moderate urinary incontinence, defined as 6–12 (ICIQ-UI 0–21).[157] This is consistent with findings from other studies indicating that postpartum urinary incontinence tends to be mild to moderate.[158,165] An interview study[166] revealed that women often view urinary incontinence during and after pregnancy as an inevitable part of becoming a mother, coping with it rather than finding it bothersome. Even the participants of our interview study, presented in *Paper IV*, expressed their ability to adapt to this symptom and found it acceptable as long as it was not a permanent condition. By contrast, another study has reported that about 20–50% of postpartum women experience urinary incontinence as impacting their quality of life,[159] and their ability to participate in physical activities.[167] Incontinence can be both a social and an environmental problem, with 33% of women requiring pads during the first 3 months postpartum.[159] Moreover, as

shown in *Paper IV-cohort*, urinary incontinence was increasingly contributing to limitations in activity and participation during the first year after childbirth.

Considering the fact that urinary incontinence tends to escalate with age,[26] impacting both quality of life[168] and women's capacity to participate in physical activities and exercise,[169,170] it is important to treat and prevent it. *Paper III* showed that participants who performed minimal low-impact exercise experienced a slight decrease in symptom severity. However, this change fell below the minimal important change of 2.5 (ICIQ-UI 0-21),[145] and is probably not clinically significant. Nevertheless, in line with findings from other studies,[117] it shows that some exercising is likely more beneficial than inactivity in the context of treating urinary incontinence.

This raises the question of the physiological consequences of physical inactivity. As visualized in *Figure 23*, a sedentary lifestyle and the absence of exercise may contribute to muscular changes as for example weakening. A case-control study[171] showed that incontinent women had lower pelvic floor muscle endurance, but no difference in maximal voluntary contraction, compared with continent controls. Pelvic floor muscle training is a well-supported treatment for stress urinary incontinence, and this is backed by several studies.[172] However, in the postpartum period, this evidence is less strong, as shown by a Cochrane review.[173] Another systematic review[174] suggested that supervised and intensive pelvic floor muscle training might yield better results.[174] The clinical assessment presented in *Paper I* could play a vital role in supervised training, as many women have problems with correctly engaging their pelvic floor muscles.[175]

Furthermore, the association between low-impact exercises, such as walking,[169] and pelvic floor muscle endurance – rather maximal voluntary contraction[171] – and decreased urinary incontinence suggests that strengthening other pelvic floor muscle functions, and perhaps even muscle groups beyond the pelvic floor, could be important. We had originally intended to explore the relationships between other aspects of pelvic floor muscle function such as pelvic floor endurance and involuntary contraction, and stress urinary incontinence. However, this was hindered by concerns about the accuracy of these assessments, related to their lower inter-rater reliability. In future studies, more objective measurements such as perineometre or EMG should be used to complement and confirm results obtained through vaginal palpation. Moreover, other muscle groups engaged in walking should also be assessed. An experimental study[176] revealed that women with stress urinary incontinence

had weaker and less flexible hip muscles compared with asymptomatic women. However, this study was not conducted during the postpartum period, and it remains unclear whether the reported weakness resulted from reduced physical activity due to urinary incontinence, as observed in *Paper IV-cohort*, or whether urinary incontinence arose from pre-existing weakness, necessitating further investigation.

Vaginal heaviness in the postpartum period

Vaginal heaviness was experienced by almost 30% of the included women at 3 months postpartum, and only by half as many at 12 months postpartum. Neither of the two hypotheses described in the Introduction,[117] namely, that exercising could help reduce pelvic floor problems through reflexive activation or that exercise could worsen pelvic floor problems by overloading the already weakened structure, could be confirmed. *Paper III* indicated that changes in vaginal heaviness were not associated with exercising. This is line with other studies about early exercising after pregnancy, which found no association between exercising three times a week and pelvic organ prolapse[177] or between moderately high-intensity exercising and bothersome pelvic floor symptoms.[165] Nonetheless, while exercise does not appear to significantly impact vaginal heaviness, it is essential to recognise that vaginal heaviness itself can lead to various activity limitations and can be a source of insecurity and concern due to its unfamiliar sensation, as seen in both the free text answers and interviews, reported in *Paper IV*. Women were apprehensive about this sensation, fearing bodily harm, and thus avoided certain activities. It has also been highlighted as a barrier to resuming running in other studies.[37,38] Even, in these studies,[37,38] information about vaginal heaviness was collected by simple questions or free-text answers.

As highlighted in the Introduction, the link between postpartum vaginal heaviness and pelvic organ prolapse remains uncertain. In *Paper IV-interview*, it was described as a sensation of weakness, as if the pelvic floor muscles were not providing enough support. To enrich this discussion, a Chi-square test (not published or presented in the Results) was conducted. This preliminary data showed that participants with vaginal heaviness have significantly weaker pelvic floor muscles at 3 months postpartum ($p < 0.01$) (*Table 7*), which could support this hypothesis and even the proposed cycle of decreased exercising, weakness and increased symptoms shown in *Figure 23*. This data analysis needs further development and control for confounding factors.

Table 7. Cross-tabulation of vaginal heaviness score ≥2 and pelvic floor muscle strength≥3.

		Pelvic floor muscle strength, n		Total, n
		<3**	≥3**	
Vaginal	<2*	154	198	352
heaviness, n	≥2*	83	59	142
Total, n		237	257	494

*reported on an ordinal scale (0-4), **rated on a modified oxford scale(0-5), n = number

Vaginal heaviness could also be associated with unnoticed pelvic floor tears,[38] potentially explaining its persistent occurrence in 14 % of participants (*Paper III*). For instance, levator ani muscle tears can remain concealed, with a prevalence of 19 % at 6 weeks and a subsequent 50 % reduction at 12 months postpartum.[178] A detailed discussion of pelvic floor tears and, specifically, levator ani muscle tears, was not within the scope of this thesis and more research about the frequently reported symptom of vaginal heaviness, its clinically relevant cut-off points and its relation to weakness and pelvic floor tears is needed.

Our result regarding vaginal heaviness should be approached with caution due to the absence of a measurement method tested for its reliability and validity for this symptom. Moreover, the choice of cut-off was solely based on clinical experience. In our observations, we noted a prevalence of vaginal heaviness ranging from 14 % to 30 %. By contrast, another study focusing on postpartum runners reported a higher prevalence of vaginal heaviness, reaching 27−34 % at 1 year postpartum.[38] This higher prevalence can be related to more vaginal heaviness during running; it can also be related to the reason that we excluded participants who answered "seldom" to the question on frequency of vaginal heaviness. Even seldom vaginal heaviness could influence activity and exercising.

Pelvic floor muscles in the postpartum period

Paper I demonstrated the complexity of assessing pelvic floor muscle function in primary care settings. The assessment of MVC using an adapted version of the modified Oxford scale showed higher inter-rater reliability in our study than it did in previous research, $\kappa = 0.33$[63] and $\kappa = 0.37$.[62] An additional study,[179] found after *Paper I* had been published, reported even higher inter-rater reliability for MVC ($\kappa = 0.78$) compared with our study, also using the lifting criteria for MVC ≥3 which may be the important component of the scale.

The same study[179] also demonstrated higher inter-rater reliability for involuntary contraction by palpation ($\kappa = 0.71$) and voluntary relaxation ($\kappa = 0.68$) compared with our reliability study. An exploratory EMG study,[180] which evaluated the reflex activity of pelvic floor muscles during forceful coughing, highlighted the importance of precise cues because of significant individual variations in coughing patterns. They suggested using instructions such as "cough as hard as you can" to standardize coughing. As we only instructed our participants to cough forcefully, the variance in how they coughed may have biased our results.

The assessment of voluntary relaxation showed fair inter-rater reliability in our study which is consistent with one previous study.[66] In 2022, a review[181] highlighted the lack of consensus in defining "pelvic floor muscle relaxation", "muscle tone" and "increased tension", potentially contributing to the difficulties to clinically rate these functions or conditions. Muscle tone measures passive resistance to stretching, while voluntary muscle relaxation involves active, conscious relaxation. Another systematic review[182] by the same research group revealed that clinical assessments of both, pelvic floor muscle tone and relaxation, are subjective, displaying low inter-rater reliability. Knowledge about patients' pain and dysfunction often influences assessors and can lead to overestimation of muscle tone.[182] However, whether blinding to symptoms while assessing muscle function is sensible still needs to be discussed. Worman et al.[182] discuss the importance of standardization; for example bladder urine volume can influence the ability to relax. This was not considered in our study. It could also be important when assessing pelvic floor muscle in the clinical context. Moreover, the clinical context of assessing the ability to relax while being vaginally palpated on an examination plinth has to be questioned.

Regarding clinical relevance, it is important to note that *Paper I* was solely focused on inter-rater reliability. Slieker-Ten Hove et al.[66] demonstrated that intra-rater reliability in assessing pelvic floor muscle function, especially regarding involuntary contractions and voluntary relaxation, is notably higher. This suggests that clinical assessments by the same physiotherapist could be valuable for women seeking reassurance and advice during their postpartum recovery, as seen in *Paper IV-interview*. Moreover, clinical observation of voluntary contractions could be a viable alternative, exhibiting moderate inter-rater reliability in our study and showing 100% agreement if rated by the same physiotherapist.[66] This is particularly valuable when vaginal palpation is not desired or possible. An interview study on postpartum urinary incontinence

indicated that the thought of being palpated internally can be a barrier to seeking help.[166]

The ABB-study gave an overview of changes in pelvic floor strength from 3 to 12 months postpartum in 504 women. While an observational study cannot definitively establish the typical course of pelvic floor muscle strength changes postpartum, it does provide an overview of a possible trajectory of pelvic floor muscle strength changes in the postpartum period. We observed that pelvic floor muscle strength is increasing during the first year postpartum. This in in line with other studies[43,183] about the recovery of pelvic floor muscle strength after childbirth. Elenskaia et al.[183] used, as we did in our study, the modified Oxford scale to assess pelvic floor muscle strength, and used a perineometer to objectively confirm their results. Both studies[43,183] also collected data about pelvic floor function during pregnancy. One showed[183] that, 12 months postpartum, most women achieve the same strength as in pregnancy, regardless of mode of delivery, while the other[43] showed that women who gave birth vaginally remained weaker at 12 months postpartum compared with their mid-pregnancy strength level. The lack of assessment prior childbirth restricts our ability to discuss pelvic floor strength recovery; we could only observe changes in the postpartum period.

In *Paper III*, we observed increasing pelvic floor muscle strength in all exercise groups during the first year postpartum. This raise in strength was not influenced by any specific type or frequency of exercising. This finding aligns with a comparable study,[177] demonstrating that pelvic floor muscle strength improves during the first postpartum year, regardless of exercise participation. These results can provide reassurance to women who may harbour concerns about pelvic floor muscle weakness and are scared to cause more damage to their pelvic floor when they start exercising, as observed in *Paper IV-interview*.

Pelvic girdle pain in the postpartum period

Paper II showed that weaker pelvic floor muscles were associated with increased pelvic girdle pain severity; even DRA width ≥35 mm showed this association. A DRA width ≥35 mm can be associated with weaker abdominal muscles, as several studies have shown.[86,91,92] This may explain its association with pelvic girdle pain severity at 3 months postpartum. When interpreting *Paper II's* results, it is crucial to acknowledge that the predictive values of these muscle functions were either below or borderline to the minimal important change for the PGQ scale, which is 6 (PGQ 0-100). However,

several studies have discussed the association between pelvic girdle pain and not only muscle weakness but also muscle tension and altered activation patterns in both the pelvic floor and abdominal muscles, as described in the introduction.[81,83-85] The force closure mechanism[77] is a complex collaboration of several muscle groups that have to work concentrically and eccentrically to allow optimal load transfer. Assessing this can be challenging in primary care physiotherapy because of the subjectivity of our assessment method. A combination of several tests is recommended.[184] In this thesis, we only found two clinical assessment methods with good inter-rater reliability, which does not allow any complex hypotheses about altered muscle control. However, the tested assessments were clinically feasible and could play an important part in a set of assessment methods for this patient group.

Paper III indicated that non-exercisers had weaker pelvic floor muscles and increased pelvic girdle pain severity. This could lead to the hypothesis that pelvic girdle pain is, at least partly, a result of decreased physical activity and exercising which can result in muscular changes such as weakness (as visualized in *Figure 23*). Psychosocial factor such as fear of pain recurrence after activity and the sensation of instability and weakness, as shown in *Paper IV-cohort and interview*, could add to this cycle. Other research, too, has shown that women with pelvic girdle pain avoid movement and activities due to the pain.[185] Further research is needed to evaluate whether encouragement to engage in, and adaption of, physical activity and exercising during pregnancy and soon after childbirth can prevent persistent pelvic girdle pain after pregnancy.

Papers II and *III* showed the challenges to evaluate changes in self-reported pelvic girdle pain when symptom severity is mild. The median PGQ score, without using cut-off points, was 14.7 (range 1.3–58.7) at 3 months and 10.6 (range 1.3–62.3) at 12 months. This low level of pain severity and disability was also noted in other studies using questionnaires to assess pelvic girdle pain,[70,186] but also in a study confirming pelvic girdle pain with provocation tests.[79] A review[68] showed that of the 25% of women who experienced pelvic girdle pain postpartum, more than 70% had mild pain. Sjödahl et al.[79] argue that healthy young women should ideally have a score of zero for pain and disability. However, Robinson et al.[70] have shown that women who report postpartum pelvic girdle pain actually exhibited fewer functional disabilities than their matched controls.

This raises the question of whether these minor issues require treatment, as it remains unclear whether the reported pain represents a condition to which women have adapted, making them less consciously aware of its intensity and functional limitations, or whether it is merely a discomfort.[70] In the former case, early intervention for pelvic girdle pain would be crucial to prevent long-term activity limitations in women. Persistent pelvic girdle pain for 11 years postpartum can have a severe impact on the daily life of an affected woman.[187] Moreover, pregnancy, childbirth, and back pain during this period were seen as risk factors for the development of functional back pain in later stages of life.[188] Zhang et al.[188] recommend early interventions during and after pregnancy and describe this time period as a "teachable moment" in which health care providers have a good opportunity to prevent long-term problems.

This thesis showed that even participants with less severe pain reported limitations in walking, running, carrying out sports activities, and carrying objects. *Paper II* indicated that participants with a PGQ score <28 showed no statistically significant decrease in pain during the first year postpartum. Pain was the main reason for perceived activity limitations, as shown in *Paper IV-cohort*. Taking a closer look at the PGQ scores in the ABB study, participants with PGQ scores between 10 and 27.99, the median for PGQ activity scale (15, IQR 9.1) was lower than the median for PGQ body function scale (20, IQR 10.21). By contrast, those with milder pain (PGQ score <10) and those with middle to high pain (PGQ ≥28) showed no differences between these two scales of the PGQ.

This suggests that a subgroup of women with milder pain, as in the definition of Stuge et al.,[141] may have adapted to their pain by moving slowly or accepting some evening or morning pain but no longer perceiving limitations in their activity. As shown in *Paper IV-interview*, women adapt to the changes in their body and find acceptance for them as long as they think the changes will not be forever. They hope that the problem will solve itself over time. Another qualitative study likewise reports that women try to ignore the pain and go on with their daily lives.[189] The work of physiotherapists is not only to treat pain but also to restore functioning.[23] An important next step is to evaluate how much this mild but persistent pelvic girdle pain influences women's health in the long term regarding activity and participation limitations.

Diastasis recti abdominis in the postpartum period

Among the three clinical assessment methods assessed in *Paper I*, DRA width measurement exhibited good inter-rater reliability, while the other two demonstrated moderate inter-rater reliability. It is important to note that variations were observed among the three rehabilitation centres in assessing DRA depth and bulging.

The good inter-rater reliability for caliper measurements aligns with a study[98] employing the same caliper positioning and measurement points as presented in *Paper I*. However, the challenges we discussed in *Paper I* regarding standardizing assessment positions and caliper use were not discussed in that study. Neither did its authors mention their rationale for using the outside jaws of the caliper, in contrast to another study[101] that used the inside jaws but faced difficulties accurately positioning them at the muscle-tendon junction. We tested both approaches and concluded that the rounding of the outside jaws will fit better into the muscle-tendon junction (see *Figure 24*), added to the fact that this positioning causes less discomfort to women. However, considering the much higher SEM and MDC in our study compared with others,[98,101] this approach needs further evaluation.

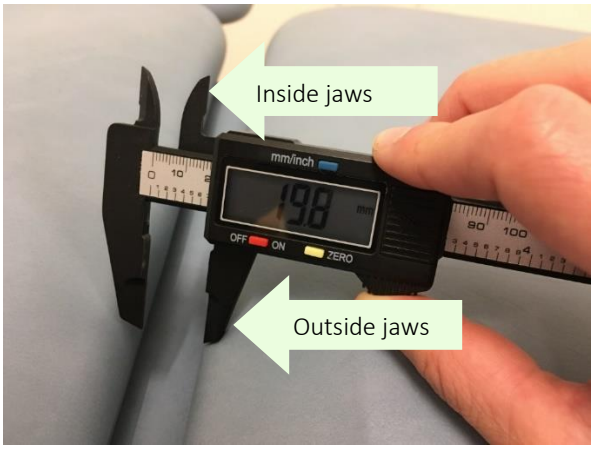


Figure 24. The inside and outside jaws of the caliper, own picture.

In line with our study, Chiarello& McAuley[101] report that the measurement point 4.5 cm below the umbilicus is difficult to measure, showing lower agreement with ultrasound and a wide SEM. As the inter-recti distance is the widest at the umbilicus, as has been shown in several studies,[90,190] and this is

the measuring point with the highest reliability and validity, it is probably the one which should be measured in clinical practice and research.

Moreover, the clinical relevance of measuring DRA width has to be discussed. Our mean DRA width values, as depicted in *Figure 18*, fall within the normal range outlined by Mota et al. (mean 23.8 ± 7.3, at 3 months postpartum).[90] Mean values in multiparous women slightly exceed this range, which is in line with another study on normal values.[95] In *Paper II*, we identified a potential cut-off point for DRA width related to pain. The dichotomous variable DRA width ≥35 mm predicted increased pelvic girdle pain severity in participants who reported pelvic girdle pain. This cut-off point was chosen based on a previous study,[105] but mainly because another research group with a comparable cohort study used it.[91] However, this cut-off point has not been tested for its lower and upper limits, and *Paper II* is, to the best of my knowledge, the first to indicate its association with pain. Our results may be called into question because we observed participants with DRA width ≥35 mm even in the pain-free group, with no statistically significant difference between the groups, which is in line with other studies.[91,95] Tuominen et al.[95] advocate having larger cohort studies because of the rarity of moderate to severe DRA. Another option would be to pool data from different cohorts.

Regardless of pain and dysfunction, abdominal healing can be a concern for women during and after pregnancy. However, *Paper IV-cohort* showed that only a small number of women from the ABB-study reported DRA as a cause of activity limitations. By contrast, in *Paper IV-interview*, women expressed concerns both about the appearance of their abdomen and about DRA as a contributing factor to weakness and pain. This aligns with previous research[191] indicating that women are primarily concerned about the appearance of their abdominal wall, but also that they tend to associate visible bulging or deformation with abdominal weakness.

Paper IV-interview showed that women wanted to understand whether the changes they perceived in their body were normal. The study also showed that they felt pressured by themselves and by society to recover quickly. *Paper III* showed that DRA width decreased during the first year postpartum, regardless of exercise type and intensity. A limitation in our study is that the observed decrease was below the MDC of 1.2 cm. However, our findings are supported by another study which also indicates a progressive reduction in DRA width during the first postpartum year.[190] Fewer than 2% of women have a moderate to severe DRA at 12 months postpartum.[89] Given the SEM ranging from 4 mm

to 5 mm and an MDC of 1.2 cm, as seen in *Paper I*, caliper measurements could serve as a screening tool for identifying moderate to severe DRA, rather than aiming for precise distance measurements. As DRA width in general does not seem to be impairing,[93] a higher degree of precision may not be important. Considering the concerns about normalcy in postpartum women, we propose using the term "increased inter-recti distance" rather than "diastasis recti abdominis" in these assessments as long as the condition is not linked to pain or disability.

When *Paper I* was published, there were, to our knowledge, no comparable studies about the clinical assessment of DRA depth and bulging. However, a recent study revealed that approximately 21% of women, 6–8 months postpartum, experience a bulge or protrusion in their linea alba.[191] In our own cohort, during the initial 9 months similar rates, of 12-21% were recorded for bulging. The same research group[192] showed a sink-in movement, which may correspond to a bottomless resistance in DRA depth, in 10% of women with a DRA, which we observed in 12%. However, as our assessments showed just moderate kappa values in *Paper I*, we cannot talk about a "true" prevalence here.[150] More research is needed about the question whether these parameters are comparable, as well as how to assess them clinically and how they are related to function.

Exercising in the postpartum period

As described above in the symptom and muscle-specific sections, this thesis indicates that low-impact exercising is beneficial rather than harmful, even in the first 3 months postpartum. In sport rehabilitation, the early re-engagement of muscles for a better recovery is well established.[118] The critical question is, What is the optimal load required for postpartum recovery? Existing research suggests a potential risk of overloading, as evidenced by associations between daily heavy lifting and an increased risk of pelvic organ prolapse postpartum,[177] as well as between moderate to vigorous intensity physical activity at 6 months postpartum and decreased pelvic organ support.[193] Shaw et al.[193] concluded that, in view of what we know today, we should recommend light physical activity to postpartum women to replace inactivity, and more research needs to be conducted about more intensive physical activity. This aligns with our results that low-impact exercising is associated with symptom reduction. However, we cannot make any conclusions about high-impact exercises because our analysis of 32 high-impact exercisers lacked sufficient statistical power.

Paper IV-cohort supports the need for more research about high-impact exercising as this is the most limited activity in the postpartum period, for over 40% of participants at 12 months postpartum. Others studies[37,194] have confirmed the difficulties in resuming high-impact and resistance exercising after pregnancy because of symptoms such as stress urinary incontinence, vaginal heaviness, pain and the insecurity about being ready. About 25% of recreational runners do not resume running for these reasons.[37] The resumption of high-impact exercising postpartum is an important research field as women may stop running during and after pregnancy despite the fact that high-impact activity is important for women's bone health.[195]

The physical transition in the postpartum period

The postpartum period is a period of change and this thesis shows that women often have a mix of several symptoms during this time. *Paper IV-interview* shows that women's acceptance of those changes depends a lot on whether they are seen as transitory, and whether the women can shift focus to other activities and adapt to the limitations. Obstacles were that women did not know what to do, whether their symptoms were normal, and where to find the right information and help. Our study population were highly educated and all spoke Swedish; however, we could see high concordance with another study[122] which included participants with lower levels of education (30% without a college degree) and a diverse racial and ethnic composition (39% Black/African American and 30% Hispanic/American).

Paper IV, both cohort and interview, had an inductive analysis design. Nonetheless, comparing its results about the physical transition to motherhood with existing studies, we observed similarities with a model described by Barimani et al.[196] rooted in Meleis' transition theory.[197] This model showed that a healthy transition to the postpartum period is facilitated by perceiving change as a natural part of life and having a robust social network and professional support. Even our participants expressed the need for support from family, friends, and professionals. They expressed that the uncertainty about whether things should be this way and if they would improve, made it challenging to cope with these changes. In the transition model,[196] reasons for difficulties in the transition to motherhood were described as wrong expectations, stress, the sensation of losing control, and the absence of professional support.

The surprising nature of physical changes after pregnancy are in line with other studies.[122,198,199] To address this, it should be discussed whether and when information about these changes could be helpful. Martin et al.[122] proposed providing educational information in the third trimester, distributing checklists and verbal and written information similar to the information patients get before surgery. However, participants of the interview study (*Paper IV*) expressed that antenatal information might create unnecessary concerns. An alternative approach would be to have an early postpartum consultation. This notion is supported by a study[200] indicating that women seek support during the initial weeks postpartum, as they have numerous questions about their physical changes, even if these are minor. Consistent with *Paper IV-interview*, that study[200] showed that women's primary concern was to establish the normalcy of their experiences.

Consulting with patients to assess the normalcy of their experiences aligns closely with an initial observation that lead to this thesis. Some women are seeking physiotherapy postpartum, even when they have either no symptoms or objectively measured minor ones. The question is whether these consultations would fall under prevention and health promotion. Fahey & Shenassa[13] published a health promotion model that advocates shifting postpartum care from symptom screening and treatment towards promoting women's health. This includes helping them find social support, enhancing their self-efficacy, aiding in coping mechanisms, and fostering realistic expectations.

This thesis shows that some women may need this health promotion, that even with mild symptom severity they can experience activity limitations and struggle to adapt to a new body. There is a need to evaluate whether physiotherapy consultations could help to find trust in the body's recovery, find suitable exercise solutions and prevent sliding into the cycle of inactivity, weakness and pain.

Methodological considerations

This thesis encompasses two studies, both of which exhibit methodological strengths and weaknesses, which will be discussed in this section. Both a quantitative and qualitative research was used in this thesis. The aspects of scientific rigour and trustworthiness (see Lincoln & Guba[201]) in these two study designs are presented in relation to each other in *Figure 25*. These aspects will be discussed further below, starting with the quantitative study.

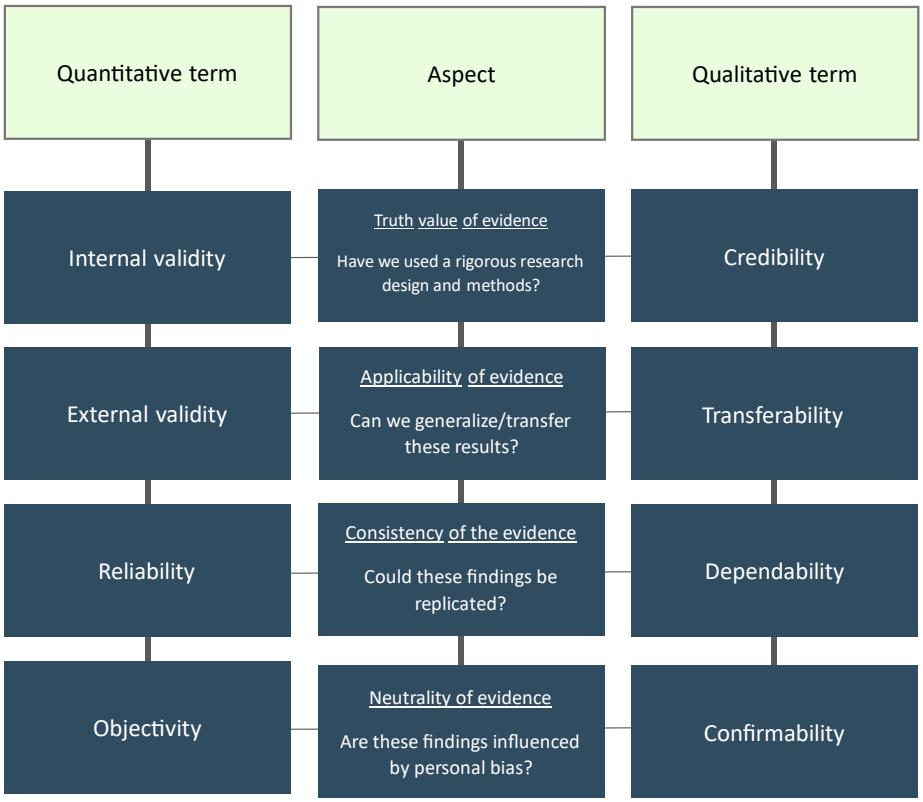


Figure 25. Different aspects of scientific rigor and trustworthiness in quantitative and qualitative research

Methodological considerations- ABB-study

Internal validity: The internal validity of an observational study depends on the selection of participants, the power calculation and the drop-out rate, but also on the quality of the assessment and instruments used.[202] Incorrect or unstable measurement methods can bias the results of a study.[153]

In the selection of the patient-reported instruments, we focused on using outcome measures that were tested in a postpartum population with acceptable to high reliability and validity. For the assessment of pelvic girdle pain, our task was relatively straightforward, as the PGQ was tested in a postpartum population,[137] validated and culturally adapted to Swedish speakers.[138] In a recent systematic review,[139] it was recommended as outcome measure to assess pain frequency, intensity and severity and activity limitations in patients with pelvic girdle pain. However, during the process of publishing *Paper III*, we

became aware of a difference between the Swedish version and the original version of the PGQ,[138] the Swedish questionnaire asking about the ability to walk longer than 10 minutes instead of 60 minutes as in the original questionnaire.[137] Subsequently, we conducted extra data analyses to evaluate the impact of this change. These analyses indicated that including or excluding this item did not significantly alter our results. However, it is essential to note that the study may have underestimated the severity of pelvic girdle pain since it did not capture individuals' difficulties with walking for longer than 60 minutes

The ICIQ-UI is the International Continence Society-recommended outcome measure for assessing urinary incontinence.[27] However, at the start of this thesis it lacked specific validation in postpartum cohorts. While there is now one study on the ICIQ-UI's psychometrics in postpartum women,[143] data regarding the minimal important change in this population are still lacking. Reviews have highlighted the lack of validated instruments for postpartum pelvic floor disorders such as urinary incontinence[203] and other symptoms, such as the vaginal heaviness/bulging.[204] The reliability and validity of the question used in this thesis concerning vaginal heaviness have not been assessed, warranting cautious interpretation of these findings.

Using the Norwegian Mother, Father and Child Cohort Study (MoBa) questionnaire may have introduced bias into our results because assessing physical activity and exercise through self-reporting is challenging. A systematic review,[205] has shown that the correlation between self-reported questionnaires and objective measures is low and that there is no superior questionnaire to assess exercising. Self-reporting carries the risk for recall bias, as participants may not accurately remember their exercise level. Nevertheless, exercise questionnaires remain a crucial component of research,[205] and researchers should carefully select the questionnaire that best aligns with their research objectives. In this thesis, it was important to use a questionnaire that assessed various types and frequencies of training, such as the MoBa questionnaire. This questionnaire had previously been used in two comparable studies.[177,206]

In the ABB Study, the clinical assessment methods for muscular changes were assessed solely for inter-rater reliability. While evaluating inter-rater reliability is an important step, the Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN) checklist[153] recommends that validity and responsiveness should also be tested. An instrument can have good inter-

rater reliability but may still not be measuring what it is intended to measure. To avoid results based on unreliable assessment methods, only the clinical assessments with the highest inter-rater reliability were used as predictors in *Paper II*. However, the results regarding the prediction of involuntary pelvic floor muscle contraction and DRA bulging on pelvic girdle pain severity should be interpreted with caution and require confirmation by further research after refining the assessment methods.

Moreover, the dichotomisation of ordinal and continuous scales, such as for MVC ≥3 and DRA width ≥35, as well as the use of cut-off points for pelvic girdle pain and vaginal heaviness, warrant discussion. Dichotomisation can lead to a loss of information as it obliterates the distinctions between different steps of the scale.[207] For instance, in *Paper II*, the predictive value of MVC ≥3 on pelvic girdle pain severity was below the minimal important change, this prediction might have been higher without the dichotomisation of the scale. Furthermore, the choice of cut-off can impact the results. In our study, the selected cut-off point PGQ ≥28 was based on a previous study,[141] while PGQ ≥10 and vaginal heaviness ≥2 were informed by clinical reasoning and explorative data analysis. Dichotomisation of MVC was necessary for the mixed-effect models of repeated measures, as over 75% of the participants exhibited an MVC of 2 or 3. The dichotomisation of DRA width was conducted to answer the research question of whether a more severe DRA was associated with higher pain levels. However, both cut-off points were exploratory and necessitate further evaluation. To prevent a loss of power, these cut-off points were not used when MVC and DRA width were outcomes in *Paper III*.

Our power calculation is the final aspect that needs to be discussed regarding the internal validity of this study. A power analysis is a calculation of the probability that the researcher will avoid a Type II error (fail to reject the null hypothesis), which is important when comparing different treatments.[208] Including too few participants can result in non-detection of the fact that there is a statistically significant difference, which is possible in the high-impact exercising group. Including too many participants is an ethical problem as it exposes people to unnecessary assessment and questionnaires and spends research resources which could go to other research instead.

We initially estimated that approximately 500 participants would be required to detect a 20% difference in pelvic floor muscle strength between 3 and 12 months postpartum. However, our initial power calculation was based on three exercise groups instead of four, and our estimated drop-out rate of 10% was

nearly doubled to 18.7%. The higher drop-out rate can be explained by the ongoing COVID-19 pandemic which started during the course of the study. The splitting of the low-impact exercise groups was caused by challenges in estimating how many participants would resume exercising, the type of exercise they would choose, and how frequently they would do it, primarily because of the lack of prior research. This led to an imbalance in the number of participants engaging in low-impact exercise and too few participants engaging in high-impact exercise. An accurately powered study with even groups as in a randomized controlled trial (RCT) or matched-control study is needed to further detect the effects of exercising on postpartum changes.

Moreover, the double assessments for *Paper I* had to be minimized for practical reasons. The power analysis in reliability studies aims to achieve higher inter-rater reliability than seen in previous studies.[150] However, our aim was not to demonstrate superiority over previous studies, but, rather, to assess the reliability of the clinical examination methods adapted for this thesis, both with the overall purpose to give clinical recommendations and to identify which parameters could be used for *Papers II* and *III* of our research.

External validity: External validity concerns the question whether the results are generalizable; in many respects, this question can be answered in the affirmative, as body mass index (BMI), mode of delivery, and parity in our population aligned with those of the entire 2019 childbirth population in Region Västra Götaland. Hence, the included group closely mirrors women typically seeking primary care physiotherapy.

However, the included group were older and had higher education than a comparable population. Data regarding ethnicity were not collected, but the inclusion criteria requiring proficiency in Swedish effectively excluded mothers with language skills other than Swedish. A Finnish study showed the underrepresentation of lower-educated individuals in health survey studies, a trend that is on the rise[209] Comparable cohort studies to our own also included predominantly highly educated persons.[40,106,177] A systematic review in the US demonstrated associations between lower educational levels, difficulties comprehending healthcare providers, and reduced utilization of postpartum health care.[210] This may only be partially applicable to Sweden, as the absence of health insurance can be a concern in the US (but not in Sweden). In Sweden, nearly 90% of women attend postpartum check-ups;[211] however, even in this study, lower-educated women may have been underrepresented. Considering that low educational level is a risk rather than a protective factor for the studied

postpartum problems such as pelvic girdle pain,[154] and, further, that low income is a risk for urinary incontinence,[212] it is important to include these women in future studies to enhance external validity.

In *Papers II* and *III*, we evaluated symptoms such as pelvic girdle pain, stress urinary incontinence and vaginal heaviness. Our cohort study did not target a specific group of people with specific symptoms but, rather, included individuals who reported them within a generally healthy group. This approach aimed to include a sample representative of those typically seeking primary care, including individuals with varying symptom severity and also individuals concerned about physical changes. Nevertheless, this is essential to acknowledge when interpreting the results about symptom severity and changes and comparing our results or generalizing them to other patient groups with these symptoms.

Moreover, the absence of clinical testing in the assessment of pelvic girdle pain should be discussed. According to the European guidelines[67] pelvic girdle pain should fall within the specific boundaries defined in the guidelines. To address this, we included a picture showing characteristic pelvic girdle pain locations in the questionnaire, also recommended by several other experts in the field.[154,213] However, the guidelines[67] also recommend confirming pelvic girdle pain by clinical testing. The focus in this thesis was on a pelvic floor and abdominal muscle assessment that could feasibly be done in a 30-minute appointment in primary care, but we have to acknowledge that the clinical confirmation of pelvic girdle pain would have strengthened the external validity for patients with pelvic girdle pain. This also applies to the risk that participants misinterpreted "pelvic floor pain" as pelvic girdle pain when completing the PGQ since the pelvic floor is in the same area as the characteristic pelvic girdle pain locations shown in the picture.

Reliability: Beside of the question about vaginal heaviness, only published questionnaires were used in this study. Detailed descriptions of the clinical assessment methods, illustrated with figures and pictures, were published in the supplementary material. For example, the pilot phase and clinical reasoning for the caliper measurement were described in detail in Supplement 1 to *Paper I*. Even *Papers II–IV* are supported by supplementary materials, giving more background information about the study population, the questionnaires and the data analysis to make our study as replicable as possible.

Objectivity: The data collection was solely performed by the six assessing physiotherapists, except for some sickness-related exceptions, and through electronic questionnaires. The assessing physiotherapists were blinded to each other's assessments and to the participants' symptoms throughout the study. They used standardized assessment protocols. However, they were not blinded to the postpartum phase, i.e. they knew whether the participant was 3, 6, 9 or 12 months postpartum, which may have affected their rating of pelvic floor muscle strength and assessment of DRA width.

Moreover, they were not blinded to the participants' delivery mode as they assessed both pelvic floor and abdominal muscle. Even this may have affected their objectivity in assessing pelvic floor muscle function. Nor was it possible to blind the participants. They knew that we wanted them to contract as strongly as possible. Their attitude to the study and the fact that they had their baby present during the assessment may have influenced their motivation and ability to contract and relax. While such factors can affect the results, they reflect real-life assessments, enhancing the study's external validity.

Methodological considerations- qualitative interview study

Credibility: The credibility of a qualitative study depends on whether the participants are able to give relevant information on the research question.[214] A purposive sampling technique was used to find participants who had different experiences of physical changes and recovery after childbirth. Additionally, the utilization of two different datasets allowed valuable comparisons, highlighting that numerous concerns and reasons for activity limitations were echoed in both the quantitative and the qualitative data.

A reason for reduced credibility was my inexperience in conducting research interviews, which may have affected my proficiency in this regard.[215] However, the interview process was overseen by my supervisors with several years of experience in this method. This supervision included evaluating the interview guide and listening to the pilot interview, after which guidance and suggestions for improving the interview technique were provided. Moreover, a semi-structured interview guide was used to stay focused on the research question, at the same time allowing to explore new ideas and thoughts that came up during the interviews.[216] Furthermore, a strategy to enhance credibility called "prolonged engagement" was used, which involved asking several follow-up questions, and encouraging participants to give examples to enrich their narratives.[214]

A source of decreased credibility was my pre-understanding of the women's experience, based on experiences from the quantitative study and work experience as a clinical physiotherapist. These factors may have influenced both the interview technique and my objectivity when analysing data. To counter this risk, the differences between an anamnestic interview and a qualitative interview were discussed with the supervisors. For the data analysis, investigator triangulation was used,[214] which means that my main supervisor and I independently from each other coded three interview texts and compared the results. Moreover, the process of finding categories and sub-categories was supervised by my main supervisor; and this process was checked for its credibility by the rest of the research group, all with several years' experience in conducting qualitative research. Member check, a method allowing participants to verify the analysis results,[201] was not feasible due to data security constraints that prevented sending the transcribed texts by post or email.

The credibility of a qualitative study also relies on the amount of data collected. It was important to ensure that enough information was collected to comprehend variations in the studied phenomena.[162] As described in the Methods section, qualitative studies do not include a power calculation. However, determination of the number of conducted interviews cannot rely solely on a subjective estimation. In qualitative research, "data saturation" and "information redundancy" indicate when to stop data collection.[130] This means collecting data until repeated narratives emerge, signifying understanding of participants' experiences. Malterud et al.[130] offered a guide for estimating informational power, without specifying sample numbers, emphasizing that numbers of participants has not to be predefined. Another guide[216] highlighted that the key to a sufficient sample size is the richness in the individual interviews. In our study, we took these guidelines into account and reached "information redundancy" after 14 interviews. By the 12-13th interview, the experiences of physical changes and recovery were familiar, echoing previous interviews, even though the women described different symptoms and changes. Notably, already, our pilot interview provided a profound insight into the experience of physical changes and recovery, only three interviews were less detailed and informative.

Transferability: Qualitative research focuses more on exploring and understanding the experiences of a specific group than on providing knowledge for a broad population. However, it should still be transferable to groups with similar problems or to a similar clinical context.[214] We encountered similar

challenges as in the ABB-study, as we, despite of extensive attempts, were unable to secure sufficient participation from women with a lower educational level or a different cultural background. However, we provided an as detailed description as possible of the participants, recruitment strategy, and study setting, without risking data security. This detail aims to equip readers with crucial information to assess the applicability and transferability of our study results to their respective cohorts.[214]

Another aspect in this section is that some participants of *Cohort 2* were affected by the COVID-19 pandemic. We recruited women 3–12 months postpartum in autumn 2022, which means that some of them had given birth in winter-spring 2021. During this time, both society and health care were still affected by the pandemic, which may have influenced the participants' experience of support needed and their information about family and friends as well as health care professionals.

Dependability: The dependability of a study depends a lot on the accuracy of the researcher in the process of coding, and of finding subcategories and categories. Graneheim, Lindgren & Lundman[162] describe that codes and supporting quotes should only fit into one category and that the same level of abstraction and interpretation should be used in each analysis step. They also highlight that this process can be challenging, and on occasion, codes may manifest at a higher level of abstraction compared to subcategories.[163]

The level of abstraction and interpretation in the different steps of the analysis can influence the results.[163] If the research question is to describe a concrete phenomenon, this level should be low. However, with our intention of reaching a deeper understanding of women's experience of postpartum changes, the level of abstraction and interpretation in our study had to be high. This implies the risk of becoming too high, making the results generalizable to all patients in transition periods or with long-term pain, for example, and no longer being specific to the postpartum period. To avoid this the results were discussed in the research group with diverse experience of qualitative research about transition periods, pain and postpartum changes. To ensure dependability, the different steps of the analysis process were documented. An example of the analysis process is presented in *Figure 12* and some supporting quotes are provided in the supplement to *Paper IV*.

Confirmability: The quality criterion of "confirmability" focuses on the neutrality of the researcher. Many of these aspects have already been discussed

above, under "Credibility". However, as described above, we sought a deeper understanding, and chose a distant approach in which some level of pre-understanding was needed.[162] The chosen approach of qualitative content analysis falls in the hermeneutic rather than the phenomenological paradigm,[162] in which the pre-understanding of a researcher is not only a weakness but also a strength. However, further confirmability could be enhanced by getting an independent researcher to read and evaluate the analysis process in NVivo, as well as look at the notes and final coding, which could be an important last step for this study.[214]

Methodological considerations in general

Considering that the results of *Paper IV-interview* about physical transition align well with an established transition to motherhood model published in 2017,[196] highlighting insecurity and the need for guidance in postpartum women, one could discuss whether the qualitative study should have come first. In a mixed method design, which can be applied both in one study and in a series of studies, the order of the studies has to be carefully considered.[125]

Based on the results of *Paper IV*, several psychological variables such as fear of movement and self-efficacy could have been included in the questionnaire of the ABB Study. As seen in *Paper II*, our predictive models for pelvic girdle pain explained only 5-11% of the variability in pain severity. This percentage increased only when we introduced pain as a predictor, which is explained by the fact that pain is predicting pain. It is clear that numerous other variables, not considered in our analyses, could be important.

However, the study question for the qualitative interview study emerged more and more during the course of the ABB study when the assessing physiotherapists reported how insecure and concerned the participating women were. Moreover, the analysis of *Papers II* and *III* showed that symptom severity was mild in the majority of participants. The transition to motherhood model was not known to me prior to this thesis and the focus in this thesis was more on biomechanical aspects such as muscle function and exercising. However, in future research the above described variables should also be included.

The use of questionnaires to self-report background factors and symptoms can be problematic. Reporting bias may exist in self-reported weight, height, pelvic floor tears, and symptom severity. Many participants filled out the questionnaire on their mobile phones, which could be influenced by factors

such as stress, poor display of the questionnaire on the phone screen, and possibly distractions from crying babies or toddlers in some cases. Moreover, as observed in *Paper IV-interview*, symptoms can be perceived differently from day to day and can be affected by sleep deprivation and stress, but also other factors such as darkness in winter or how much you expect from your body in daily life. Pain is a subjective sensation and can be influenced by several psychological and social factors.[75] Sleep problems and tiredness are associated with lowered self-rated health in the postpartum period.[123] In further studies, additional information about sleep and stress in relation to pelvic girdle pain, stress urinary incontinence and vaginal heaviness, as well as symptom variation in relation to daily demands should be studied.

Conclusion

The postpartum period is a phase in a woman's life where she must adapt to and accept numerous changes. While minor changes, such as a slight gap between the abdominal muscles or mild pain in the pelvis or lower back, might be manageable, other symptoms like persistent stress urinary incontinence, pelvic girdle pain, and vaginal heaviness can affect daily activities and exercise. Women are often taken aback by these changes and struggle to discern by themselves what is considered normal. Healthcare providers can have an important role in informing and guiding these women to prevent a cycle of pain, inactivity, muscle weakness, and increasing symptoms.

Primary care physiotherapists could be an additional resource in postpartum care by assessing postpartum changes such as pelvic floor muscle strength and screening for an increased inter-recti distance, for example, in women still experiencing pelvic girdle pain at 3 months postpartum or in case of persistent stress urinary incontinence.

Guidance in active recovery can be important for women, who are uncertain about the level of strain their bodies can withstand postpartum. While this thesis does not provide a definitive answer to this question, low-impact exercise during the first 3 months postpartum can be recommend as it may help to reduce symptoms such as pelvic girdle pain and stress urinary incontinence during the first year postpartum.

Clinical implications

The results of this thesis are based on an observational cohort study and a qualitative interview study. Observational studies cannot establish causality, and their results should be interpreted cautiously as they can be affected by several observational biases, as discussed in the methods section. Similarly, the results of an interview study may not apply to all patients. It is important to see the clinical implications more as noteworthy thoughts and guidance when meeting postpartum patients rather than absolute truths that cannot be questioned.

Stress urinary incontinence

- Health care providers should be aware that over 30% of postpartum women experience urinary leakage during the first year after childbirth.
- There is a risk that stress urinary incontinence creates a negative cycle of avoiding physical activity and exercise, which could in turn lead to muscle weakness and increased incontinence. Health care providers can play an essential role in breaking this negative cycle.
- Physiotherapists, even if not specialised in pelvic floor assessment, should inquire about stress urinary incontinence when treating postpartum women, and more physiotherapists need training in assessing pelvic floor muscles.

Vaginal heaviness

- Health care providers should inform women about the possibility of experiencing vaginal heaviness in the first postpartum months, as it can be an unfamiliar and, for some, a distressing experience. This information could be provided in late pregnancy, especially since this symptom is most prevalent in the first 3 months postpartum — a period when many women have limited contact with health care but numerous concerns and questions.
- Vaginal heaviness tends to decrease within the first 6 months, unrelated to exercise level.
- Physiotherapists should recognize that vaginal heaviness may lead to insecurity among postpartum women, potentially affecting their activities and exercise routines.

Pelvic floor muscles

- Health care providers can inform women that pelvic floor muscle strength tends to increase during the first year postpartum. While nearly 50% had a pelvic floor strength of <3 at 3 months (modified Oxford 0-5), this decreases to only 15% at 12 months.
- Vaginal palpation for assessing pelvic floor strength is a method that showed substantial agreement amongst experienced physiotherapists.
- Physiotherapists should be aware that their clinical assessment of involuntary pelvic floor muscle contraction and voluntary pelvic floor muscle relaxation might differ from that of a colleague. Such assessments require careful interpretation, taking into account factors like standardised coughing and how knowledge about a patient's pain influences the rating.

Pelvic girdle pain

- Health care providers should be aware that approximately 27% of women experience pelvic girdle pain in the first few months following childbirth. Whilst this pain is mild for 90% of these women, it can still affect their ability to run, exercise, or lift heavier objects.
- Clinical assessment of pelvic floor muscle strength and screening for a more pronounced diastasis recti abdominis (≥3.5 cm) might be important in women experiencing pelvic girdle pain.
- Engaging in low-impact exercise at least twice a week may help alleviate pelvic girdle pain.

Diastasis recti abdominis

- Health care providers can inform patients that the distance between the rectus abdominis muscles decreases during the first year postpartum for most women. Fewer than 3% of our participants exhibited a more severe diastasis recti abdominis (≥3.5 cm) at 12 months postpartum.
- Measuring the width of diastasis recti abdominis at the umbilicus using calipers demonstrated good consistency between two assessing physiotherapists. However, it requires experience with the callipers and a standardised protocol. The distance can be measured with a standard error of measurement of approximately 4-5 mm.
- Diastasis recti abdominis depth and bulging affect about 10-20% of postpartum women. However, their clinical assessment remains subjective, and our comprehension of their clinical significance is limited.

Exercising postpartum

- This thesis indicates that resuming low-impact exercise at least 2 times a week can help reduce pelvic girdle pain and the severity of stress urinary incontinence.
- Participants who had not resumed exercising (more than strolling) in the first 3 months experienced increased stress urinary incontinence at 12 months compared with 3 months postpartum.
- Women can experience a pressure from themselves and society to get back into shape after pregnancy; this needs to be considered when encouraging more exercise after childbirth. At the same time, exercising can be a source of energy.
- We had too few participants engaging in high-impact activities to draw any conclusions. Over 40% of our participants found it difficult to resume high-impact activities.

Women's experiences of physical changes and recovery postpartum

- Women are surprised and insecure about their physical changes during the postpartum period.
- They want information on normalcy, what they can do actively, and how these changes will develop over time.
- They experience that the focus shifts to the baby after childbirth, whilst the mother deals with many new and unfamiliar symptoms.
- Activity can be limited by pain or urinary leakage, but also by a fear of the recurrence of pain.
- Some women are scared about damaging their body and having to live with future consequences.

Future research

As described in the introduction, the clinical assessment of pelvic floor and abdominal muscles is a relatively new field for physiotherapists, and only a few have additional training in vaginal palpation. This study demonstrated that experienced physiotherapists showed good inter-rater reliability in assessing maximum voluntary contraction and measuring diastasis recti abdominis and that the results of these assessments could be associated with higher pain severity. An important question for future research is whether physiotherapists should take on some of the responsibility for postpartum care when women experience persistent symptoms.

We need to evaluate whether the routine postnatal care provided in maternity clinics, which already includes questions about urinary incontinence and vaginal examinations, is sufficient for most women, and which women should be referred to physiotherapists for persistent symptoms such as urinary incontinence, persistent vaginal heaviness, and pelvic girdle pain. In this context, we should also determine what additional training midwives would need so that women no longer feel that healthcare providers themselves have insufficient knowledge about women's postpartum concerns.

This thesis showed that urinary incontinence and pain were reasons for several activity limitations. However, these results were based solely on descriptive data, and in the next step, we should investigate where the cut-off lies between acceptable symptoms that could be considered the normal course after childbirth and symptoms that could lead to activity limitations and long-term problems. We should also examine the effects of pelvic floor muscle tears, particularly levator ani muscle tears, on activity limitations and persistent problems. Furthermore, we need to determine whether women from different cultural and socioeconomic backgrounds than those included in our study

experience similar activity limitations and have the same information and support needs, as this was not explored in our studies.

Paper IV showed that many women have difficulties resuming high-impact exercise up to a year after giving birth. *Paper III* lacked the statistical power to draw conclusions about associations between high-impact exercising and pelvic girdle pain, urinary incontinence and vaginal heaviness. As high-impact exercise offers several additional health benefits compared to low-impact exercising, a sufficient powered observational study or RCT is needed to assess the effects of high-impact exercise during the postpartum period.

Acknowledgements

Fem år har gått och det finns en hel del personer som har gjort den här resan möjlig för mig och som jag vill tacka för det:

Mitt första tack går till alla **deltagare i ABB-studien** som har kommit till alla undersökningar, fyllt i långa frågeformulär trots småbarn, sjukdom, trötthet och en pågående pandemi. Jag tackar också de **14 kvinnorna i intervjustudien** som ville dela sin berättelse om tiden efter förlossningen, sina upplevda symptom och sin återhämtning med mig. Det var en förmån att få dyka in i er värld av sömnbrist, amning, blöjbyte. Tack för er öppenhet kring hur ni upplevde kroppen efter förlossningen.

Utan deltagare hade ingen av studierna blivit av, men inte heller utan er som gjorde alla undersökningar: Jag tackar **Lisa, Ulrika, Ute, Johanna, Anna-Lena** och **Vanesa**. Jag vet att det är tack vare er att kvinnorna kände sig motiverade att komma till alla undersökningar trots en rådande pandemi. Ni skapade en atmosfär som fick dem att känna sig välkomna och sedda trots att de bara fick en undersökning. Stort tack för er engagemang och motivation.

Under de senaste fem åren har jag haft den stora förmånen att ha fyra kloka kvinnor runt mig som har gett mig förutsättningarna för att kunna genomföra det här. Jag tackar min huvudhandledare Maria Larsson, och mina bihandledare Annelie Gutke, Monika Fagevik Olsén och Gun Rembeck:

Maria, från mitt första kaotiska utkast på en projektplan, har du hjälpt mig att skapa ett projekt, söka finansiering och bli doktorand. Jag har alltid uppskattat din tydlighet, att säga när något kan förbättras och också att berömma när det är bra. Du har låtit mig testa mina vingar, lärt mig att hitta mina egna motiveringar och ord och samtidigt alltid har funnits där med en trygghet, tydlighet och lugn så att jag aldrig har behövt känna mig vilse. Jag kommer att sakna den tryggheten nu när jag ska göra det här själv.

Annelie, att samtidigt få dela erfarenheten kring kvinnorna som vi träffar i vår kliniska vardag och lära mig av den stora erfarenheten du har om att forska om dessa problem har varit otroligt utvecklande för mig. Jag har uppskattat att kunna diskutera mina idéer och funderingar, både små och stora, med dig. Att få resonera tillsammans, vända på frågeställningar och lära mig att motivera mina argument och val har varit lärorikt, roligt och spännande. Stort tack för all din hjälp.

Monika, din erfarenhet och klokhet tillsammans med din nyfikenhet på nya perspektiv och idéer, har varit en stor inspirationskälla för mig. Du har utmanat mig när det har varit nödvändigt, uppmuntrat mig att tänka utanför boxen och

oftast ställt frågan: "Kan du inte uttrycka det mer precist och kortfattat?" Oftast visade det sig att jag kunde. Jag är tacksam för din vägledning och stöd.

Gun: Du har gett mig möjligheten att se alla mina frågeställningar och resultat ur ett "barnmorske-perspektiv." Jag har uppskattat mycket dina spontana samtal när du har en tanke eller fundering. Du har hjälpt mig att se saker från olika synvinklar. Tack för att du har prioriterat att stötta mitt projekt trots att barnbarnen behöver dig och det ibland blir sena kvällar. Din hjälp har varit ovärderlig.

Jag tackar alla **barnmorskor** som har hjälpt till med rekryteringen och **Mia Fernando** och hennes fantastiska blogg för alla inlägg om mina studier.

Tack till **FoU centrum Göteborg och Södra Bohuslän**, inte bara för allt finansiellt stöd utan också för all hjälp som jag har fått under åren av **Carin, Inger** och **Ulrika**.

Jag tackar **Marcus Praetorius Björk** för all hjälp med statistiken. Att du haft tålamodet och kunskapen att kunna göra komplexa sammanhang begripliga för mig har hjälpt mig mycket genom åren.

Stina Gustavsson och **Jenny Ström**, utan er hjälp med att mata in och transkribera mitt material hade jag nog inte hunnit med någon träning eller socialt liv de senaste åren. Tack för at ni räddade mina kvällar.

Jag tackar **Clara Qvick** som har gjort illustrationerna av bäckenbotten. Det var utvecklande och spännande att fundera tillsammans med dig om det bästa möjliga sättet att illustrera dessa komplexa muskelslingor.

Jag tackar den **Nationella forskarskolan i allmänmedicin**, för lärorika veckor i Umeå och Sundsvall och för den otroliga chansen att jag fick göra en pre-doc i Belgien. Jag tackar **grupp 11** för många lärorika, inspirerande och roliga stunder.

Sara Berggren, tack för alla dina kloka tankar, många spännande diskussioner om både forskning, träning och barnen. Tack för att du hjälpte mig med min kappa.

Tack också till **Lena Nordeman** för värdefulla och kloka råd kring hur jag kan förbättra min kappa.

Jag tackar alla **mina doktorandkollegor** för att ni har stått ut med mina alldeles för långa manuskriptutkast, mycket bra input och många bra diskussioner.

I deeply thank the Pain in Motion research group, **Jo Nijs** and **Liesbet de Baets** for three inspiring and educative months in Brussels, Belgium. Thank you for letting me be part of your group.

Jag tackar **Tone Lindersköld-Burell** som har varit min chef på Närhälsan Gibraltar rehabmottagning. Jag vet ibland inte ens hur det var möjligt att jag har kunnat jobba kliniskt så flexibelt som jag har behövt som doktorand, men det har varit möjligt tack vare dig. Att alltid ha min plats på Gibraltargatan och att veta att om du säger "Inga problem, det löser sig," då gör det verkligen det, har alltid betytt jättemycket för mig och det vill jag tacka dig för.

Jag tackar även alla **mina kollegor på Gibraltargatan**. Jag vet inte hur många gånger jag har presenterat mitt projekt i olika sammanhang och har med stolthet sagt att jag jobbar på Närhälsan Gibraltar rehabmottagning. En plats där det jobbar ett gäng smarta, duktiga människor som på dagarna gör allt för att hjälpa sina patienter, och på natten vet hur man lever det ”dolce vita”. Tack för att jag alltid fick vara en av er.

Ich danke meiner Familie in Deutschland, meinen Eltern, **Dorle** und **Henning** und meinen Schwiegereltern, **Rainer** und **Irene** für all eure Unterstützung in den letzten Jahren, und meinen Brüdern, **Martin** und **Fabian**, und Schwägerinnen, **Kathrin** und **Franzi**, für viele wichtige Gespräche, und gemeinsame Zeit. **Amelie**, ich danke dir dafür, dass du immer da bist wenn ich dich brauche, mich verstehst und siehst- in jeder Lebenssituation.

Jag tackar även mina vänner. Tack för all spontan hjälp med barnen, och för att ni drar mig ur skrivar-bubblan för en middag eller en löprunda. Ni ger mig mycket energi.

Felix, Du har nog redan nu mer tålamod för dina forskningsprojekt än jag. Tack att du låter mig se världen med dina ögon, där man kan bygga och uppfinna nästan allt med hjälp av en PET flaska och några pinnar.

Leia, ibland önskar jag att jag kunde följa med dig in i din värld av fantasi och kreativitet. Du har en förmåga att se och känna av din omvärld som jag ibland är avundsjuk på. Tack att du låter mig vara med.

Florian, jag skulle nog kunna tacka dig för så himla mycket, för de små saker, t. ex. att det alltid finns på något magiskt sätt finns mat hemma hos oss, för att all hjälp med olika excel-filer.. eller för de stora saker, att jag utan att behöver fundera på hur det löser sig hemma kan bo i Bryssel i tre månader. Men mest tackar jag dig för att vi aldrig tappar varandra oavsett vad livet har för utmaningar , att du är lugnet när mitt liv är kaos och att du orkar lyssna på alla mina tankar och funderingar när du egentligen vill somna på kvällen.

Det här projektet var finansierat av FoU primär och nära vård Göteborg och Södra Bohuslän, regionala FoU medel och Renée Eanders fonden. Stort tack!

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